PAEDIATRIC ELECTROENCEPHALOGRAPHY IN SUB-SAHARAN AFRICA:

ACCESS TO EFFECTIVE SERVICES, TRAINING CAPACITY AND APPLICABILITY

OF TEACHING MODULES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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ETHICAL APPROVAL

This research was approved by the Human Research Ethics Committee of the University of Cape Town (HREC REF: 481/2018) and was conducted in accordance with the ethical principles of the Declaration of Helsinki. Informed consent was obtained via REDCap and from interviews prior to participation in the study. Copies of the REDCap surveys and interview questions and current HREC approval are included in the Appendix of this thesis.

DECLARATION ON THE INCLUSION OF PUBLICATION OH A PHD THESIS

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2. V Kander, J Hardman, JM Wilmshurst. Understanding the landscape of electrophysiology services for children in sub-Saharan Africa. Epileptic Disorders, 2021 - Wiley Online Library. Available from: https://onlinelibrary.wiley.com/doi/full/10.1684/epd.2021.1351
3. V Kander, J Hardman, JM Wilmshurst. Clinical practice applicability and relevance to non-specialists of a paediatric EEG online learning tool. BMC Medical Education, 2024 – Springer. Available from: https://link.springer.com/article/10.1186/s12909-023-05017-2
4. V Kander, J Hardman, JM Wilmshurst et al. Expert opinions on paediatric EEG training for non- epilepsy specialists in sub-Saharan Africa. Epileptic Disorders, 2025 – Wiley Online Library. Available from: https://onlinelibrary.wiley.com/doi/full/10.1002/epd2.70010

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LIST OF ABBREVIATIONS

Academy of Neurodiagnostic Technology..ACADNDT

Accreditation Council for Graduate Medical Education.................................ACGME

African Paediatric Fellowship Programme...APFP

American Academy of Neurology .... AAN

American board of registration of electroencephalographic and evoked potential technologists...ABRET

Analysis of Variance...ANOVA

Antiseizure medication...ASM

Archana Patel ....AP

Artificial intelligence EEG ....AI-EEG

Asian Epilepsy Academy...ASEPA

Bachelor of Technology ………………………………………………………… BTECH

BioMed Central ………………………………………………………………… BMC

Central nervous system ....CNS

Chahnez Charifi Triki..CCT

Clinical Neurophysiology...CN

Continuous EEG ....cEEG

Coronavirus disease ....COVID

Cumulative Index to Nursing and Allied Health Literature.............................CINAHL

District Hospital ………………………………………………………………… DH

List of Abbreviations cont.

Doctor of Philosophy .... PHD

Electroencephalogram .... EEG

Education Resources Information Center .... ERIC

Elton B. Stephens Company .... EBSCO

Epilepsy Education .... EpiEd

Gagandeep Singh .... GS

Geraldine Boylan .... GB

Ghaieb Aljandeel .... GA

Global Organisation of Health Education .... GOHE

Gretchen Birebeck .... GB

Handbook .... HB

High Income Countries .... HICs

Human Immunodeficiency Virus .... HIV

Human Research Ethics Committee... HREC

Intensive Care Unit .... ICU

International Child Neurology Association (virtual learning environment)....... ICNApedia

International Child Neurology Teaching Network .... ICNTN

International Federation of Clinical Neurophysiologist .... IFCN

International League Against Epilepsy .... ILAE

International prospective register of systematic reviews .... PROSPERO

List of Abbreviations cont.

Intersectoral Global Action Plan for Epilepsy ....IGAP

Jaime Carrizosa ....JC

Joanne Hardman ....JH

Jo Wilmshurst ....JW

Jorge Vidaurre Jorge..JVJ

Kette Valente...KV

Kevin Jones ....KJ

Lala Seck ....LS

Low-income country LIC

Low middle-income countries ....LMICs

Master of technology ....MTECH

Master of Science ....MSc

Melody Asukile ....MA

Mitsuhiro Kato ....MK

Multiple-choice questions ....MCQs

Net promoter score ....NPS

Paediatric Epilepsy Training ....PET

Paediatric electroencephalography in sub-Saharan Africa ....PES

Population, Intervention, Comparison, Outcome ....PICO

Record ....REC

List of Abbreviations cont.

Red Cross War Memorial Children's Hospital..RCWMCH

Reference ....REF

Research Electronic Data Capture ....REDCap

Resource limited countries ....RLCs

Sandor Beniczky ....SB

Scientific Electronic Library Online ....SciELO

South Africa ....SA

Special Interest group ....SIG

Standardized Computer-based Organized Reporting of EEG........................SCORE EEG

Standard Deviation ....SD

sub-Saharan Africa ....SSA

Texas ....TX

Veena Kander ....VK

Virtual Epilepsy Academy...VIREPA

Uniform Resource Locators..URL

United Kingdom ....UK

United States of America..USA

University of Cape Town ....UCT

Upper middle-income country ....UMIC

World Federation of Neurology ....WFN

List of Abbreviations cont.

World Health Organization ....WHO

Zenaib Kone ....ZK

ABSTRACT

Misinterpretation and misuse of an electroencephalogram (EEG) leads to misdiagnosis and unnecessary use of anti-seizure medications (ASMs). This is prevalent in countries that lack qualified trained personnel to perform and interpret EEGs. Interpretation of paediatric EEGs is complicated, owing to brain maturation and many epilepsy syndromes manifesting from infancy to adolescence. This can be compounded if the EEG is not performed correctly, with technical artefacts mimicking abnormalities. Paediatric neurologists and neurologists are scarce in sub-Saharan Africa (SSA), as are trained paediatric technologists and technicians. This lack of specialised professionals exacerbates the difficulty of providing quality neurodiagnostic services and accessing essential care for paediatric patients, especially in SSA and other low income (LIC) and low middle income countries (LMIC).

This thesis explored the question of who performs paediatric EEGs in SSA and whether they have the experience to report on these studies. The overall aim of this work was to establish a pedagogy in basic paediatric interpretation that could be used internationally to decrease existing gaps in paediatric EEG training. The study was divided into four chapters, with two additional chapters for the introduction and conclusion of the work.

Chapter 1 presents the background and aim of the study, namely, to understand paediatric electroencephalography practice with the intent to develop tools to improve the ability to perform and deliver this service, especially in Africa. Chapter 2 presents a published systematic review analysing published reports critiquing EEG training programs accessible to non-specialist clinicians worldwide, over a 30-year period. Chapter 3 provides information from a web-based survey exploring who performs and interprets EEG studies in SSA. Chapter 4 provides information based on the use of an EEG training handbook, from a web-based survey of 50 participants who registered for the online course. Chapter 5 presents qualitative data from 15 experts on training non-epilepsy specialists in paediatric EEG interpretation. In chapter 6, I conclude the correlation of data provided from the four articles.

There is a need for critiqued training resources to enable non-epilepsy specialists to utilise EEG. This healthcare cadre is considered to be appropriate with adequate support to perform this role, and the EEG training handbook was found to be a useful tool to teach non-epilepsy specialists in paediatric EEG interpretation, thus further bridging the knowledge gap in SSA.

SCOPE AND LAYOUT OF THE THESIS

This thesis represents the culmination of my work and research in the field of paediatric neurophysiology, specifically for children in sub-Saharan Africa. This dissertation includes four publications which has been incorporated in text boxes. The layout and structure are as follows: -

Chapter 1 (Introduction and Aims) outlines the rationale for the development of a sustainable curriculum for paediatric EEG and interpretation in SSA and LMICs. This chapter also lists the study aims and objectives.

Chapter 2/Publication 1: "Evaluation of EEG training curricula for nonspecialist clinicians: a systematic qualitative review." The objective of this 1st paper was looking at curricula content and EEG training programs for non-specialist clinicians in low middle income countries.

Chapter 3/Publication 2: "Understanding the landscape of electrophysiology services for children in sub-Saharan Africa". This 2nd paper we went on to understanding EEG services for children in sub-Saharan Africa by looking at who performs and interprets EEG studies.

Chapter 4/Publication 3: "Clinical practice applicability and relevance to non-specialists of a paediatric EEG online learning tool". This qualitative subjective descriptive study looked at the online handbook and whether it was a relevant tool to learning paediatric EEG.

Chapter 5/Publication 4: "Expert opinions on paediatric EEG training for non-epilepsy specialists in sub-Saharan Africa". This qualitative study performed on epileptology and advocacy experts, addressed whether non-epilepsy specialists can be trained in paediatric EEG interpretation.

Chapter 6 (Discussion and Conclusion) embodies the discussion of overall findings, the study strengths and limitations, further directions and conclusions. It illustrates the potential overall significance of the work presented in this thesis on developing a pedagogical model for paediatric EEG training and interpretation in Africa for Africa. It highlights the importance of the work done here, and how the pedagogical model would further benefit children living with epilepsy worldwide, in particular in SSA and LMICs.

CHAPTER 1 – Introduction

1.1 Introduction

Sub-Saharan Africa (SSA) has the highest burden of neurological diseases in the world, as reflected by the high prevalence of people with epilepsy [1]. It is also a region where most epilepsies start during childhood [2]. In 2011, the estimated prevalence of childhood epilepsy in SSA ranged from 3 to 26 per 1000 children [3] . It is estimated by the World Health Organization (WHO) that children in resource limited countries are 16 times more likely to die before the age of 5 years than in resource equipped countries [3] . The six common conditions causing almost 75% of childhood deaths are neonatal causes (preterm birth, infections and asphyxia), malaria, pneumonia, human immunodeficiency virus (HIV) infection, diarrhoea and measles [3] . Many of these conditions could be reduced significantly with simple preventative measures such as mosquito nets for malaria, penning of pigs for neurocysticercosis and effective antenatal care [4]. Preventable secondary sequelae from conditions such as malnutrition, neuroinfectious, and trauma often result in a legacy of children living with neurological deficits, including epilepsy [5].

Although, in general, epilepsy is diagnosed on clinical grounds, performing an electroencephalogram (EEG), which measures electrical activity of the brain, in addition to, or in conjunction with, the clinical diagnosis, assists and enhances both the delineation of syndromes and the management of epilepsy [6]. This tool is inexpensive and, with its high sensitivity and specificity, remains the most widely used test for neural function [7]. However, performing an EEG requires a specific set of skills, especially when performed on children, where misinterpretation can easily be made. An inaccurately reported EEG can be as detrimental to a child as having no access to the tool at all [6]. In this case the potential for inaccuracy can be attributed to poor technique or inadequate appreciation of brain maturation changes and common artefacts [6].

Typically, an EEG study is performed by a neurophysiology technologist or EEG technician. In South Africa (SA), a technologist studies for four years, (two years theory and two years practical training, in the field of neurophysiology) and obtains a Bachelor's degree thereafter. An EEG technician completes a minimum of one year of training (theory and practical) before performing an exit exam from the training institution. In high income countries access to training is readily available, whereas in SSA even the entry point to become a technologist or technician is very limited. Little is known about the potential access to training in this field in SSA. There are only two training centres in SA. Furthermore, there is little data with regard to the level of EEG training and knowledge in current neurophysiology practices in SSA, especially for paediatric electrophysiology. Data is lacking as to who the main providers of services are across the spectrum, from trained neurophysiologists through to diverse categories of health practitioners. It could be hypothesised in the African setting that training specific cadres of health practitioners, namely medical officers and nurses, with niche skills in paediatric neurophysiology, has the potential to assist in the performing and interpretation of EEGs, as well as with the burden of the clinical management of epilepsy in SSA. At present in resource limited countries, paediatric EEGs are read by non-epilepsy specialists who are not formally trained in the specifics of this task [6]. These include adult neurologists and psychiatrists.

To promote access to EEG training and promotion of skills in EEG interpretation, the researcher wrote a handbook/module in the form of a guideline to learning to interpret paediatric EEGs [8]. It is understood that this is the first such handbook/module published in Africa. Currently it is in the form of an online course on the International Child Neurology Association webpage (http://icnapedia.org/vle/) and is accessible to anyone interested in learning paediatric EEGs. The aim of the handbook/module is to establish a resource for health practitioners to improve their knowledge base with regard to the interpretation of basic EEG and to ensure safe practice in the use of this tool.

1.2 Aims

To explore and understand access to paediatric electroencephalography in Africa and to develop tools to improve the ability to perform and deliver this service.

1.3 Objectives

The following lists the objectives to be achieved in the course of this study:

1. To review the published literature relating to EEG training worldwide.
2. To investigate existing paediatric electrophysiology training units in Africa.
    a. To investigate and understand the extent and nature of access to electrophysiology studies, specifically EEG, available in Africa, and who performs and interprets EEG studies in Africa e.g. (non-epilepsy specialists, level of qualification, expertise, and experience in paediatrics etc.).
3. Paediatric online course: a proposed training model with online chat/group support
    a. To review the potential impact and viability to influence change in knowledge and practice of an on-line resource using chat/group support.
4. Existing training guidelines for electrophysiology
    a. To review internationally high income and resource limited training concepts of paediatric electrophysiology and to consider to what extent the training centres in Africa align with these.
5. To develop a pedagogical model that will be effective, viable and sustainable in the African setting
    a. To consolidate the framework for curriculum content and teaching methods for Africans within Africa

CHAPTER 2 – Literature review

This chapter includes a systematic review of literature published relating to EEG curricula and EEG training for non-specialist clinicians worldwide.

Journal: Epileptic Disorder
Title: Evaluation of EEG training curricula for nonspecialist clinicians: a systematic qualitative review
Authors: Veena Kander[1], Joanne Hardman[3], Jo M. Wilmshurst[1,2]
DOI: 10.1684/epd.2021.1270
PMID: 33885363
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ABSTRACT

Objective. Neurologists and epileptologists are scarce in sub-Saharan Africa (SSA). Whilst electroencephalograms (EEGs) are becoming more available in the region, interpretation is typically undertaken by non-specialist clinicians with limited or no training. This is a systematic review of the peer reviewed literature on EEG training of non-specialist clinician's worldwide, assessing the efficacy of the training methodology and the curricula content.

Methods. The published literature was searched for papers relating to EEG training of non-specialist clinicians worldwide (1/01/1989 – 30/06/2020). All regions of the world were included and assessed for content on efficacy of curricula and potential adaptability or applicability to resource poor settings. The grey literature was searched using ProQuest, Primo data bases and exploration of the references from review articles. The websites of the International League Against Epilepsy, International Federation of Clinical Neurophysiologist, American Academy of Neurology and World Federation of Neurology for were reviewed for reports (non-peer reviewed) which described roll-out and impact of novel EEG training curricula.

Results. There was limited data. From 2613 articles, 15 complied with the study question. Ten studies were performed on cross-speciality clinicians, four on neurology registrars and one on a combination of healthcare workers. There was diversity of curricula models used. The studies themselves lacked consistency and directness. A few training programs were trialled in low-middle income countries (LMICs) n=2 and paediatric training was included in only n=2. An ideal training curriculum was not evident nor evaluated for resource poor settings. However, diverse teaching models were reported and set the foundations for further development of EEG training curricula for non-specialist clinicians.

Significance. There is a lack of access to education in EEG training and interpretation for non-specialist clinicians in LMICs. Existing models need to be expanded or adapted and evaluated for this population group.

Key words: Electroencephalography, EEG, curriculum, efficacy, education, teaching

INTRODUCTION

Sub-Saharan Africa (SSA) has the highest prevalence of active epilepsy [9]. Many countries in SSA either have no neurologist or so few that neurological needs cannot be met for the affected population [10]. In 2016, a survey explored access to adult and paediatric neurology training programmes and found that out of 17 sub-Saharan African countries there were 0.6 neurologists per million people [11]. Adult neurology with EEG training programmes were available in Burkina Faso, Cameroon, Republic of Congo and Mozambique whilst South Africa, Senegal, Ethiopia, Madagascar and Nigeria offered adult and paediatric training programmes with EEG components [11]. In North Africa, Morocco, Tunisia and Egypt have access to neurology training programmes (https://wfneurology.org/training-centres ; https://www.stneuro.tn/en). The University of Dakar, Senegal in West Africa has been training neurologists since 2000 [12], with the first epileptology diploma in Africa founded in 2010 [12]. According to the World Health

Organization (WHO) there are only 0.002 paediatric neurologists per 100 000 population in low middle-income countries (LMICs) [10]. The number of paediatric neurologists has increased over the last decade but still not to the minimal recommended ratios per population as found in high income countries (1 per 100 000) [10]. The lack of qualified paediatric neurology doctors in Africa is largely due to a shortage of training opportunities [13]. Many professionals must seek training outside of their home countries and do not return, a phenomenon known as the "brain drain" [14].

In resource equipped, and high-income settings, access to trained neurophysiologists and epileptologists is routine. Centres with resources to follow detailed curricula in line with national and regional groups in high income countries (HIC's) such as those based in North America and Europe as well as countries such as Japan and Australia ensure that qualifying practitioners are exposed to the breadth of knowledge required to be competent in the interpretation of electroencephalograms (EEGs) e.g.(https://www.urmc.rochester.edu/education/graduate-medical-education/prospective-fellows/neurophysiology-fellowship/curriculum.aspx). Understanding the efficacy of these curricula is important to measure. Adapting such curricula for use in resource limited settings is an additional challenge. In many LMICs there is marked variation regarding who performs and interprets EEGs, from clinical medical officers and nurses through to adult neurologists and psychiatrists [15]. There is a lack of consistency in the training for these health practitioners. EEGs, when available, are often interpreted by personnel who have no or little experience in their interpretation especially studies performed on children [2, 16].

A misinterpreted EEG recording can have significant implications for patient care, with the potential of erroneous labelling of a predisposition to epileptic seizures or missing an epileptogenic recording, leading to over or under treatment respectively [17]. Over reading normal variants and non-epileptic transients are amplified by lack of EEG training [17, 18]. Whilst all neurologists should have EEG training during their residency, this exposure can be limited and affect their ability to interpret EEGs [17, 19-21]. As gold standard practice, all neurologists should be trained to read EEGs performed on children and adults. Once the label of epilepsy is suggested by an official report it is very difficult to withdraw this perception [17]. The diagnosis of epilepsy relies on documenting a thorough and consistent clinical history. The more experienced the clinician the less frequently EEGs are requested, in comparison to junior or general medicine clinicians who are more inclined to automatically order the test under the assumption that the study is essential for diagnosis and management of epilepsy [17, 22].

EEG is a complicated field especially in the paediatric age group owing to brain maturation and the complexity of performing studies on children. Attaining effective EEG skills parallel Blooms models on educational learning objectives [23]. Blooms theory identifies domains of learning around cognitive skills i.e. learning, thinking, and understanding a subject. The importance of basic theory is fundamental to create an EEG interpretation. Having a solid core foundation would allow clinicians to be able to interpret both adult and paediatric EEGs.

EEG is a non-invasive intervention which is inexpensive compared to other screens, such as neuroimaging, and with its high sensitivity and specificity remains the most widely used test for neural function [24]. When used appropriately it can be a valuable diagnostic tool to support the diagnosis of epilepsy and to aid patient management [8, 18]. However, in many LIMCs the cost of an EEG (mean value = $24) remains beyond the capacity of the local population.

The aim of this review is to collate and analyse the published data which evaluates the efficacy of existing EEG training programs for non-specialist clinicians. For the purposes of this report the term non-specialist clinicians encompasses any practitioner who has not undergone a formal specialist epileptology training curriculum. Ideally this analysis would direct how best to understand the most effective models for curricula and teaching formats of EEG training programs for this group of clinicians. Lastly, we aim to investigate which curricula have been or could be effectively adapted for LMICs and especially those which include interpretation of EEGs performed on children. This review is not exploring training at the level of epileptologists but is a pragmatic look at the most effective way to train non-specialist clinicians who need to have skills in EEG reporting inclusive of cross-speciality clinicians who require some specific EEG skills. This includes critique of “inhouse” training during residencies and critique / guidelines of optimal tools for this training. An additional aim is to document assessments of “external” learning aids and courses to either train or upskill knowledge in EEG reporting.

Methodology:

Search strategy:

A systematic review was undertaken independently by a senior librarian and the researcher using standard search terms.

The following terms (table 2.1) were searched by using key words and MeSH terms and were combined using Boolean operators. A search was performed on the following databases:

- PubMed – Medline;
- Scopus;
- Web of Science (Core collection and SciELO);
- EBSCO Host (ERIC, Academic Search Premier, CINAHL, Africa Wide).

Phase 2 consisted of a grey literature search for additional reports not captured through the initial screen using the Primo data bases (articles and dissertations), Google scholar (first 20 pages) and the references of review articles which meet the study inclusion criteria.

Only peer reviewed studies published in English between 1 January 1989 and 30 June 2020, were included in the review. Few papers were identified which addressed the evaluation of the efficacy of EEG training curricula. Wider exploration of the topic through non-peer reviewed sources identified more data but little cohesion across these groups as well as with the grey literature search. The PubMed search strategy is outlined in table 2.1 and prism flow diagram is presented in figure 2.1. The study was registered with PROSPERO (CRD42020189040).

In addition, a search was done on the websites of the International League Against Epilepsy (ILAE), International Federation of Clinical Neurophysiologist (IFCN), American Academy of Neurology (AAN), World Federation of Neurology (WFN), online courses (e.g. South Africa), Global Organisation of Health Education (GOHE) and an independent neurophysiology training consultant (Academy of Neurodiagnostic Technology) for reports (non-peer reviewed) describing roll-out and impact of novel EEG training curricula (table 2.2).

Inclusion criteria

Our inclusion criteria encompassed all studies in English assessing the efficacy of EEG training curricula worldwide both for adults and paediatrics over the 30.5-year period as seen in table 2.1. Articles were excluded that were not original (teaching/learning EEGs). Articles were selected based on content of abstracts for full review. This permitted identification of further grey literature selection of those which met the inclusion criteria. The above text summarizes the literature identified including reports from websites, correspondence, and major associations. We felt it was important to illustrate the impressive range of resources available but were unable to include these courses in the study as the efficacy of the curricula had not been measured. These resources could still provide valuable sources of support and guidance for the development of LMIC applicable curricula tools. Furthermore, we included articles on cross-speciality specialists as recognition of EEG waveforms is compulsory in their practice.

Units of analysis were of core common themes and trends that the researcher identified and coded accordingly (table 2.3); Population studied related to the trainees i.e. sample size, type of trainee health care practitioner; Interventions equated to curricula followed, number of EEGs used in testing, adult versus paediatric EEGs and type of trainer; Comparators related to knowledge gained as assessed by pre-training assessment by pre-training assessment e.g. multiple choice questions/written exam, and post training assessment also multiple choice questions/written exam/pattern recognition. The outcomes were then collated in the discussion as the most effective methodologies and curricula used to be adapted for competency in EEG interpretation suitable to LMICs (figure 2.2).

RESULTS

A total of 2366 articles (28/05/2020-29/06/2020) were found on the initial screening and 247 on a grey literature search. Two relevant articles were identified during a hand search on the author Fahy, who was notable for extended research into EEG curricula. Following abstract review 17 articles were identified for full text exploration. Two articles were subsequently excluded, despite their addressing EEG teaching, one was a survey of a video-based EEG curriculum [25] and the other was an overview which combined the studies by Fahy *et al* [26] and were already captured in the study.

Whilst many opportunities for training were identified from websites, correspondence, and major associations, without supporting data which evaluates the efficacy of the modules used, it is difficult to gauge the relevance, use and viability of the training across all settings. As a result, they were not included in the analysis but were expanded on the discussion and are presented in table 2.2. For some of the programs the webpages and news report highlighted teaching activities, but detailed training content format and outcome data was lacking. This was the case for the WFN and AAN initiatives where there are active collaborations and promotions of neurology training in Africa but further information for EEG courses was not available.

Fifteen studies met the inclusion criteria and are summarised in table 2.3. The researcher used quantitative descriptive statistics to analyse the articles. The studies were assessed and evaluated based on the descriptive statistics of similar core themes identified in each article as mentioned above - trainees, curriculum, EEGs, adult or paediatric practice, pre- and post-testing (n=15).

Population:

Out of the 15 articles, two target population groups were identified:

- clinicians learning EEG to diagnose seizures/epilepsy;
- clinicians learning EEG for splinter skills required for cross-speciality clinicians as described below.

For the former, four studies addressed the needs of neurology residents and one a combination of healthcare workers (paediatricians, neurology registrars and medical officers). For anaesthesiology and other cross-speciality clinicians training, the Accreditation Council for Graduate Medical Education (ACGME) requires EEG monitoring experience to identify critical and clinically compromising rhythms (https://www.acgme.org). For the latter the remaining ten studies mostly addressed outcomes for anaesthesiology residents as well neurosurgery, medical students, critical care fellows (pulmonary and surgery) and intensive care unit (ICU) nurses [27-36]. Only one study was undertaken solely with paediatric residents who originated from LMICs [8]. Of the 15 studies only two studies were performed in LMICs whilst the remaining 13 were in HICs [8, 18]. Of the four studies which critiqued neurology practitioners' skills, three were performed in HICs and one on clinicians from LMICs [18, 37-39].

The trainees completing the courses consisted of a range of disciplines, including medical officers, paediatricians, neurology residents, neurologists "with limited experience", medical students, internists, anaesthesiology residents as well critical care physicians/fellows (pulmonary and neurosurgery) and ICU nurses. Sample sizes in the studies were small with most ranging from one to 33 participants, and only one with 108 participants, which made interpretation of the results across all domains challenging.

Interventions: Curricula

Fahy et al [27, 28, 32] and Chau et al [29, 32] in three and two studies respectively used the same curriculum, two reports did not include the curriculum content and the remaining eight reports had a variety of content subjects noted but none were complete or comprehensive (e.g. syllabus for clinical EEG)[40]. Although some curricula were repeated none of the study designs were consistent. The duration of training varied across all articles (10 minutes - 41 months) with a median of 1 month. The results showed that in ten of the studies a neurophysiologist undertook the main teaching, in two an epileptologist and in three the teacher was not stated. There was no difference in outcomes whether training was with an epileptologist [38, 39] or a neurophysiologist [8, 27-33, 35, 36]. The face-to-face components included lectures and practical sessions [8, 18, 27-29, 31, 32, 36, 39]. Those with podcasts consisted of two ten-minute and 50-minute recorded sessions [30, 33, 35]. Online teaching utilised either a handbook [8] or an online program [26, 37] as well as an interactive EEG database with the automated program [38]. The different curricula and methodologies caused some bias limiting comparison across studies.

Number of EEGs

The total number of EEGs interpreted as part of the training ranged from 10-50. The diversity of the EEGs varied from 10 seconds to several minutes' epochs from cEEG recordings to full EEGs (20-30 minutes). This would have resulted in bias as the people reading full EEGs or more epochs had a better advantage over the ones with 10 or 23 second epochs.

Adult versus paediatric EEGs

One report addressed solely paediatric EEG learning [8] and the other a combination, the remaining nine studies were only focused on adult EEGs. Four studies did not include details of the EEGs read.

Comparators:

Pre- and post-training EEG skills assessment

EEG skills were assessed prior to training in 13 out of the 15 studies. A combination of multiple-choice answers, reporting EEGs and online survey were given to test the skills of the participants. Bias was possible as prior EEG experience of participants was not including before commencing training. The key issues with skills assessments were that two studies did not perform pre- and post-testing; however, they used pattern recognition as an informal means of testing. In addition, three surveys were completed on the handbook, simulation, and online course respectively. All the studies showed some measure of improvement in the student's competency after training. The post-assessments supported a general trend that all the above EEG training systems improve knowledge but not the level of competence after two 10-minute sessions or one 45-minute session as per Blooms theory. Only two studies addressed long term retention of knowledge [31, 36].

Discussion

The outcome of this study to evaluate the most effective methodologies and curricula used for non-specialist competency in EEG interpretation suitable to LMICs was limited by the lack of data. Several core common themes and trends emerged namely blended learning such as face to face, podcasts, automated, simulation and online teaching were the most popular tools to teach EEG interpretation.

Our results show that only two studies were performed in LMICs and the rest in HICs. In most parts of the world especially LMIC's, EEGs are reported by non-specialist clinicians with limited or no training in EEG. As access to electrophysiology equipment is becoming more readily available in most LMIC's, abnormal readings will increase owing to the lack of EEG training. To address this need initiatives such as GOHE in conjunction with Maggie Marsh-Nation are upskilling the training of neurophysiologists in LMICs (table 2.2). Paediatric neurologists are few or completely absent in many LMICs. Interpretation of paediatric EEGs by untrained clinicians can be very daunting and detrimental to the patient if diagnosed incorrectly. The burden of epilepsy is highest in LMICs, however if misdiagnosed or misclassified can have a major impact on affected children [41]. Our findings showed that only two of the studies taught paediatric interpretation (table 2.3). Out of the non-peer review reports, only one course did not include paediatrics (table 2.2). Owing to the requirement for EEG competence training for cross-speciality residents in the United States of America (USA) and in most HICs, ten studies were performed on this group. There was marked lack of consistency in training for non-specialists compared to cross-speciality clinicians, although, none had the intention to train at the level of an epileptologist but rather to ensure competency in reading EEGs. ACGME has only a few specific requirements for clinical neurophysiology (CN), however, some neurology residents are graduating without meeting these milestones [21].

This study showed that EEG interpretation was not only taught to neurologists, but to a wide range of disciplines who are required to learn how to interpret EEGs. For comprehensive patient care, rather than acute interventions, for example as occurs for anaesthetics and intensive care, EEGs should be interpreted by neurologists. This supports the need for minimum EEG training for neurology residency during their rotation in terms of quality (supervision from an epileptologist) and quantity (months and number of studies) [17]. There is a knowledge gap in basic sciences especially EEG training for neurology residents [19-21, 42]. EEG interpretation is a difficult concept to learn as it not only involves pattern interpretation but an understanding of the disease process, clinical context and ability to communicate EEG findings to a non-specialist [28]. But it is expected that all qualified neurologists should be able to interpret EEGs [17]. Schuh *et al* (2009) reported that the mean length of rotation a neurology resident in the USA spends in paediatric neurology and adult EEG attachments is 3.1 and 1.5 months respectively. Inadequate exposure to subspecialty training especially in neurophysiology is a common trend [20, 21, 42, 43].

As such there is a lack of formal teaching or dedicated time allotted to learn how to interpret EEGs for USA neurology residents [21]. Daniello and Weber [21] found marked differences in training durations from a few minutes to several years, and that some had no training but deferred to a "self-taught" handbook. The adequate training duration time is debatable and further compounded by time constraints for busy neurology residents. Some studies documented didactic training time included within residents' clinical schedules [38]. Many residents are not confident in reporting EEGs owing to the lack of time spent in neurophysiology [21]. Residents may lack the resources to undertake a fellowship in neurophysiology. Of clinicians training in adult neurology in the USA only 25% planned to pursue a neurophysiology fellowship [20]. The added value of the subspecialty was questioned based on the effort and expense [44]. To adapt a curriculum for a less skilled and resourced population a strong established format would ideally form the foundations for this process. It is worrying that there appear to be inconsistencies even within resourced and experienced settings.

Our study found there were vast methodological differences between the studies such as study design and sample size. Theory content varied from two topics to over six chapters in thirteen of the articles and sample sizes were small in all except one study. Two studies did not document what theory was taught and as a result it is not known what basic theory each resident received [18, 38]. Although the theory of electrode placement was taught in some articles, there was no mention of the participants performing EEGs themselves and learning how to trouble shoot (artefacts, machine trouble etc) in the studies. We found similar curricula topics being taught in both the non-peer review as well as in some of the papers being evaluated for example polarities which forms the core of EEG understanding [8]. This can strengthen the concept of what modules are important to understand EEG pattern recognition. The gold standard would be for a standardized curriculum and learning tool to be selected or developed to facilitate the best learning outcome for LMICs.

EEG examples covered were mostly from adults, only one study was on paediatrics and another a combination. Four did not mention which examples were reported. This highlights how vulnerable children are in having their EEGs read by clinicians who lack training in paediatric EEG interpretation. Owing to the lack of paediatric exposure in this context, it would be difficult to achieve experience in this area. EEG interpretation is most effective based on pattern recognition, as such the higher the exposure to a variety of patterns the greater the successful yield of accurate interpretations [18]. Many studies used 10-23 second epochs for interpretation [18, 27-30, 36, 38], which would be challenging, if not impossible for one without experience. Further a relevant clinical history and the state of the patient should be given before interpretation.

Using pre- and post-assessment skills evaluates if the student has gained knowledge. These were done in thirteen studies and two used pattern recognition as an informal way of testing. During EEG training it is important to be exposed to all EEG waveforms, normal variants and key abnormal EEG patterns assisting with diagnosis and treatment [18]. Infrequent normal variants and fluctuation of normal sharply contoured activity and artefacts can lead to over interpretation of EEG and erroneous use of anti-seizure medication [16]. This is especially the case for the paediatric age group where over diagnosis is as dangerous as under-diagnosis. Some settings, such as neonatology, are very complex and care is compounded by the expansion of increased on-site monitoring. As such, there is also an urgent need for neonatology EEG training programmes [45]. Only two studies addressed long term retention which would reflect a better outcome evaluation. Although all improved in knowledge gained, demonstrating direct clinical impact from the training is more challenging to evaluate.

The outcome showed that the educational methods used in the studies were diverse. Podcasting proved to be a popular accessible tool available via internet at low implementation costs which could be explored to replace conventional teaching. However, podcasting alone is not optimal for learning. True learning, in the sense of cognitive development, requires that the student is actively engaged in constructing meaning; something that cannot be done through a monological podcast [46]. This was one justification for the lack of improvement found in one study [30]. As another tool there was support for EEGs being taught via simulation as well [28]. Overall trainees will still need interaction in order to develop their cognitive skills [23].

Limitations of study

Whilst every attempt was made to cover search strategy for studies addressing evaluation of EEG training for non-specialist clinicians, only a limited number of articles were found for this review. Further the majority articles were performed on adult EEG interpretation and only one purely on paediatrics, with another one a combination. Another limitation to the study is that only two of the studies addressed the training of clinicians from LMICs and the rest were based in HICs. The latter concentrated on cross speciality clinicians who required some form of EEG training to be competent in their duties.

CONCLUSION

To answer our original question, we set out to understand what design curricula was being taught and what teaching strategies were used to upskill EEG interpretation for non-specialists. This study was not addressing established and expert specialist training i.e. epileptologists. We found that further studies are needed which evaluate quality of current training and explore methods for adaptation to permit diverse introduction of teaching across all regions of the world. Based on the current data it is not possible to state whether the above studies can address the need for non-specialist clinicians to learn a complex skill such as EEGs and to perform competently in their clinical practice. Whilst exploring an effective model for learning the interpretation of EEGs, five different teaching methods were identified. These included:

- face to face;
- podcasting;
- automated program styles of teaching;
- simulation;
- online programs.

There are many different teaching resources for EEG but only those which had been evaluated were included. As such more studies are needed which are standardized to permit better analysis, to enable identification of novel teaching methods and systems that should be promoted and strengthened. The combination of face to face and online learning are core teaching methods to learn EEG interpretation [8]. Many online courses [8, 34, 37, 47] are yet to be critiqued. Collaboration is essential to fill the gap by working together in educating the African continent and other LMICs in safe EEG practice [48].

In conclusion, we did not find an ideal curriculum but found similarities with key concepts taught that can be adapted, to design an ideal curriculum and teaching strategy that should be viable for both HIC and LMIC. Our aim is to make non-specialist clinicians in LMICs competent in their knowledge in basic neurophysiology. This study found that paediatric EEG training is non-existent in some EEG training programs and as stated, few are based in LMICs. Owing to the rapidly developing field of technology, many of the future teaching methods could be undertaken online or via podcasts given the time restraints of residents (blended learning).

What this paper adds
1. Different models of formal and informal short courses of EEG learning are in use.
2. Four teaching methods were identified e.g. didactic / podcasting / online and automated teachings.
3. Paediatric and adult EEG learning tools which have undergone critique are scarce.
4. An effective or ideal model for teaching EEGs in LMICs has not been identified.

Author contributions:

Veena Kander: Wrote the manuscript based towards for PhD thesis, collected and analysed article data and formatted conclusions

Jo Wilmshurst: Supervisor of PhD thesis, proofread and made corrections to the manuscript content.

Ethical Approval

The study protocol was passed by the Red Cross Children's Hospital Research Committee and the University of Cape Town Ethics Committee REC/REF 481/2018. This article is based on the research I conducted for my Doctor of Philosophy Degree in Neurophysiology. In relation to the journal's position on issues involved in ethical publication: We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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Gill Morgan, a subject librarian at the University of Cape Town, independently ran the review. Dilshaad Brey, senior librarian at the University of Cape Town, assisted with the use of the different databases. Roberto Sass, senior librarian at the University of Cape Town, assisted with the importing of all articles into endnote. None of the authors has any conflict of interest to declare.

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Legends for Tables and Figures

Table 2.1: PubMed Search strategy

Table 2.2: Websites for non- peer review reports

Table 2.3: A systematic review of the peer reviewed literature on EEG training of non-specialist clinicians worldwide based on the following themes [trainees, curricula, EEGs, adults or paediatrics, pre- and post-testing (n=15)]

Figure 2.1: Population, Intervention, Comparison, Outcome (PICO)

Figure 2.2: Prism flow diagram

Table 2.1: PubMed Search strategy

#1	MeSH terms:	"Electroencephalography"[Mesh]
#2	Free text:	Electroencephalography OR electroencephalogram OR EEG OR electroencephalograms
#3	#1 OR #2	
#4	MeSH terms:	"Curriculum"[Mesh]
#5	Free text:	Curriculum OR curricula OR pedagogy
#6	#4 OR #5	
#7	MeSH terms:	"Education"[Subheading] OR "teaching "[Mesh] OR 'Learning" [Mesh]
#8	Free text:	Education OR teaching OR learning OR training
#9	Free text:	train OR instruction
#10	#7 OR #8 OR #9	
#11	Free text:	Efficacy OR result OR results OR outcome OR outcomes
#12	#3 AND #6 AND #10 AND #11	
Outcome:		
#13	Filter	Date 01/01/1989-30/06/2020 Language - English

Table 2.2: Websites for non-peer review reports

Source	Teaching course	Teaching format	Target group	Outcome measures
International League Against Epilepsy (ILAE) https://www.ilae.org/files/dmfile/Announce_EEG-Basic-20191.pdf	VIREPA - EEG Basic1The role of EEG in the Diagnosis and Management of Epilepsy	The course has 9 units, one-week introduction to the VIREPA e-learning platform, followed by 7 learning units of three weeks each and a final task unit	A minimum of 4 months of practical experience with clinical EEG is required as well as 3 years of training in neurology, neuropediatric, clinical neurophysiology, psychiatry or neurosurgery, or combinations	Tasks completed within an active online communication process among all participants, guided by the experts in the discussion forum on the e-learning platform.
	Epilepsy education (EpiEd)	The web based educational tool comprises of seven domains and three levels (entry, proficiency and advanced proficiency)	Neurologists/healthcare professionals of all levels/ allied health professionals/nurses/care givers and governments	Awards a certificate on participants who meet the performance, proficiency or passing standard for assessments
	SCORE EEG Educational Platform	SCORE EEG is an interactive web-based training platform where students can practice their EEG reporting skills. They can also compare their EEG findings to the findings of an EEG expert	Clinical neurophysiologists /Epileptologists	
	The Asian Epilepsy Academy (ASEPA)	EEG course was established in 2000. Part 1 (written), consists of 150 questions Part 2 (oral), two 30-minute sections	Practicing neurologists or psychiatrists, neurology, epilepsy or EEG trainees and experienced EEG technologists	On passing both parts 1 will become certified electroencephalographers
International Federation of Clinical Neurophysiologist (IFCN) https://www.ifcn.info/courses.asp	Special Interest Group (SIG) will lead the educational program	Online teaching resources, teaching stands in congresses	Training of Clinical Neurophysiologists and visiting fellows	
International Child Neurology Association - virtual learning environment (ICNApedia) https://icnapedia.org/vle/	Online paediatric course	Consists of 10 chapters with a quiz after each chapter. Chapter 11 consists of 16 examples of real-life scenarios where they can test their knowledge. This course is self-paced.	Paediatric neurologists/residents, neurophysiologists and non-specialists interested in learning basic paediatric EEG interpretation	Certificate on completion.
Study EEG Online, University of Cape Town, South Africa https://studyeegonline.com/	EEG online distant learning	It is a part-time course, which runs for 6 months, and consists of 9 modules lasting 3 weeks.	Neurology/neurophysiology trainees in clinical EEG	Certificate on completion NB: course has been evaluated but report is still pending
Academy of Neurodiagnostic Technology (acadndt) by Maggie Marsh-Nation	Online EEG portal	18-month course consists of 12 modules with a quiz after each module. The course is self-paced.	Neurophysiologists/ EEG technicians/ Neurologists/residents	Certificate on completion

The Global Organization of Health Education (GOHE)	EEG workshops and online teaching with paediatric content	Face to face teaching plus online teaching resources. To date GOHE has done projects in Ethiopia and Nigeria and a congress in India.	Training technologists in sub-Saharan Africa and in low or low middle-income countries	Certificate on completion with progress towards the American Board of Registration of Electroencephalographic and Evoked Potential Technologists (ABET)

Table 2.3: A systematic review of the peer reviewed literature on EEG training of non-specialist clinicians worldwide based on the following themes [trainees, curricula, EEGs, adults or paediatrics, pre- and post-testing (n=15)]

	Population	**Interventions**					**Comparators**				
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				MCQs/written exam	MCQs/written exam	[2]Pattern recognition	Pre-test mean values	Post-test Mean values
[1]Fahy et al, 2008, USA	N= 33 Anaesth residents N=7 Had evaluations before and after in the in-depth EEG exposure N=12 Had new educational exposure N=14 Had traditional teaching without in depth EEG exposure	1 Month	Neurophysiologist	Covered a wide range of theory: - 1) Basics of monitoring (general; dipole characters; electrodes; component requirements and montages), 2) physiologic basic of EEG (maturation with age; changes with wake/sleep cycle; normal EEG tracing; recognition of artefact and abnormal EEG tracings, 3) clinical applications (epilepsy; coma; brain death; cerebral ischemia;	11 EEGs pre and post-test	Adult EEGs	25 MCQ's including 11 EEG tracings of a 10s screenshot	25 MCQ's including 11 EEG tracings of a 10s screenshot		Mean scores (N=7) 10.7%	18.86% N=12 19.17% N=14 9.5%

				prognostic indicator; burst suppression; anaesthetic effects and other effects).							
	Population	**Interventions**					**Comparators**				
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				MCQs/written exam	MCQs/written exam	[2]Pattern recognition	Pre-test mean values	Post-test Mean values
[1]Fahy et al, 2009, USA	N= 8 Anaesth residents	1 Month	Neurophysiologist	Theory same as above	11 EEGs pre and post-test	Adult EEGs	25 MCQ's including 11 EEG tracings of a 10s screenshot	25 MCQ's including 11 EEG tracings of a 10s screenshot done after: - 10 EEGs; 15 EEGs and 20 EEGs interpreted		Mean scores 8.0%	15.12% (10 EEGs) 15.88% (15 EEGs) 18.12% (20 EEGs)
[1]Chau et al, 2010, USA	N= 9 Neurosurgery residents	45-minute session	Neurophysiologist	Generators of EEG potentials, electrode placement and terminology, fundamentals of frequent bands, common artefacts, normal adult EEG and abnormal patterns (slowing, burst suppression and ictal patterns)	15 EEGs pre and post-test	Adult EEGs	25 MCQ's with 15 EEG tracings of a 10s screenshot.	25 MCQ's with 15 EEG tracings of a 10s screenshot.		Mean scores 12.0%	19.67%

[1]Meriem Bensalem-Owen et al, 2011, USA	N= 10 Anaesth residents	Two recorded 10-minute podcast sessions.	Neurophysiologist	Curriculum covered included clinical applications, physiologic basis and monitoring.	10 EEGs post-test	Adult EEGs	25 MCQ’s	25 MCQ’s after podcast and then another 25 MCQ’s after 10 EEG tracings of a 10s screenshot.		Mean score 9.50%	13.4%(podcast) 16.2% (10 EEGs)
	Population	**Interventions**					**Comparators**				
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				MCQs/written exam	MCQs/written exam	[2]Pattern recognition	Pre-test mean values	Post-test Mean values
Ochoa et al, 2012, USA	N= 15 Neurologists	6 Months		EEG recording technical concepts Montages and localization rules Normal EEG background, artefacts, and variants Abnormal EEG and clinical significance	40 EEGs		40 MCQ’s	40 MCQ’s Completed survey on program		Mean score 61.7%	87.8%
[1]Fahy et al, 2014, USA	N= 20 Anaesth residents N= 10 (10 EEG group + long term retention) N=10 (15 & 20 EEG group + long term retention)	1 Month	Neurophysiologist	Theory same as 2008 and 2009	10, 15 and 20 EEGs post-test	Adult EEGs	25 MCQ’s with 11 EEGs	10 EEG group 25 MCQ’s and 11 EEGs. 20 EEG group 25 MCQ’s after 15 and 20 EEG’s with 11 EEGs each. Long term retention (12 months) was tested with 40 item evaluation tools and 19 EEGs		Mean scores (N=10) 42.8% (N=20) 34.4%	63.2% Long term retention =6.9% 63.2% Long term retention=62.3%

	Population	Interventions					Comparators				
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				MCQs/written exam	MCQs/written exam	[2]Pattern recognition	Pre-test mean values	Post-test Mean values
[1]Chau et al, 2014, USA	N= 9 Pulmonary care fellows	4 Hours	Neurophysiologist	EEG potential generation, Terminology and electrode placement, fundamentals of frequent bands, common artefacts, normal adult EEG (awake and asleep) and Abnormal EEG patterns	10 EEGs pre and 10 EEGs post-test		25 MCQ's including 10 EEG tracing	25 MCQ's including 10 EEG tracing		Mean score 7.56%	Mean score 16.67%
Kander et al, 2015, SA	N= 11 Health care professionals N = 8 Paediatricians N= 3 Medical officers	5 Participants had 6 weeks to 24 months training 6 Had no training	Neurophysiologist	6 chapters covering: - 10/20 system, montages instrumentation, polarities, artefacts, waveforms, normal variants, activation procedures, Epileptiform activity, Reporting on EEGs, examples of reporting, epileptic disorders with illustrations and lastly a table on disorders from neonatal period to adolescence	40 EEGs of 100sec each (10 epochs) 20 structured EEGs 20 prospective EEGs	Paediatric EEGs	Reporting 10 structured and 10 prospective EEGs consisting of 10 epochs each	Reporting 10 structured and 10 prospective EEGs consisting of 10 epochs each after reading handbook Completed a survey on the handbook		Mean score Tutored (N=5) 47% Not tutored (N=6) 12%	(N=5) 74% (N=6) 32%

	Population	Interventions					Comparators				
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				MCQs/written exam	MCQs/written exam	[2]Pattern recognition	Pre-test mean values	Post-test Mean values
[1]Fahy et al, 2015, USA	N= 14 [Podcast group (medical students)] N= 10 (Control group – 1st year resident)	Two recorded 10-minute podcast sessions.	Neurophysiologist	Curriculum covered for both podcast and conventional didactics included basics of EEG, including EEG monitoring, physiologic basis and clinical applications.	10 EEGs post-test		25 MCQ's for both control group and medical students	Podcast group: after podcasting and after 10 EEGs Control group- after 10 EEGs		Mean scores Medical students (N=14) 8.43% Control group (N=10) 9.70%	13.64% after podcast 14.86% after 10 EEGs 13.44% after 10 EEGs
Weber et al, 2016, USA	N= 20 Adult neurology residents	2 Weeks (12) and 4 weeks (8)	Epileptologist		20 EEGs pre and 20 EEGs post-test	Adult EEGs	35 MCQ's with 5 choices per question on a 10-15s EEG screenshot	35 MCQ's with 5 choices per question on a 10-15s EEG screenshot		Mean scores 42.7%	75.4%
[2]Venkatraman et al, 2016, UK	N= 1 Neurology resident	1 Month	Epileptologist	EEG montages, lead placement and terminology	First 25 and last 25 EEGS of the 106 done in the one month	Adult EEGs			Statistical evidence increased for all findings accept epileptiform activity and posterior dominant rhythm		

	Population	Interventions						Comparators			
Study	**Trainees**			**Curriculum**	**No of EEGs used in testing**	**Adult versus paediatric EEGs**	**Pre-training EEG skills assessment**	**Post-training assessment**		**Statistical significance of training outcomes**	
	Sample size	**Time of EEG training**	**Epileptologist/ Neuro physiologist**				MCQs/written exam	MCQs/written exam	[2]Pattern recognition	Pre-test mean values	Post-test Mean values
[2]Dericioglu et al, 2017, Turkey	N= 11 Adult neurology residents	3 Months (5) and 4 months (6)			30 different EEG recordings of 10 sec epochs	Adult and paediatric EEGs			Self-limited and focal ictal onset patterns were the most difficult to recognize.		
[1]Fahy et al, 2019, USA	N=15 Critical care fellows (pulmonary, surgery and anaesth)	Web-based training module		EEG basics Clinical exposure EEG interpretation	10 EEGs		25 question evaluation tools	25 question evaluation tools		Mean score from baseline to after 10EEGs 2.8%	7.7%
[1]Fahy et al, 2020, USA	N=9 (Pulm n=5), (Anaesth n=2), (Surgery n=2)	Flipped classroom and screen-based simulation 50-Minute video podcast	Neurophysiologist	Theory same is Chau 2014	10 EEGs	Adult EEGs	25 question evaluation tools	25 question evaluation tools Participants completed a post simulation survey		Mean score from baseline to after 10 EEGs 10.8 7.56	15.6 (simulation) 16.67 (controls from 2014 study)
Legriel et al, 2020, France	N=180 Critical care staff (senior physicians, fellows, residents, medical students and nurses)	90-minute face to face EEG course	Neurophysiologist	Theoretical notions and illustrative EEG tracings	23s epochs or several minutes from cEEG	Adult EEGs	10-point EEG survey	10-point EEG survey at: - Day 1 Day 15 Day 30 -face to face EEG evaluation Day 90		Mean Score Pre-test 3	Day 1 - 7 Day 15 - 7 Day 30 - 7 Day 90 - 8

1 Study was done 9 times by same group of authors; 2 Pattern recognition as an informal means of post-testing

Abbreviations: Anaesth - Anaesthiology; Pulm - Pulmonary

Population	Non-specialist clinicians*
Intervention	EEG training in LMICs
Comparators	Knowledge before and after EEG training
Outcome	The most effective methodologies and curricula used for competency in EEG interpretation suitable to LMICs

Figure 2.1: Population, Intervention, Comparison, Outcome (PICO).

***** Non-specialist clinicians equate to healthcare professionals who are not specialists in epileptology

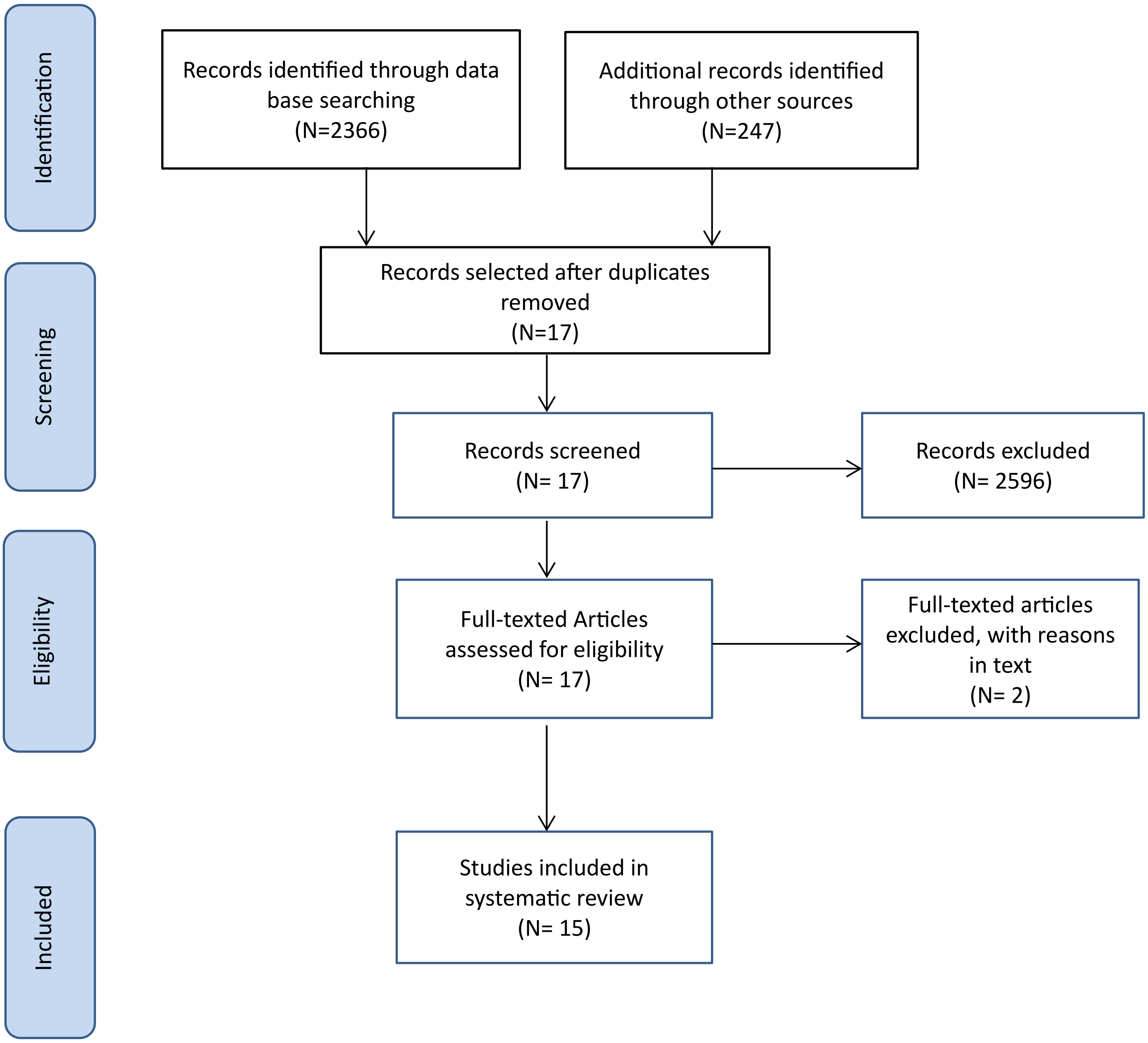

Figure 2.2 Prism flow diagram.

CHAPTER 3 – Electrophysiological services in sub-Saharan African

This chapter explores who performs and interprets paediatric EEGs in sub-Saharan Africa and whether there is a need for an apprenticeship training program.

Journal: Epileptic Disorder

Title: Understanding the landscape of electrophysiology services for children in sub-Saharan Africa.

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ABSTRACT

Objective: Incidence of epilepsy is greatest in infancy and childhood; this is especially evident in Sub-Saharan Africa (SSA). The aim of this study was to understand access to electrophysiology services in SSA including which health practitioner performs and interprets paediatric electroencephalogram (EEG) studies as well as their training in paediatric EEG.

Methods: A web-based survey was sent to a cohort of health care practitioners who manage children with epilepsy in SSA. The questions addressed whether EEG was available to these health care practitioners, how the practitioners, accessed EEG and who assisted interpretation of the study results. The survey was circulated (June-December 2019) to 305 participants from 32 African countries.

Results: A total of 73 (16 partial and 57 complete) surveys were returned from 18 countries. The respondents fell into two main categories: Those with access to an EEG machine 44/73 (60%) and those without access to an EEG machine 29/73 (40%). In 32% (23/73) there was no dedicated technician and 34% (25/73) no neurologist. Access to a neurologist resulted in the highest proportion of EEGs performed per annum. 77% (56/73) of the respondents agreed that there was need for a paediatric apprenticeship in

EEG skills. Qualitative data to justify need for paediatric EEG training was grouped into three themes: - (1) "professional development"; (2) "better care"; and (3) "help paediatric patients and neurologists".

Significance: There is a lack of paediatric EEG training amongst doctors and technicians working with epilepsy in SSA. Expanding training beyond current capacity in SSA, for technicians and practitioners involved in EEG is necessary.

Keywords: EEG, sub- Saharan Africa, technicians, paediatrics, interpretation

INTRODUCTION

Sub-Saharan Africa (SSA) has the highest burden of neurological diseases in the world, as illustrated by the high prevalence of people with epilepsy [49]. Infants and children have the highest incidence of epilepsy of all age groups, this is especially evident in SSA [49]. Active and lifetime epilepsy prevalence burden in SSA ranges from active at 9 per 1000 population and lifetime at 16 per 1000 [50], and active childhood epilepsy in SSA, is reported to range from 3.6 to 44 per 1000 children [51].

Whilst epilepsy is diagnosed on clinical grounds, performing an electroencephalogram (EEG), in conjunction with the clinical assessment, can assist and enhance the diagnosis, delineation of syndromes and the management of epilepsy [6]. This tool should be inexpensive and, with its high sensitivity and specificity, remains the most widely used test for neural function [24]. However, performing an EEG requires a specific set of skills especially when performed on children, where misinterpretation can easily occur. An inaccurately reported EEG can be as detrimental to a child as having no access to the tool at all [6]. Inaccurate implementation of the tool can be due to lack of both technique and knowledge of brain maturation and artefacts [6].

As gold standard, an EEG study should be performed by a neurophysiology technologist or EEG technician and interpreted by a specialist with formal training in epileptology. In high income countries access to training from technician to specialist is readily available, whereas in SSA even access to train as a technologist or technician is anecdotally very limited. Further there is little data regarding the level of EEG training and knowledge in currently practicing neurophysiology services in SSA, especially for paediatric electrophysiology. In the African setting clinicians have heavy clinical workloads and rarely have the capacity to work in a single area of specialisation e.g., as an epileptologist or neurophysiologist. The practitioner performing the study should be able to highlight important findings which need acute interventions as well as providing the referring clinician with adequate information from the study to aid clinical assessment. Based on this, in centres lacking neurologists with electrophysiology training, establishing whether the practitioner performing EEGs, i.e., the technician, has some clinical background beyond the technical ability to perform the study is important.

Methodology

We designed a 15-minute web-based survey consisting of 42 questions for health care practitioners who manage children with epilepsy in SSA (*appendix 3*). The survey explored how the health care practitioners were able to access care for their patients with paediatric neurology conditions inclusive of how this related to EEG services in their country, with a special focus on paediatric electrophysiology. We used research electronic data capture (REDCap) from the University of Cape Town's (UCT) web applications, and this was widely circulated via the web (June-December 2019). Names of participants were collated from articles, internet searches, from across the African Paediatric Fellowship Program (APFP) alumni colleagues and from the Paediatric Epilepsy Training (PET) programs held across the African continent (Kenya/Uganda/Ghana/Tanzania). The target population totalled 311 participants from 32 African countries. The survey collected data on, access to a neurologist, waiting times for EEG, number of EEG studies performed, personnel performing EEGs, their training experience (formal or informal), the type of practitioner interpreting paediatric studies and the usefulness of an apprenticeship in paediatric EEGs. The questions were mainly drop-down box options with a few open-ended questions formatted, to provide specific qualitative data for analysis. The aim of the study was to investigate and understand the extent and nature of access to electroencephalography studies in SSA, especially for paediatric patients. Also, the level of competence of the practitioner performing and interpreting the studies. In addition, we looked at an apprenticeship training programme that will focus on technicians to learn basic paediatric EEG interpretation for safe practice. The study was approved by the ethics committee of the UCT, Cape Town, South Africa (481/2018).

Statistical analysis

All survey data was exported from REDCap into "Stata 14.0 (StataCorp, College Station, TX)" for analysis and p-values were obtained using chi square (X^2) statistics. Qualitative data were analysed using thematic themes and comparison techniques.

Inclusion and exclusion criteria

Completed and partially completed questionnaires were included for analysis. Whilst the extent of partially completed questionnaires varied, we included those in which had most critical questions were answered. Questionnaires with inadequate fields completed were excluded.

RESULTS

Out of the 311 participants, 6 were removed owing to duplication and retirees from the field of practice. The survey was sent to 305 participants of which 232 failed to complete. The survey was resent to non-respondents four times in the subsequent six months (June-December 2019). In total 57 respondents successfully completed all fields of the survey. For the remaining 16 not all data fields were completed by the respondents, but sufficient data was captured to allow analysis for sub-sections. The combined 73 (16 partial and 57 complete) surveys were analysed from 18 countries which equated to 24% of the total participants sent the survey (figure 3.1). The 18 countries that responded in-line with the world bank ratings were 44% (8/18) from low and 56% (10/18) from low middle-income countries. The number of respondents from each country can be seen in figure 3.2, Nigeria had the highest number of respondents, followed by Kenya, and Ghana. Countries had respondents from across all levels of healthcare (primary/district/secondary/tertiary) and private institutions (figure 3.3). EEG training was explored in South Africa previously and was not included in the data base [8]. The response from Tunisia was an outlier, as not part of SSA, but as this participant was inadvertently included in the survey list after partaking in one of the PET courses and was retained in the study as a useful comparison example of North versus SSA practice. There were no differences between practice in Tunisia compared to the countries of SSA. The 14 countries with no respondents had world ranking which ranged from low, low middle and upper middle-income countries (https://www.ilae.org/files/dmfile/World-Bank-list-of-economies-2020_web2.pdf).

The respondents fell into two main categories, those with access to EEG capacity and those unable to access this resource with or without a trained technician. This varied considerably and is illustrated in *figure 3.1*.

Access to EEG equipment and technicians: Of the respondents,60% (44/73) had access to a service with EEG equipment and a neurologist, and 91% (40/44) of the EEG services that the respondents used, had access to a technician as well. Of the 9% that lacked a dedicated technician, the EEGs were outsourced to the neurophysiology/adult and child neurology departments. The prior background details of the technicians are documented in *table 3.1*. Of the 40% (29/73) who did not have on-site access to EEG equipment, 34% (10/29) could outsource to a technician to perform EEGs and 5/10 (50%) of this group who outsourced had access to a neurologist. The 5/10 respondents with no access to a neurologist, 3/5 came from primary or secondary hospitals and 1/5 was from tertiary and 1/5 from private. The remainder (19/29) were unable to access either EEG equipment or personnel to perform the studies and had no access to a neurologist in 52%

(15/29). The majority of these respondents came from primary or secondary hospitals, but 4/15 were based in a tertiary hospital. Only 14% (4/29) had access to a neurologist in this group.

Respondent characteristics against number of annual EEGs conducted *(supplementary table 3.1, supplementary figure 3.1)* and demographics of the group managing patients with epilepsy. There were discrepancies in the distribution of respondent ages by annual hospital EEG studies performed. Respondents from hospitals doing < 100 EEGs per year tended to be younger than those from hospitals doing 100 or more EEGs per year (figure 3.3 and table 3.2). For example, in the lower EEG studies performed category, only 10% of respondents were 45-54 years old (and 57% were 35-44 years old), compared to 37% (35-44 years old) and 37% (45-54 years old), respectively, of respondents in the higher EEG burden category. There was no statistical difference in the sex ratios of the respondents. The majority (40/72) were general paediatricians, and the remainder were adult neurologists, child neurologists, general physicians, general practitioners, psychiatrists, neuro-developmental specialist and a few unknown. 70% (51/73) of the above respondents came from tertiary level hospitals. Only 66% (48/73) of the respondents had access to a neurologist in their hospital. The annual EEGs undertaken when compared to the availability of an in-house neurologist (figure 3.3) found that a higher percentage of neurologists yielded more EEGs per annum compared to if there was no neurologist (25%) with a p value of (<0.0001). Respondents from primary level or district hospitals lacked in-hospital neurologists, and all reported requesting less than 100 EEGs done per annum. Sixty percent of respondents from secondary level hospitals lacking an in-hospital neurologist reported an EEG turnover of greater than 100 EEGs per year, compared to 50% of those in secondary level hospitals with an in-hospital neurologist. The lack of an in-hospital neurologist tended to be slightly higher (10% absolute difference, 60% vs 50%), suggesting a tendency for requesting more EEGs for diagnoses. In both tertiary hospitals and private practice, having an in-hospital neurologist (vs not having an in-hospital neurologist) available was associated with greater number of EEGs performed: 44% vs 0% of respondents from tertiary hospitals reported > 100 EEGs per annum, 76% vs 75% of respondents from private practices reported > 100 EEGs per annum. However, for in-hospital neurologists in tertiary and private practice the absolute difference was only 1%. In 71% of cases (34/48) neurologists were managing adults and children with epilepsy, in 25% (12/48) only children and the remainder just adults. In the absence of a neurologist a range of personnel provided neurology care is documented in *supplementary table 3.1*. In this setting the majority of children with epilepsy were seen by paediatricians, a smaller percent by psychiatrists or medical officers with an interest in neurology.

Would an apprenticeship in paediatric EEGs benefit the respondent's practice? In total, 77% (56/73) were in an agreement for the need for an apprenticeship, 4% (3/73) said no need and no response was given in 19% (14/73). The non-responders had access to a neurologist in 71% (10/14) of cases, so that 29% had no access to a neurologist. Most of the non-responders came from tertiary hospitals (71%) and the remainder from private and primary/secondary hospitals.

The qualitative data with verbatim quotes was grouped according to the following three common themes:

- "professional development" (improve skill/enhance quality of interpretations). 48% (27/56) of the participants fitted into this theme e.g., "*as a paediatrician I would be able to interpret EEGs for my patients and not relying on what the technician says which would help in the management of my patients"; "interpretation of paediatric and adult EEG is difference, it will improve skills and interpretation"; "it would help with proper EEG study and interpretation, helping ultimately to an appropriate decision making"*.
- "better care" (improve quicker diagnosis) accounted for 29% (16/56) e.g., *"accurate classification of epilepsy which leads treatment and good outcome"; "better interpretation*

of results, better care to paediatric patients"; "the person will be fully available for paediatric patients".

- "help paediatric patients and neurologists" resulted in 23% (13/56) of the responses e.g., *"the physiologist would be better able to flag paediatric EEG problems"; "quality of management of paediatric epilepsy would be improved if there are dedicated paediatric EEG services and personnel"; "it would increase expertise as an encephalographer and engender training of others*".

A breakdown of the available EEG services is provided in *table 3.2*. As previously stated, 60% (44/73) of the respondents had access to EEG equipment within the respondent's hospital (p= 0.003). Paediatric EEGs were performed in a range of different locations: the majority were performed in an adult neurology department (54%); 34% a paediatric department and the remaining either within a psychiatry department (5%) or by EEG technicians (7%) in the neurophysiology facility. Most EEGs were performed within a week of the request. Breaking the data down further and looking at the turnaround time for undertaking EEG in the setting of access to a neurologist and an EEG machine (41/48), varied such that 77% (37/48) occurred within 1 month and 8% (4/48) waited longer. In the 15% (7/48) where no EEG machine was present and the EEGs were outsourced, the EEG waiting times were also within a month. In the setting where no neurologist and no EEG machine (25/73) were available onsite, in 72% (18/25), surprisingly most of the EEGs were also done within a month via outsourcing and only 8% (2/25) had longer waiting times. In the 20% (5/25) that had an EEG machine with no neurologist, the results were similar to above. Only 2 clinicians, an adult neurologist from Sudan and a child neurologist from Cameroon, reported performing >1000 EEGs per year, the highest annual EEGs performed were between 100-500 in 44% of cases. The EEGs were statistically more likely to be performed on a combined adult and paediatric population rather than dedicated paediatric groups (p=0.004).

The respondents were significantly more likely to have access to someone to perform EEGs on their patients (68% cases; p=0.001). In addition, they were significantly more likely to be associated with departments which had more than one technician (p<0.001). In the 32% who did not have access to a technician, the respondents were asked an open-ended question "how an EEG service can be provided within their practice"? The following three key themes emerged in response added with verbatim quotes. 43.5% alluded to "training" (*"good training programmes are lacking"/ "training technicians")* and 13% on "reporting" (*"interpretation not adequate for paediatric EEGs"/ "paeds EEGs often get sent to another tertiary institution to have them read and interpreted"* and some stated *"district hospital"* which accounted for 4.5% (*"we always have to send to a tertiary centre in the big city miles away for EEG to be done").* The respondents were asked who read and interpret their paediatric EEGs. Surprisingly the group confirmed that this was by paediatric neurologists in 37% followed by a range of other personnel. In terms of the level of paediatric experience the interpreter had, only 34% had > 1-year experience in EEG training.

Table 3.1 provides the breakdown of the employment and training experience of centres with one EEG technician and centres with two EEG technicians. This table highlights their background prior to training; type of employment; their training, where it occurred and duration and lastly what qualification they received. Formal training in the one EEG technician category was more in demand versus informal training. Informal training for the two EEG technician category scored higher than formal training. Local training was popular for both EEG technicians followed by a combination of local and international training.

Discussion

Surveys can be an effective way to gather information but can also be a burden to the receiver as well as ending up in the spam folder. Despite resending the survey, only a quarter replied from 18/32 low and low-middle income countries in SSA and 24% of the invited participants (73/305). This figure still falls within a good net promoter score (NPS) survey response rate (https://www.genroe.com/blog/acceptable-survey-response-rate-2/11504). These countries have many specific challenges when it comes to the burden of epilepsy especially when most individuals with epilepsy have onset during childhood [2, 4] . This survey provided a useful insight of EEG services for epilepsy in SSA and the need for paediatric EEG training.

The responses confirmed that just over two-thirds of the patients had access to neurologists, who saw mostly a combination of paediatric and adult patients. Access to a neurologist was also more likely in a tertiary (urban) than rural setting. Most children with epilepsy are treated by medical officers, paediatricians, and psychiatrists rather than specialist child neurologists. Access to an EEG service was available in a higher proportion than expected but this was when there was a neurologist available. A neurologist was statistically more likely to undertake more EEGs per year than services that lacked access to a neurologist. It is hoped that this reflects the clinical expertise of these neurologists to identify patients who would gain the most from the investigation, with clearly identified clinical questions that the study would aid answering such as to differentiate syndromes and to rule out non-epileptic cases. This was not the case in a study by the authors in a centre where > 1000 EEGs are performed per annum, paediatric neurologists requested more appropriate EEG compared to paediatricians and non-specialists [22] . However, the survey did not capture how often the EEG studies resulted in a change in practice, but this trend has been illustrated to be the case in another study by the authors [8] . Paediatric EEGs were performed by a spectrum of healthcare departments mostly by those with adult care clinicians. Neurologists in SSA are scarce and even more so paediatric neurologists [4, 51] . With the recommendation from the World Health Organisation of a minimum of one child neurologist per 100 000 of population, it may take many years for SSA to have sufficient neurologists and paediatric neurologists to be equivalent to resource equipped countries [15]. Hence alternate options to deliver health care are needed.

Overall, there was no difference in EEG waiting times whether there was a neurologist and EEG machine onsite compared to no neurologist and no EEG machine, and the study had to be outsourced. However, in terms of paediatric EEGs the survey could not address evidence for improved care, nevertheless the verbatim quotes supported why paediatric apprenticeship training would be beneficial. Many centres had one or more technician who performed their EEGs and were employed fulltime. Various forms of training occurred, and informal training (local) was preferred after formal and local training. In both EEG technician groups, the training time for the majority was under a year and only a handful of technicians trained for greater than a year. Illustrating limited access to training, many people performing EEGs either had a certificate in isolation or lacked any qualification. Ideally to perform EEGs a science background is useful as the field requires technical skills as well as some knowledge in anatomy. Centres with two technicians can be more effective in yielding more EEGs per annum and the combined expertise and teamwork supports a more competent practice. An EEG laboratory in SSA with one trained technician is a bonus, but two technicians is even more profound. This enables teamwork and multidisciplinary care, with retention and ongoing promotion of skills leading to better developed units and invested workers. Further, this permits higher patient turnover and improves centres expertise. In variance to practice in resourced settings, technicians in SSA could be more effective if qualified as a medical officer or nurse to aid case assessment. This would also target the burden of the clinical management of epilepsy in SSA.

There were no EEG services available for one third of the respondents. Respondents were asked to comment *"how we can fill this void in their practice"?* Comments like *"training programmes*", *"the need for an EEG machine and reports are dependent on a neuro technologist"* are a few that stood out. District hospitals also tend not to be equipped with specialised equipment and many patients must travel long distances to get their tests done, often at a significant service fee. However, a small percentage had access to a technician outside their service to perform their EEGs as well as access to a neurologist. Although no EEG service was available, many still were in favour of having someone undergoing the apprenticeship.

Two-thirds of the respondents reported that they were interested in an apprenticeship programme. Three frequent key themes re-occurred amongst the responses relating to professional development, better care for patients and help for paediatric patients and neurologists. The overall response for why apprenticeship training was needed was to improve diagnosis and management for paediatric patients as well as improving skills both for doctors and technicians. An apprenticeship program has been developed as a sub-section of the African Paediatric Fellowship Program which trains Africans for Africa [4]. The APFP has been training paediatric neurologists since 2008 and offers a unique model for training i.e., it is cost effective, modelled on relevant training curricula, and leads to local retention and ongoing postgraduate support (https://theapfp.org). Currently nine paediatricians have trained in paediatric neurology inclusive of electrophysiology skills via the APFP from Kenya (2), Tanzania (1), Ghana (1), Uganda (1), Serra Leone (1), Nigeria (1) and Sudan (2). Three are currently in training from Kenya (2), Sudan (1) and Botswana (1) and will add to the above figures. Further paediatric trainees from Sudan (1), Uganda (1), Zimbabwe (1), Kenya (1), Nigeria (2) and Mali (1) are accepted to enter the program. This would also target the burden of the clinical management of epilepsy in SSA. In 2019 the researcher ran a pilot project to support the training needs of a trainee from Kenyatta University, Department of Medical Physiology who was the APFP's first clinical technology fellow. With an MSc in Biotechnology, the fellow trained on-site for six months, based in the neurophysiology unit at Red Cross War Memorial Children’s Hospital. He focused his skills on EEG interpretation and other critical elements of paediatric neurodiagnostic before returning home to Kenya in August to lead the neuro-clinical diagnostic team in their new University Teaching and Research Hospital. The neurophysiology / paediatric neurology team at the authors' training site supports in-house child neurology trainees based in Kenya who join the weekly meetings on EEG interpretation and will spend time in the department for study module attachments.

Overall, more training nodes are needed across Africa to improve healthcare workers knowledge and to help elevate the burden of neurological disorders especially epilepsy, in Africa.

Study Limitations:

Only a quarter of the respondents replied to the survey from half of the countries, which may have resulted in some bias with regard to the countries that elected to respond. If all countries had responded a much broader insight into the needs for paediatric EEG training in SSA would have resulted. However, an NPS response rate above 20% is regarded as a good survey response rate. The countries that did not respond only 5/14 came from upper middle and the rest from low and low-middle income countries (9/14). It is unknown if the latter countries thought the survey was irrelevant to them due to their limitations treating patient with epilepsy. There is also some selection bias as the survey was sent mostly to paediatricians (55%) who were intentionally targeted as the key care providers for children with epilepsy in Africa. Some of the above trained with the APFP program or visited the department for short term training in paediatric neurology and EEG. Whilst this was a small proportion of main group, these child neurology trainees often returned as the first specialist in their country and were truly insightful of the challenges and needs to access EEG in their setting. Most incomplete answers came from tertiary/academic hospitals. Some of the respondents may not have been able to answer all the questions *i.e.*, those invested and interested in the field were more likely to respond.

CONCLUSION

This study addresses the lack of paediatric EEG access and knowledge amongst doctors and technicians working with children with epilepsy in SSA. Viable training models are needed to target the deficit of practitioners skilled in paediatric EEG in SSA. Examples such as the APFP apprenticeship training programme will focus on technicians, namely technology trained, nurses or medical officers, who would be taught a basic curriculum in EEG for paediatrics giving them the foundation to provide safe practice and interpretation of paediatric EEGs in SSA. The technicians would support newly qualified paediatric neurologists returning home to establish service delivery in one's country and to provide good electroencephalographic paediatric practice. Cohesion with similar collaborative programs is needed to build a strong and sustainable workforce.

Author contributions:

Veena Kander: Wrote the manuscript based towards for PhD thesis, collected and analysed article data and formatted conclusions.

Joanne Hardman: Co-supervisor of PhD thesis, proofread and assisted with coding qualitative data.

Jo Wilmshurst: Supervisor of PhD thesis, proofread and made corrections to the manuscript content.

Ethical Approval

The study protocol was passed by the Red Cross Children's Hospital Research Committee and the University of Cape Town Ethics Committee REC/REF 481/2018. This article is based on the research for a Doctor of Philosophy Degree in Neurophysiology by Veena Kander.

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Legends for Tables and Figures

Figure 3.1. Flow diagram of survey response

Figure 3.2. Participant countries represented

Figure 3.3. Bar graph showing annual burden of EEG requests over availability of in-hospital neurologist within different levels of service delivery

Table 3.1. Employment and training characteristics of centres with one and two EEG technicians

Table 3.2. Characteristics of available EEG services

Supplementary documents

Supplementary figure 3.1. Pie chart showing distribution of respondent age categories by annual number of EEG investigations conducted in hospital

Supplementary table 3.1. Comparison of respondent characteristics by number of annual EEGs conducted from primary/secondary/tertiary and private institutions

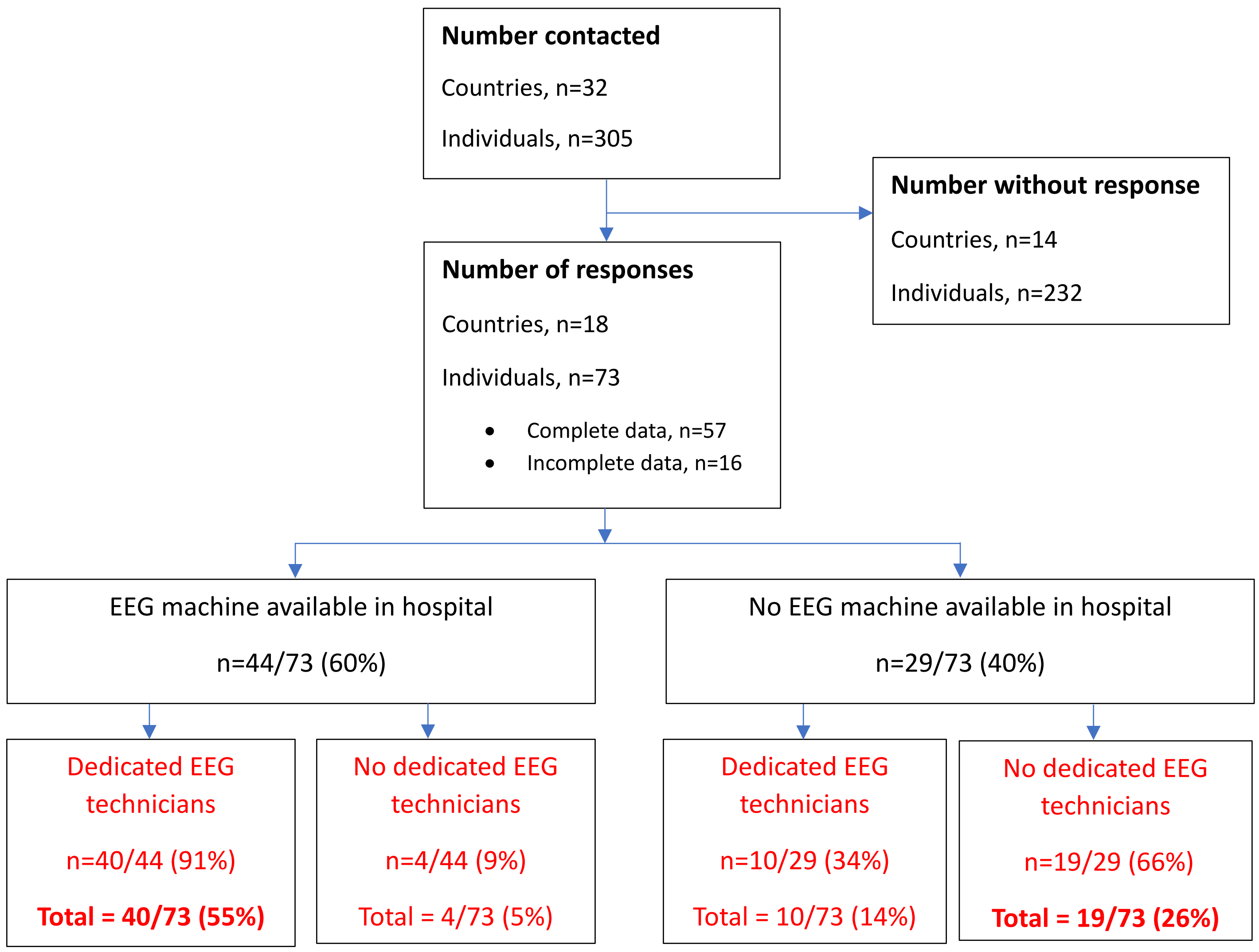


Figure 3.1: Flow diagram of survey response.

Figure 3.2: Participant countries represented.

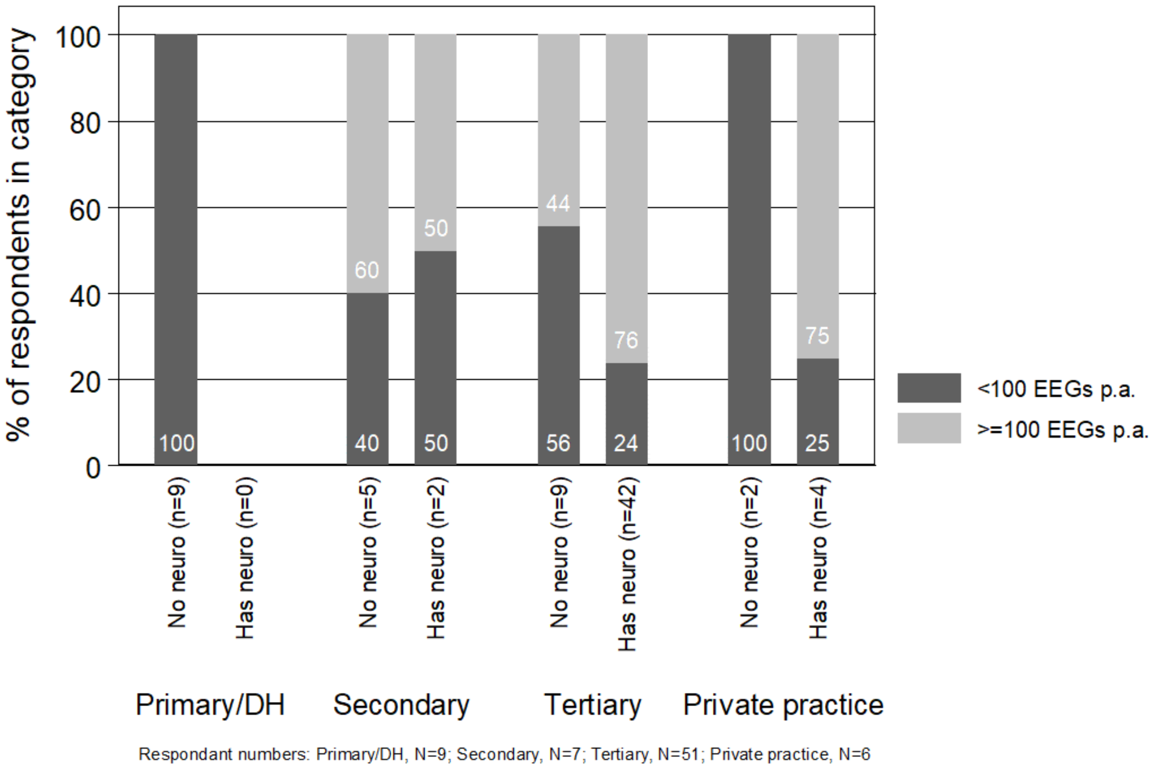


Figure 3.3: Bar graph showing annual burden of EEG requests over availability of in-hospital neurologist within different levels of service delivery.

Table 3.1: Employment and training characteristics of centres with one and two EEG technicians

	Centre with one EEG technician (N=50)	Centre with two EEG technician (N=29)
Pre-EEG training background of technician		
Nurse	16 (32%)	12 (41%)
Doctor	13 (26%)	8 (27%)
Physiology/EEG technician	9 (8%)	3 (10%)
Clerk	2 (4%)	5 (17%)
Other	2 (4%)	1 (3%)
No response	8 (16%)	0
Type of employment		
Full-time	35 (70%)	26 (90%)
Part-time	9 18%)	3 (10%)
Other	1 (2%)	0
No response	5 (10%)	0
Type of training		
Formal	22 (44%)	11 (38%)
Formal and informal	6 (12%)	5 (17%)
Only informal	15 (30%)	13 (45%)
No response	7 (14%)	0
Location of training		
Locally	24 (48%)	21 (72%)
Internationally	9 (18%)	3 (10%)
Combined, local and international	12 (24%)	5 (17%)
No response	5 (10%)	0
Duration of training		
< 3 months	10 (20%)	8 (28%)
3-6 months	10 (20%)	6 (21%)
7-12 months	8 (16%)	7 (24%)
> 1 year	14 (28%)	8 (27%)
No response	8 (16%)	0
Qualification obtained		
Certificate	23 (46%)	13 (45%)
Certificate & Degree	1 (2%)	2 (7%)
Degree	1 (2%)	1 (3%)
Bachelors	2 (4%)	1 (3%)

	Centre with one EEG technician (N=50)	Centre with two EEG technician (N=29)
Masters	3 (6%)	1 (3%)
None	12 (24%)	12 (41%)
No response	8 (16%)	0

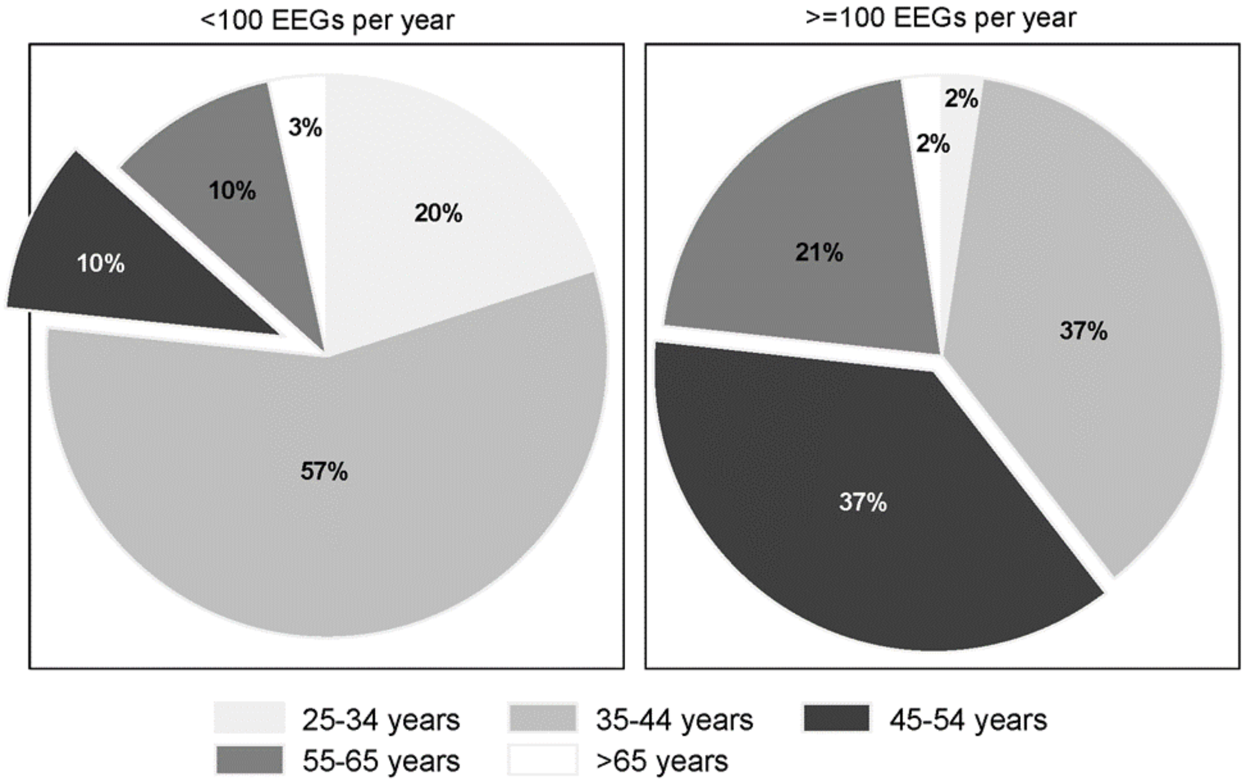
Formal training – a structured programme earning a certificate on completion. Comparison was between all centres with technicians (N= 50) to the subgroup who had two or more EEG technicians N= 36/50, however, for some subsections the questions were not completed in 7. Formal statistical analysis was undertaken in N=29.

Table 3.2: Characteristics of available EEG services

Characteristic	Total respondents (N=73)	Annual EEGs ≥100 (n=43)	Annual EEGs <100 (n=30)	*P*
Level of service (location of respondent)				**0.001**
Primary level/district hospital	9 (12%)	0	9 (30%)	
Secondary level hospital	7 (10%)	4 (9%)	3 (10%)	
Tertiary level hospital	51 (70%)	36 (84%)	15 (50%)	
Private practice	6 (8%)	3 (7%)	3 (10%)	
EEG machine available in hospital				**0.003**
No	29 (40%)	11 (26%)	18 (60%)	
Yes	44 (60%)	32 (74%)	12 (40%)	
Department performing paediatric EEG in hospital				0.27
Adult/unspecified neurology	24/44 (54%)	19/32 (59%)	5/12 (42%)	
Paediatric Neurology	15/44 (34%)	10/32 (31%)	5/12 (42%)	
Psychiatry	2/44 (5%)	2/32 (6%)	0	
Neurophysiology/technicians	3/44 (7%)	1/32 (3%)	2/12 (17%)	
Waiting time for EEG				0.16
<1 week	39 (53%)	27 (63%)	12 (40%)	
1-4 weeks	28 (28%)	12 (28%)	16 (53%)	
1-3 months	4 (5%)	3 (7%)	1 (3%)	
3-6 months	2 (3%)	1 (2%)	1 (3%)	
Number of annual EEGs				n/a
<100	30 (41%)	0	30 (100%)	
100-500	32 (44%)	32 (74%)	0	
500-1000	9 (12%)	9 (21%)	0	

Characteristic	Total respondents (N=73)	Annual EEGs ≥100 (n=43)	Annual EEGs <100 (n=30)	*P*
Who are the EEGs preformed on?				0.004
Adults	2 (3%)	1 (2%)	1 (3%)	
Children	6 (8%)	3 (7%)	3 (10%)	
Adults and children	42 (58%)	32 (74%)	10 (33%)	
No answer	23 (31%)	7 (16%)	16 (53%)	
Dedicated people to perform EEGs?				0.001
No	23 (31%)	7 (16%)	16 (53%)	
Yes	50 (68%)	36 (84%)	14(47%)	
Number of EEG technicians in the department				<0.0001
1 person	14/50 (28%)	5/36 (14%)	9/14 (64%)	
2 or more person's	36/50 (72%)	31/36 (86%)	5/14 (36%)	
Characteristics of primary person who reads and interprets paediatric EEGs	N=59	N=35	N=24	
Background of person				0.16
Adult neurologist	15 (25%)	12 (34%)	3 (12%)	
Paediatric neurologist	22 (37%)	13 (37%)	9 (38%)	
Psychiatrist	2 (3%)	1 (3%)	1 (4%)	
EEG technician	4 (7%)	1 (3%)	3 (12%)	
Combination EEG technician with specialist	11 (19%)	7 (20%)	4 (17%)	
Other	5 (8%)	1 (3%)	4 (17%)	
Level of paediatric EEG training the interpreter had				0.06
< 3 months	6 (10%)	5 (14%)	1 (4%)	
3-6 months	17 (29%)	14 (40%)	3 (12%)	
7-12 months	9 (15%)	4 (11%)	5 (21%)	
> 1 year	20 (34%)	8 (23%)	12 (50%)	
Other	7 (12%)	4 (11%)	3 (3%)	

Values are n (column %), p-values from chi^2 test.
Abbreviations: EEG, electroencephalogram; tech, technician



Supplementary figure 3.1: Pie chart showing distribution of respondent age categories by annual number of EEG investigations conducted in hospital.

Supplementary table 3.1: Comparison of respondent characteristics by number of annual EEGs conducted from primary/secondary/tertiary and private institutions.

Characteristic	Total respondents (N=73)	Annual EEGs ≥100 (n=43)	Annual EEGs <100 (n=30)	*p*
Age of respondent				**0.009**
25-34	7 (10%)	1 (2%)	6 (20%)	
35-44	33 (45%)	16 (37%)	17 (57%)	
45-54	19 (26%)	16 (37%)	3 (10%)	
55-65	12 (16%)	9 (21%)	3 (10%)	
>66	2 (3%)	1 (2%)	1 (3%)	
Gender				0.24
Male	40 (55%)	26 (60%)	14 (47%)	
Female	33 (45%)	17 (40%)	16 (53%)	
Location of respondent				**0.001**
Primary level/district hospital	9 (12%)	0	9 (30%)	
Secondary level hospital	7 (10%)	4 (9%)	3 (10%)	
Tertiary level hospital	51 (70%)	36 (84%)	15 (50%)	

Characteristic	Total respondents (N=73)	Annual EEGs ≥100 (n=43)	Annual EEGs <100 (n=30)	*p*
Private practice	6 (8%)	3 (7%)	3 (10%)	
Hospital has a neurologist				
Yes	48 (66%)	36 (84%)	12 (40%)	<0.0001
No	25 (34%)	7 (16%)	18 (60%)	
Type of patients managed by neurologist at hospital				0.70
Adults only	2/48(4%)	1/36 (3%)	1/12 (8%)	
Paediatric only	12/48 (25%)	9/36 (25%)	3/12 (25%)	
Combination (both)	34/48 (71%)	26/36 (72%)	8/12 (67%)	
Person providing paediatric neurology care in absence of neurologist				0.24
Paediatrician	16/25 (64%)	5/7 (71%)	11/18 (61%)	
Psychiatrist	1/25 (4%)	1/7 (14%)	0	
Medical officer with neurology interest	2/25 (8%)	1/7 (14%)	1/18 (6%)	
Combination of above	4/25 (16%)	0	4/18 (22%)	
Other	2/25 (8%)	0	2/18 (11%)	
Respondent interested in paediatric EEG apprenticeship				0.95
Yes	56 (77%)	33 (77%)	23 (77%)	
No	3 (4%)	2 (5%)	1 (3%)	
No answer	14 (19%)	8 (19%)	6 (20%)	

Abbreviations: Numbers are n (column percentage) with p-values from Chi^2 test.

CHAPTER 4 – Handbook

This chapter includes a qualitative subjective study of the online handbook looking at the efficacy of the handbook and whether it is a viable tool to learn paediatric EEG interpretation.

Journal: BMC educational journal

Title: Clinical practice applicability and relevance to non-specialists of a paediatric EEG online learning tool

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ABSTRACT

Background: Paediatric electroencephalography (EEG) training is inadequate amongst healthcare practitioners and technicians managing children with epilepsy in sub-Saharan Africa. An entry level handbook was developed for healthcare practitioners in sub-Saharan Africa and subsequently made globally accessible via the International Child Neurology Teaching Network.

Aim: To investigate the usefulness of a paediatric online EEG handbook.

Method: A survey of the ICNApedia online EEG handbook was circulated (December 2021 - June 2022), to all 108 handbook registered participants (39 countries) via the research electronic data capture (REDCap) from the university of Cape Town (UCT).

Results: Fifty participants from 25 countries responded: 8 from high income, 16 upper-middle income, 21 lower-middle income and 5 from low-income. 32 (64%) fully and 18 (36%) partially completed the survey. 35/50 (70%) had completed the handbook and seven respondents had partially completed the handbook. Responses supported the handbook as a good entry point to learn EEGs, especially for paediatrics. Likert scale ratings supported the handbook as relevant for gaining/enhancing knowledge and improving diagnosis and management of patients with confidence. The handbook was considered user friendly, comprehensible, and provided a practical experience. For improving EEG reading skills the handbook helped skills development via reinforcement and good illustrations. 29/32 (90%) of respondents confirmed that they are using learnt skills from the handbook in their current work.

Conclusion: In resource limited settings non-specialist clinicians often provide extended services including EEG interpretation. The survey supports that the handbook is supporting this niche skills area, especially for the accessibility of knowledge gained. The handbook will continue to be adapted in-line with survey feedback.

Keywords: Electroencephalography, paediatric EEG, online teaching, low-middle income countries

INTRODUCTION:

Epilepsy is one of the most common neurological disorders of the central nervous system (CNS) and commonly begins in childhood [51]. There is limited access to quality, reliable and cost-effective health care facilities in resource limited countries (RLCs). Access to diagnostic equipment [EEG and neuroimaging] and personnel is also limited with geographic disparity in distribution (urban vs rural) [5].

Lack of paediatric EEG expertise in Sub-Saharan Africa (SSA) led the researcher to develop a handbook on paediatric EEG interpretation. The handbook aims to improve and increase basic interpretation skills amongst those treating children with epilepsy in SSA for safe practice and not to make them epileptologists. In 2015, the researcher demonstrated that early used of the handbook was effective as a learning tool, although face to face training strengthened the outcome [8].

In 2021, a systematic review was performed on EEG tools for the non-specialist and found that whilst available, they are rarely critiqued for quality of impact [52]. The study found similarities with key concepts taught and that paediatric EEG training was not adequately addressed in some EEG training programs. Of the published studies critiquing existing training programs, the lack of consistency and directness limited comparison [53].

This report aims to assess the usefulness and applicability of the handbook by the users in real-time clinical practice.

Methodology

We developed a 15-minute web-based survey consisting of 26 descriptive and interpretative questions (appendix 4). The survey was emailed to 108 participants from 39 countries who registered to do the online course since it went live in 2016 on the International Child Neurology Association website ICNApedia.org. Subsequently it has been embedded into the epilepsy module of the International Child Neurology Teaching Network (ICNTN) in 2021. Research electronic data capture (REDCap) from the University of Cape Town's (UCT) web applications were utilised to circulate the survey via the web with weekly eblasts (24th Dec 2021 – 24th June 2022). In addition, the author sent out emails with REDCap links on a weekly basis. Informed consent was obtained from all the participants. The survey collected data on participants (demographics; hospital location (tertiary, secondary, primary, public, private); whether they treat children and report on paediatric EEGs; training received in paediatric EEG (when it occurred and how long). They were then asked if they completed the handbook or not. The last section focused on their experience and opinion of the handbook. The questions were mainly formatted as drop-down options, where possible with Likert scales, and open-ended questions. Data was analysed and presented using descriptive statistics. Open-ended questions were analysed for themes that emerged in the data rather than imposed deductively [54]. We included all complete surveys and those that answered at least half of the survey questions. The study was approved by the ethics committee of the UCT, Cape Town, South Africa (481/2018).

Statistical analysis

All the survey data was exported from the online data management software REDCap into Stata v14.2 (StataCorp, College Station, TX, USA) for analysis. Figures presented were generated using Microsoft Excel. Data were presented as proportions since most of the variables collected were categorical and the p values were generated using chi square ($\chi 2$) or fisher's exact test. The mean age and the standard deviation of the cohort was reported and to test the association in the different income groups the ANOVA test with a Bonferroni correction was used. The handbook, comparison between the proportions of responders versus non-responders by country income level was assessed using the Z-test. A p-value of less than or equal to 0.05 was used to denote statistical significance.

Results

We received 50 (46%) out of 108 responses to our survey (figure 4.1). Out of the 50 participants, 35 (70%), obtained a certificate from the online course (figure 4.1). As based on the world bank classification (https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2021-2022) the breakdown of the 50 participants and per country is seen in figures 4.1 and 4.2.

Inclusion of the partially completed survey responses provided valuable additional information from 10 participants who had either completed (7) or partially (3) completed the handbook. 58/108 (54%) did not access the survey, of whom 24 (41%) consented but did not go on to complete the survey. 34 (59%) failed to acknowledge the invitation to be part of the study. The breakdown of the countries that did not respond is available in supplementary figure 4.1. The comparison of the participants who completed the handbook between the responders and non-responders by income country is seen in table 4.1. There is no difference in participants from upper middle-income (UMI) and lower middle-income countries (LMICs), however, there is a threefold number of participants from the high-income countries (HICs) of non-responders compared to the responders. Low-income country (LIC) participants can only be seen in the responders group. 26 (45%) non-respondents who completed the online handbook with certificates failed to complete the survey.

Participants information

Overall, there was a female participant preponderance amongst the survey respondents (56%), although most participants from LICs were male (80%). The average age of the study group was 43 years (SD +/-10) with most being paediatric neurologists 23/50 (46%) across the different income countries except for LMICs as illustrated in figure 4.3.

Most participants worked in the tertiary care setting (35) and private (12) and a minority in community care (2) and secondary care (1). 47/50 (94%) are actively involved in the management of children with epilepsy, but only 26 (52%) report paediatric EEGs. 20 (76.9%) reported that they had had previous EEG training. Some participants had multiple exposures of EEG training. The majority,12/20, trained during a fellowship program followed by 11 for online courses. Surprisingly only 3 had training during their registrar rotation who further went on to do fellowship (3) and online courses (2). For those who had undergone EEG training the time ranged from <3 months to 13 years of training as seen in table 4.2. The handbook data is described below in further detail.

Online handbook course

Close to three quarters of the respondent 35/50 (70%) completed the online course. Respondents were balanced from the LIC, LMIC and UMICs. But this differed for HICs where half of the respondents who had registered did not attempt the online course is available in supplementary figure 4.2. Seven partially completed the online course and eight did not. As such they read some of the chapters and either attempted the post chapter quizzes or not. The consensus for this was “not having time to complete the handbook” in (6/11). The year of completion ranged across 6 years (2017-2022). Completion time was variable from less than a week to 8 months owing to having a “busy schedule” in 11 as reason for delay. 11/19 (58%) were not aware they could use the chat to clarify any information.

Experience and opinion of the handbook – Likert scale

The experiences of the respondents with respect to already having skills in reading paediatric EEGs varied by income country. Over half of the participants 17/32 (53%) on the Likert scale disagreed/strongly or disagreed with not having paediatric skills before the handbook. A higher proportion of responses came from LMIC (11) seen in figure 4.4. 30/50 (60%) found the handbook relevant to their current work and (2) stayed neutral (figure 4.6). For the rest of the experiences and opinions figures 4.5 - 4.8 the respondents were generally agreeing/strongly or agreeing. 30 (60%) gave additional explanatory comments for their rating. Out of which 2 failed to complete all explanatory comments although they both strongly agreed/agreed on their experience and opinion of the handbook. The authors both analysed the qualitative data for themes and agreement between the authors on the identification of themes was obtained. Thematic analysis using descriptive themes was done. The following themes emerged in relation to each question. These are provided in the analysis below and discussed later in the text.

Thirty participants responded to the question whether using the handbook has improved their paediatric EEG reading skills overall (figure 4.5) and gave reasons for their rating. Three sub-themes emerged inductively from the data.

Theme 1: Improvement of paediatric reading skills

1) User friendly

Participant 25: Simplicity in explanation.

Participant 26: Easy.

Participant 28: The knowledge and skills in the book were useful.

2) Comprehensible (helped my knowledge)

Participant 6: Reaffirmed knowledge.

Participant 3: I was able to understand the EEG rhythms and identify them.

Participant 14: I learnt the basic EEG knowledge and interpretation skills.

3) Practical examples

Participant 21: Used as a refresher.

Participant 18: I got more comfortable with paediatric EEGs and my confidence grew.

When asked whether using the handbook has improved paediatric EEG reading skills in the following topics is available in supplementary figures 4.3.1 - 4.3.4. Here again 30 participants gave their reasons for their rating. The following two sub-themes emerged here: -

Theme 2: Identification of basic concepts in EEG reading

1) Reinforcement

Participant 10: Repetition of concepts.

Participants 28: The chapter on identification of EEG abnormalities was useful.

2) Good illustrations

Participant 7: The book was well illustrated.

Participant 19: The sections were presented in a clear manner.

29 participants are using learnt skills from the handbook in their current work (figure 4.7). Only one participant strongly disagreed "I see adult patients only, but the course did help me in getting the basic concepts of EEG. I am still trying to get my hospital to purchase an EEG machine". The following theme stood out from the responses.

Theme 3: Relevance - to application

Participant 18: I am a neurophysiologist working with EEGs every day.

Participant 20: I am currently a neurology trainee hence the skills learnt are quite relevant.

Participant 19: I daily encounter patient with epilepsy and EEG knowledge is key.

In relation to the handbook's impact on the improvement of respondents' clinical care (figure 4.8) elicited one central theme. This is illustrated with quotes drawn from the data below.

Theme 4: Improved reading of EEG

Participant 18: I can confidently give back feedback on EEGs and provide more sufficient Health care to my patients.

Participant 20: The skills are useful in formulating diagnosis and choosing appropriate intervention for the patients.

Participant 22: It became evident in my practice.

Participant 31: My knowledge for epilepsy has improved a lot and how I manage the patients based on the EEG abnormalities I can identify after the course.

When asked whether they would recommend this handbook to others is available in supplementary figure 4.4, three sub-themes emerged in the data and are reported below.

Theme 5: Recommendation of handbook

1) Develops understanding

Participant 16: Well researched book.

Participant 17: Best introduction of EEGs that I have found.

2) User friendly

Participant 12: The handbook does explain the basic concepts in a simplified manner.

Participant 7: Easy and concise.

3) Affordability

Participant 9: Although a basic course, it is affordable and accessible.

In response to suggestions to improve the course, two sub-themes emerged below. We can see that the addition of videos and case studies to the handbook would improve the overall course according to these respondents.

Theme 6: Improvement to course

1) Videos

Participant 12: Some online video lectures to clarify difficult concepts would be helpful.

Participant 22: Online video sessions.

2) Case studies

Participant 5: A few case studies would be helpful.

Participant 20: Include patient or clinical scenarios as examples.

The impact of Coronavirus disease (COVID) lockdown ensured that much interaction over the past two years has been online. With this in mind, respondents were asked whether the interface that they are presented with could be improved. One theme emerged: Interaction. The need for interaction in online spaces is a recurrent issue in online learning/teaching platforms and is illustrated in the following quotes [55].

Theme 7: Interaction

Participant 5: Interaction with others may be useful, having a weekly online meeting may also be useful.

Participant 6: I would suggest more inactive activities.

Finally, the participants were asked to list any positive aspects of taking the course. 29 participants indicated that one of the most significant achievements of the handbook lies in its accessibility as is illustrated below.

Theme 8: Accessibility for knowledge

Participant 9: Short, accessible. A good introduction to EEGs.

Participant 7: It makes you clear and indications of use of EEG.

Participant 11: It provides foundational knowledge and understanding.

Participant 18: Gain more knowledge on child EEG

Discussion

The questions this study sought to answer were whether the online handbook is useful, whether the participants liked the handbook and their reasons for this. This entry level handbook was originally developed for healthcare practitioners in sub-Saharan Africa and has since been added to the epilepsy module of the International Child Neurology Teaching Network (ICNTN) making it accessible across the world covering high to low-income countries. The handbook as stated promotes entry level safe practice for the use of EEG as a tool.

30/50 (60%) found the handbook relevant to their work, so it was not surprising that the majority of the participants (33) working with children with epilepsy responded. In our study, our findings favoured a female preponderance [56]. Previous studies support that females are more likely to complete online courses whilst there are mixed gender results at partaking in surveys [56].

When comparing data from table 4.1, the proportion of respondents who completed the handbook from the LMIC was significantly higher than the non-respondents who completed the handbook ($p<0.001$). LIC's were only present among the responders.

Six out of the eleven participants that partially or did not complete the handbook with the agreement of *"not having time to complete",* this is a common clinical and paediatric theme that needs resources that are *"digestible".* The above themes, user friendly, accessible, and comprehensive fulfils that resource.

More participants from LMIC (11) and UMIC (4) disagreed respectively with the notion that they were skilled in reading the EEG before the handbook compared to those from LIC (3) or UMIC (5) who strongly agreed.

For the rest of the questions on the handbook, participants' experiences, and opinions were positive with an overall agree/strongly or agree across all income countries.

The qualitative data was analysed by VK and JH and at times a single or several sub-themes emerged. The themes documented will be used for the ongoing upscaling of the handbook. The theme that stood out most was the accessibility of knowledge gained. Other sub-themes arose such as having more case studies with supporting EEG waveforms; availability of online sessions for interaction to discuss information and assist with clarification, as we all experienced only online interface during the COVID pandemic. There is a huge need for more training in neurophysiology. Further of the existing published studies critiquing existing training programs the lack of consistency and directness limited comparison [53].

Limitations

This is a qualitative subjective study and whilst doctors claimed to have learned from this tool this does not necessarily guarantee that they have genuinely acquired knowledge. The main study limitation related to participants failing to complete the survey even after they received weekly email eblasts for 6 months including personal emails with the survey URL. Almost half failed to complete the survey 58/108 (54%) even though 24 (41%) consented to participate in the survey. 26 (45%) of the participants completed the handbook with certificates but failed to complete the survey. The non-respondents could have added valuable information. Further statistical reports for "medians" could not be performed owing to the data set up being categorical responses. Pre and post testing was not performed in this cohort but has been undertaken in a previous group.

Conclusion

Participants found the handbook to be useful both for their clinical practice and for the accessibility of the knowledge contained in the book. The study was aimed at participants from resource limited settings. The handbook is an entry point to equip clinicians for safe practice to enable them to also undertake more complex training if needed. The handbook is central to EEG training and of especial relevance to the African Paediatric Fellowship Program (APFP) which trains paediatric neurologists from sub-Saharan Africa [13]. These qualified paediatric neurologists return to their countries and at times are the only paediatric neurologist in the country. They recruit a colleague to be trained in assisting them with performing EEGs. This handbook is also used in the curriculum to train EEG technicians as well as clinicians.

Key points

- An entry level paediatric EEG handbook was developed for non-specialists.
- Practitioners in real time clinical practice found the handbook to be useful and applicable.
- The handbook was affordable, easy to use and concise.
- The users confirmed change in practice following completion of the handbook.

Author contributions:

Veena Kander: Wrote the manuscript based towards for PhD thesis, collected and analysed article data and formatted conclusions.

Joanne Hardman: Co-supervisor of PhD thesis, proofread and assisted with coding qualitative data.

Jo Wilmshurst: Supervisor of PhD thesis, proofread and made corrections to the manuscript content.

Declaration

This article is based on the research I conducted for my Doctor of Philosophy Degree in Neurophysiology. In relation to the journal's position on issues involved in ethical publication: We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

Ethical Approval and Consent to Participate

This article confirms that all the experiments in the study were conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all the participants. The study was approved by the ethics committee of the UCT, Cape Town, South Africa (481/2018).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Legends for Tables and Figures

Figure 4.1: Flow diagram of survey responses

Figure 4.2: Countries with colour coding for number of responders (red 1-2; orange 3-4; light green 9-10 and medium green 11-12)

Figure 4.3: Distribution of the professions by the country income grouping of the survey participants

Figure 4.4: Prior handbook skills in paediatric interpretation n=32

Figure 4.5: Reading skills n= 32

Figure 4.6: Relevance of handbook to current work n=32

Figure 4.7: Application of handbook to current work n=32

Figure 4.8: Improved clinical care n=32

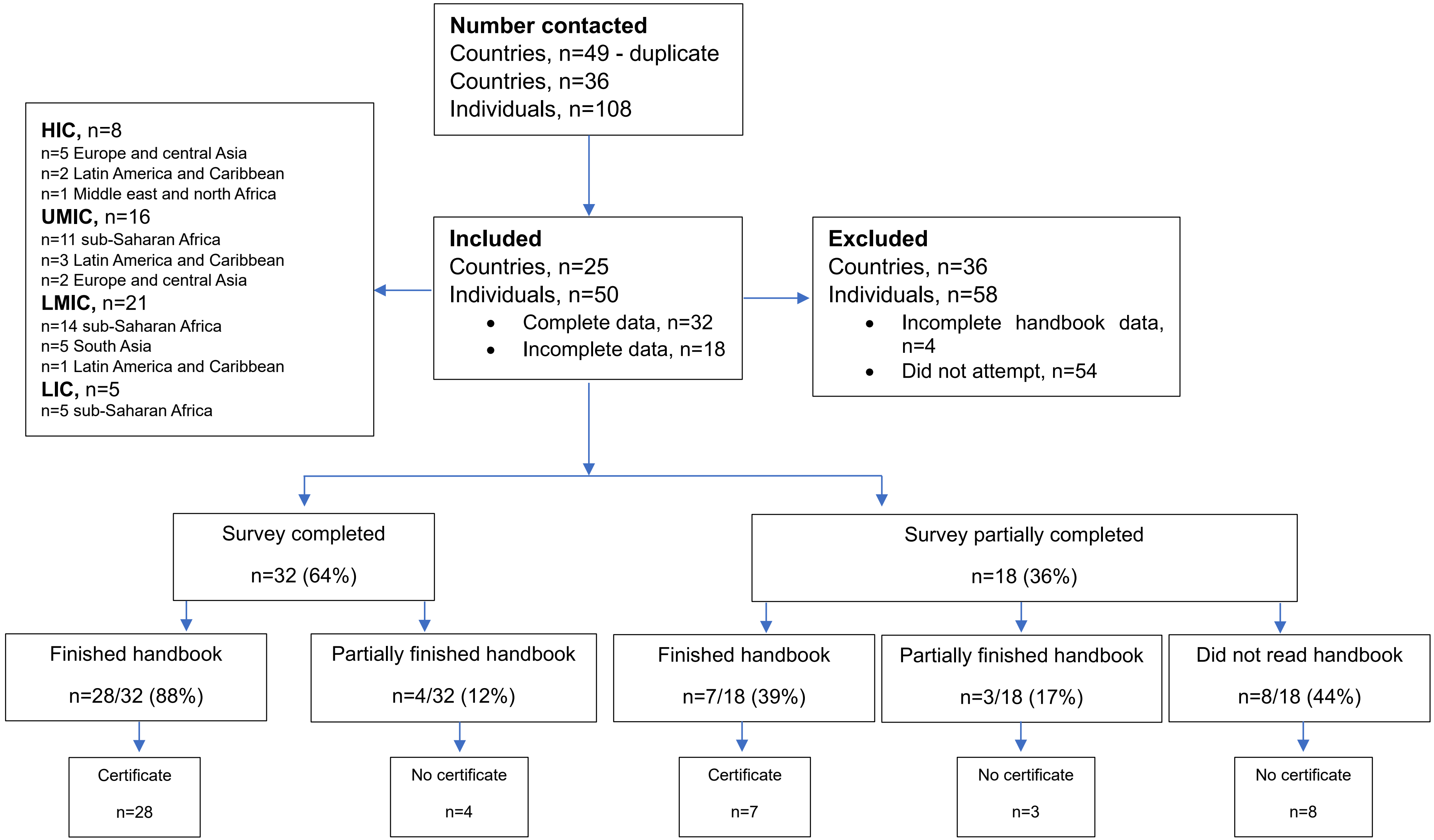


Figure 4.1: Flow diagram of survey responses.

Table 4.1: Comparison of study survey respondents versus non-respondents by income country

No. of Countries	No. of participants	Responders-completed HB	No. of Countries	No. of participants	Non-responders-completed HB	p-value
HIC (8)	8	2 (25%)	**HIC (16)**	23	13 (56%)	0.12
UMIC (7)	16	11 (69%)	**UMIC (10)**	14	7 (50%)	0.30
LMIC (7)	21	18 (86%)	**LMIC (9)**	21	6 (29%)	<0.001
LIC (3)	5	4 (80%)				-

HB- handbook, comparison between the proportions of responders versus non-responders by country income level assessed using the Z-test

Table 4.2: Comparison of respondent characteristics by the country income grouping of the survey participants

Characteristic	Total	Low Income Countries	Low-Middle Income Countries	Upper-Middle Income Countries	High Income Countries	p-value
N	50	5	21	16	8	
Sex of participants						
Female	28 (56.0)	1 (20.0)	11 (52.4)	9 (56.3)	7 (87.5)	0.12
Male	22 (44.0)	4 (80.0)	10 (47.6)	7 (43.8)	1 (12.5)	
Age in years	42.9 (±10.1)	42.8 (±6.3)	43.0 (±11.0)	42.9 (±11.1)	42.6 (±9.5)	0.63
Profession						
Adult Neurologist	5 (10.0)	1 (20.0)	3 (14.3)	1 (6.3)	0	0.11
Allied Professional	4 (8.0)	0	3 (14.3)	1 (6.3)	0	
Paediatric Neurologist	23 (46.0)	4 (80.0)	4 (19.1)	9 (56.3)	6 (75.0)	
Specialist	7 (14.0)	0	3 (14.3)	2 (12.5)	2 (25.0)	
Other	11 (22.0)	0	8 (38.1)	3 (18.8)	0	
Specialisation						
Developmental paediatrician	2/7 (28.6)	-	0	1/2 (50.0)	1/2 (50.0)	0.20
Neonatology	1/7 (14.3)	-	0	0	1/2 (50.0)	
Paediatrician	4/7 (57.1)	-	3/3 (100)	1/2 (50.0)	0	
Allied professional						
Neurophysiologist	4/4 (100)	-	3/3 (100)	1/1 (100)	-	1.00
Other						
Clinical officer	1/11 (9.1)	-	1/8 (12.5)	0	-	1.00
Paediatric neurology registrar	10/11 (90.9)	-	7/8 (87.5	3/3 (100)	-	
Hospital						
Community clinic	2 (4.0)	0	0	1 (6.3)	1 (12.5)	0.31
Private	12 (24.0)	0	6 (28.6)	5 (31.3)	1 (12.5)	
Secondary care	1 (2.0)	0	0	0	1 (12.5)	
Tertiary care	35 (70.0)	5 (100)	15 (71.4)	10 (62.5)	5 (62.5)	

Characteristic	Total	Low Income Countries	Low-Middle Income Countries	Upper-Middle Income Countries	High Income Countries	p-value
Treat paediatric epilepsy	47 (94.0)	5 (100)	19 (90.5)	16 (100)	7 (87.5)	0.56
Report Paediatric EEG	26 (52.0)	3 (60.0)	12 (57.1)	9 (56.3)	2 (25.0)	0.46
Previous EEG training	20/26 (76.9)	2/3 (66.7)	10/12 (83.3)	6/9 (66.7)	2/2 (100)	0.74
EEG training						
Registrar	3 (6.0)	0	2 (9.5)	1 (6.3)	0	1.00
Fellowship program	12 (24.0)	2 (40.0)	5 (23.8)	3 (18.8)	2 (25.0)	0.83
Online course	11 (22.0)	1 (20.0)	7 (33.3)	3 (18.8)	0	0.30
Other	2 (4.0)	0	2 (9.5)	0	0	-
Hospital EEG department	1 (2.0)	0	1 (4.8)	0	0	-
Private clinic	1 (2.0)	0	1 (4.8)	0	0	-
Training time						
<3 months	1/20 (5.0)	0	1/10 (10.0)	0	0	0.88
3-6 months	6/20 (30.0)	1/2 (50.0)	4/10 (40.0)	1/6 (16.7)	0	
7-12 months	10/20 (50.0)	1/2 (50.0)	4/10 (40.0)	3/6 (50.0)	2/2 (100)	
Other	3/20 (15.0)	0	1/10 (10.0)	2/6 (33.3)	0	
Completion of online course						
Yes	35 (70.0)	4 (80.0)	18 (85.7)	11 (68.8)	2 (25.0)	***0.02***
Partially	7 (14.0)	0	1 (4.8)	4 (25.0)	2 (25.0)	
No	8 (16.0)	1 (20.0)	2 (9.5)	1 (6.3)	4 (50.0)	
Reason for non-completion						
Didn't have time to complete	6/11 (54.6)	1/1 (100)	0	3/3 (100)	2/4 (50.0)	0.49
Not aware of the online course	1/11 (9.1)	0	1/3 (33.3)	0	0	
Didn't read it	1/11 (9.1)	0	1/3 (33.3)	0	0	
Didn't receive the handbook	2/11 (18.2)	0	1/3 (33.3)	0	1/4 (25.0)	
I don't have it	1/11 (9.1)	0	0	0	1/4 (25.0)	
Year of completion						
2017	7/34 (20.6)	1/4 (25.0)	3/17 (17.7)	2/11 (18.2)	1/2 (50.0)	0.97
2018	1/34 (2.9)	0	1/17 (5.9)	0	0	
2019	3/34 (8.8)	0	1/17 (5.9)	1/11 (9.1)	1/2 (50.0)	
2020	3/34 (8.8)	0	2/17 (11.8)	1/11 (9.1)	0	
2021	13/34 (38.2)	2/4 (50.0)	6/17 (35.3)	5/11 (45.5)	0	
2022	7/34 (20.6)	1/4 (25.0)	4/17 (23.5)	2/11 (18.2)	0	
Completion time						
< 1 week	8/35 (22.9)	1/4 (25.0)	3/18 (16.7)	4/11 (36.4)	0	0.94
1-2 weeks	3/35 (8.6)	0	3/18 (16.7)	0	0	
3-4 weeks	12/35 (34.3)	2/4 (50.0)	6/18 (33.3)	3/11 (27.3)	1/2 (50.0)	
> 1 month	1/35 (2.9)	0	1/18 (5.6)	0	0	
Other	11/35 (31.4)	1/4 (25.0)	5/18 (27.8)	4/11 (36.4)	1/2 (50.0)	
Completion time (Other)						
5 weeks	1/11 (9.1)	0	1/5 (20.0)	0	0	
6 weeks	1/11 (9.1)	0	0	0	1/1 (100)	
2 months	2/11 (18.2)	0	1/5 (20.0)	1/4 (25.0)	0	
10 weeks	1/11 (9.1)	0	1/5 (20.0)	0	0	
3 months	1/11 (9.1)	0	0	1/4 (25.0)	0	
4 months	2/11 (18.2)	0	1/5 (20.0)	1/4 (25.0)	0	

Characteristic	Total	Low Income Countries	Low-Middle Income Countries	Upper-Middle Income Countries	High Income Countries	p-value
6 months 8 months	2/11 (18.2) 1/11 (9.1)	1/1 (100) 0	0 1/5 (20.0)	1/4 (25.0) 0	0 0	
Reason for the delay - Busy schedule	11/11 (100)	1/1 (100)	5/5 (100)	4/4 (100)	1/1 (100)	-
Online facilities	20/39 (52.6)	2/4 (50.0)	12/18 (66.7)	5/13 (38.5)	1/4 (25.0)	0.42
Reasons for not using the chat Did not need it Did not understand how to use it Was not aware of availability of chat	 6/19 (31.6) 2/19 (10.5) 11/19 (57.9)	 0 0 2/2 (100)	 3/6 (50.0) 1/6 (16.7) 2/6 (33.3)	 2/8 (25.0) 1/8 (12.5) 5/8 (62.5)	 1/3 (33.3) 0 2/3 (66.7)	 0.89

p-value of ≤0.05 was considered statistically significant
proportions (%) for the columns reported as n/N (%) (except if data is missing - denominator added in the n column)
continuous data expressed as mean (±standard deviation (SD)) since data is normally distributed
p-values derived using Chi-squared test/ Fishers exact test for categorical data
p-values derived using Anova test for variance with a Bonferroni correction for continuous data

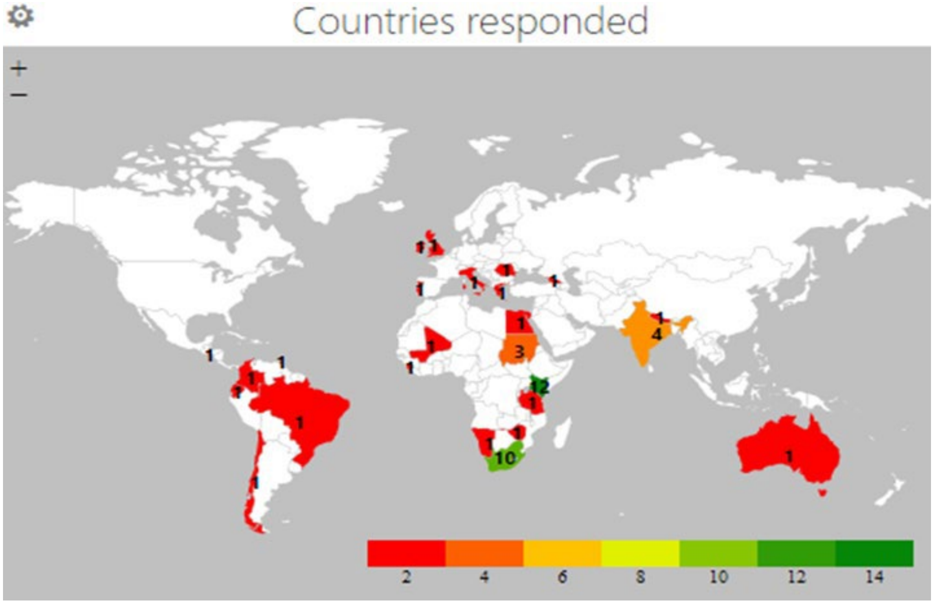


Figure 4.2: Countries with colour coding for number of responders (red 1-2; orange 3-4; light green 9-10 and medium green 11-12).

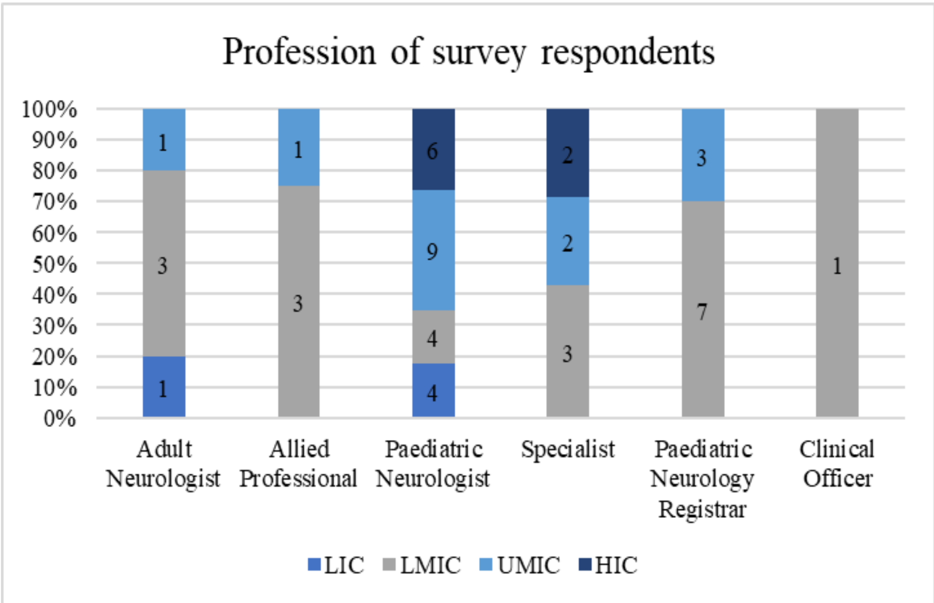


Figure 4.3: Distribution of the professions by the country income grouping of the survey participants.

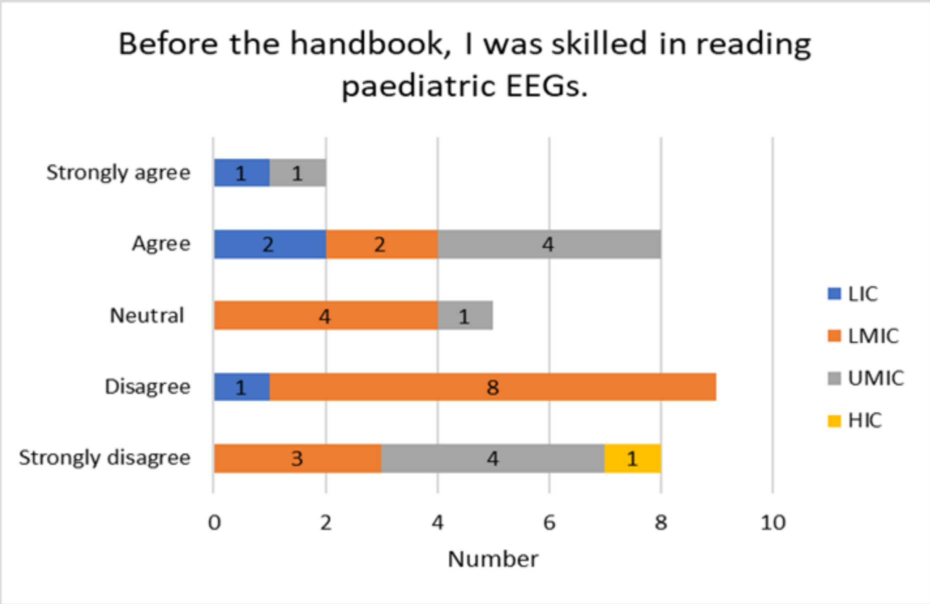


Figure 4.4: Prior handbook skills in paediatric interpretation n=32.

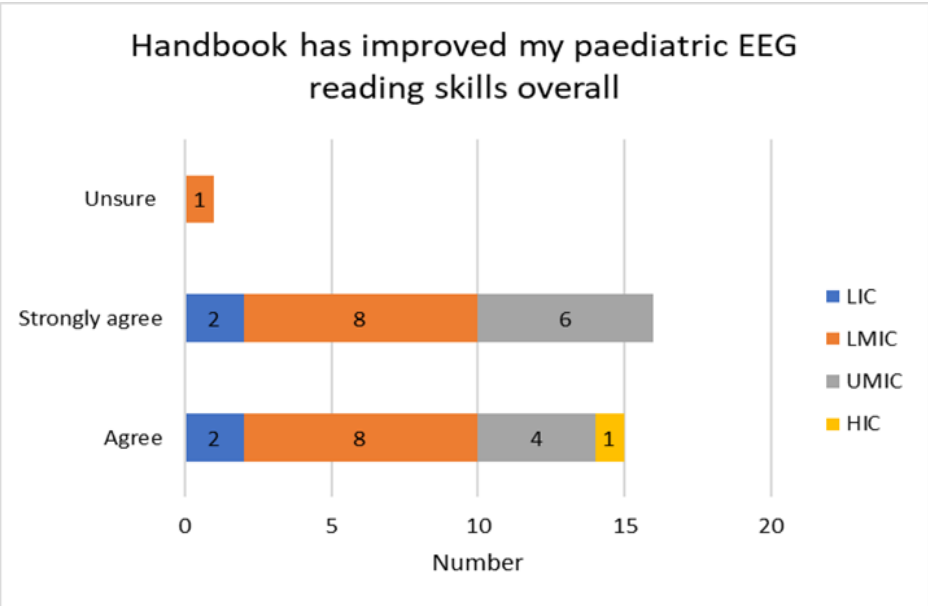


Figure 4.5: Reading skills n= 32.

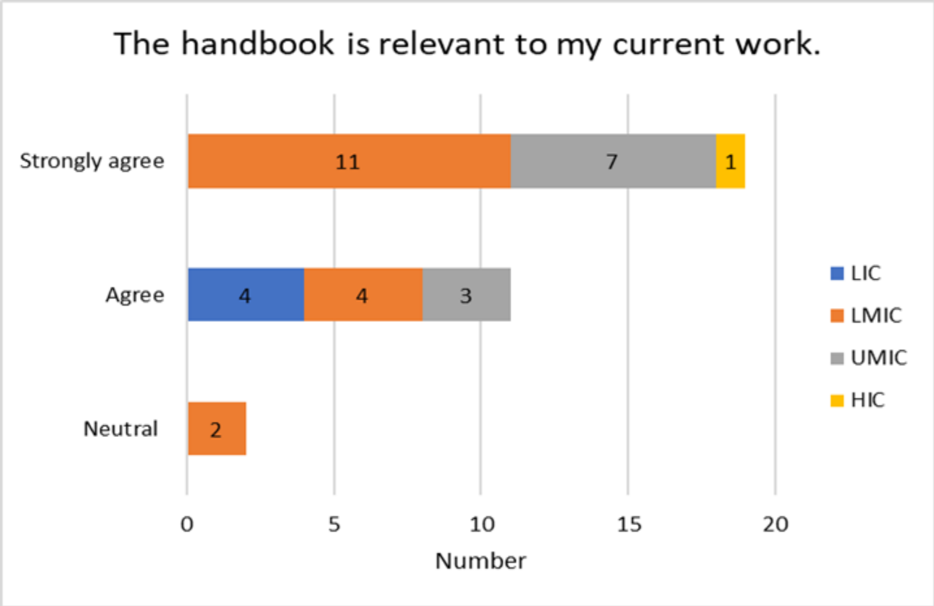


Figure 4.6: Relevance of handbook to current work n=32.

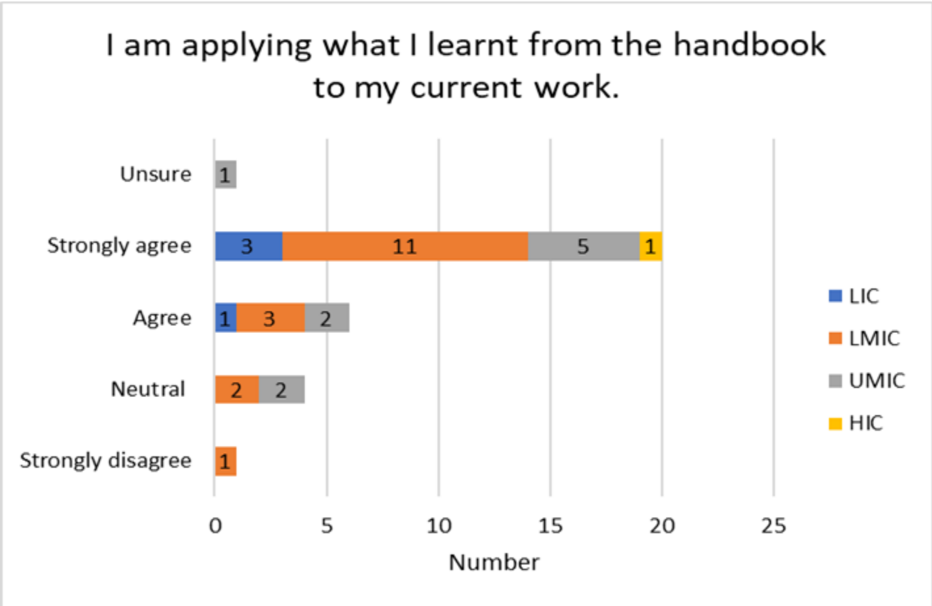


Figure 4.7: Application of handbook to current work n=32.

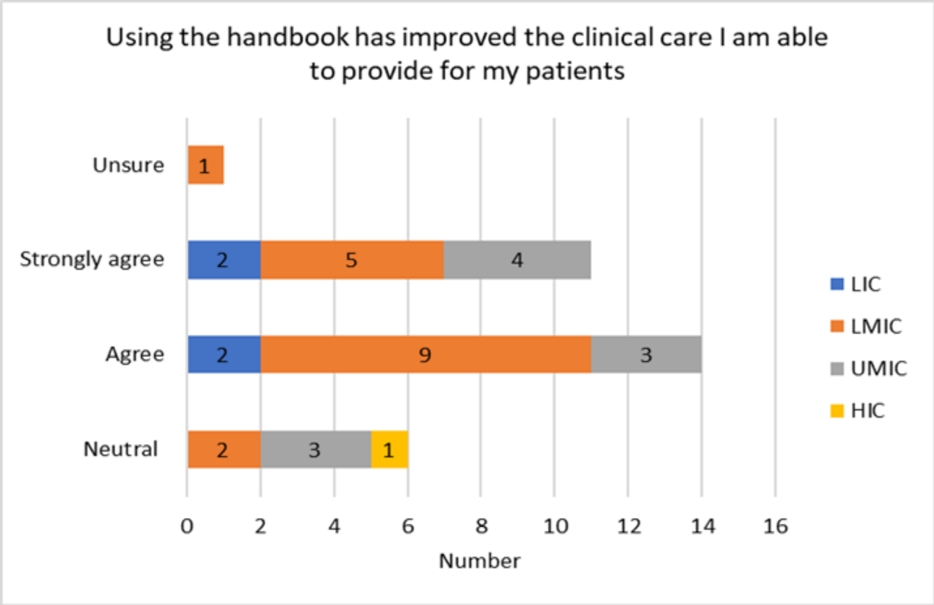
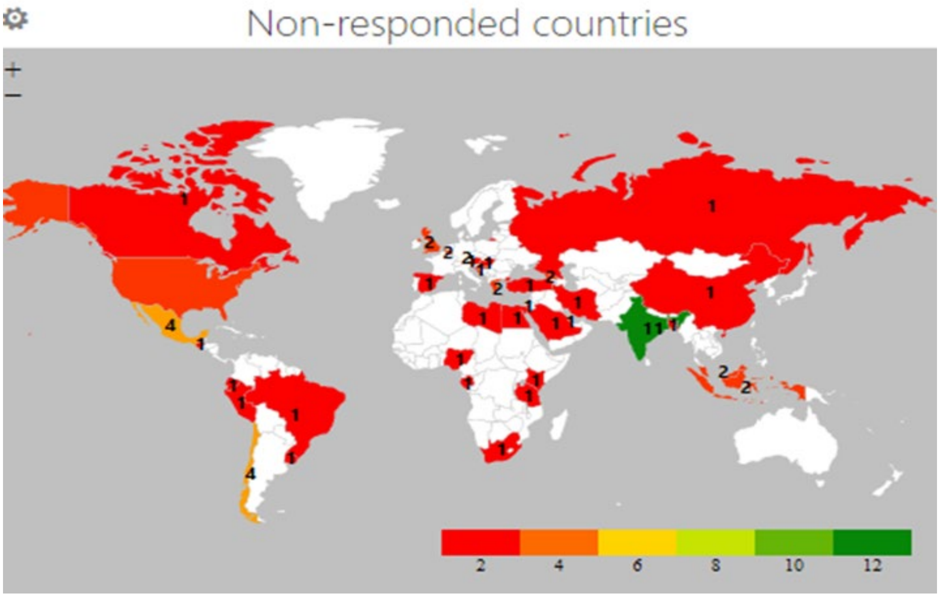
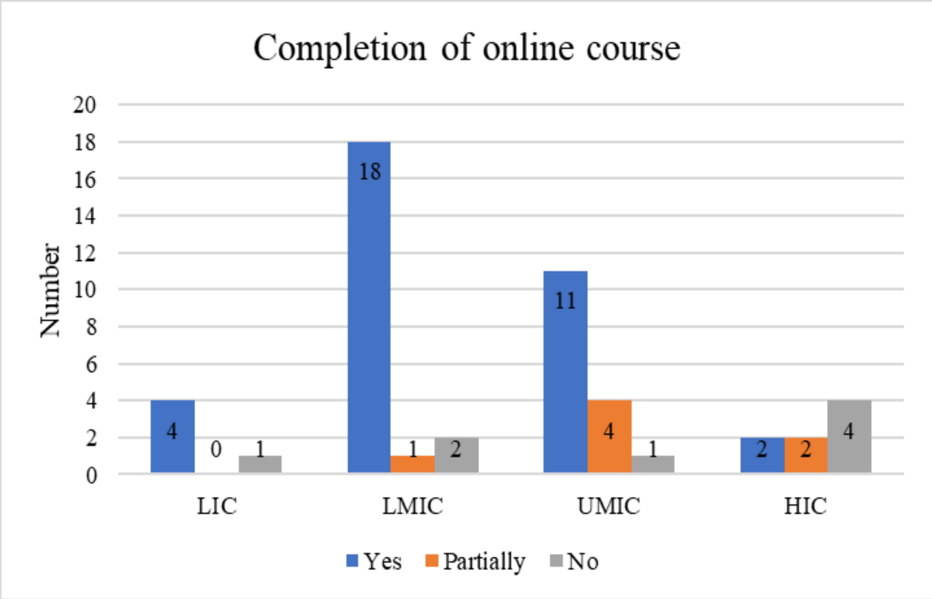


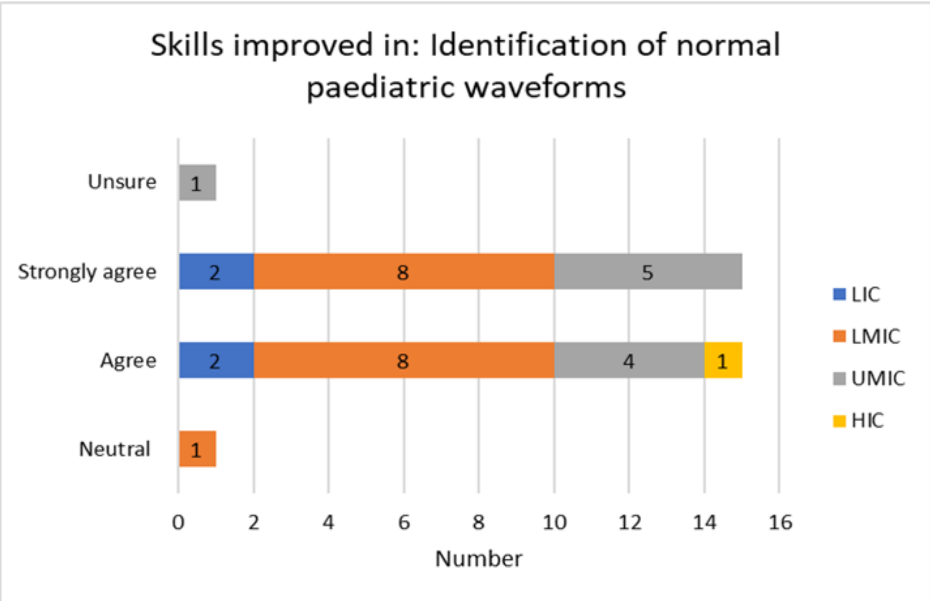
Figure 4.8: Improved clinical care n=32.



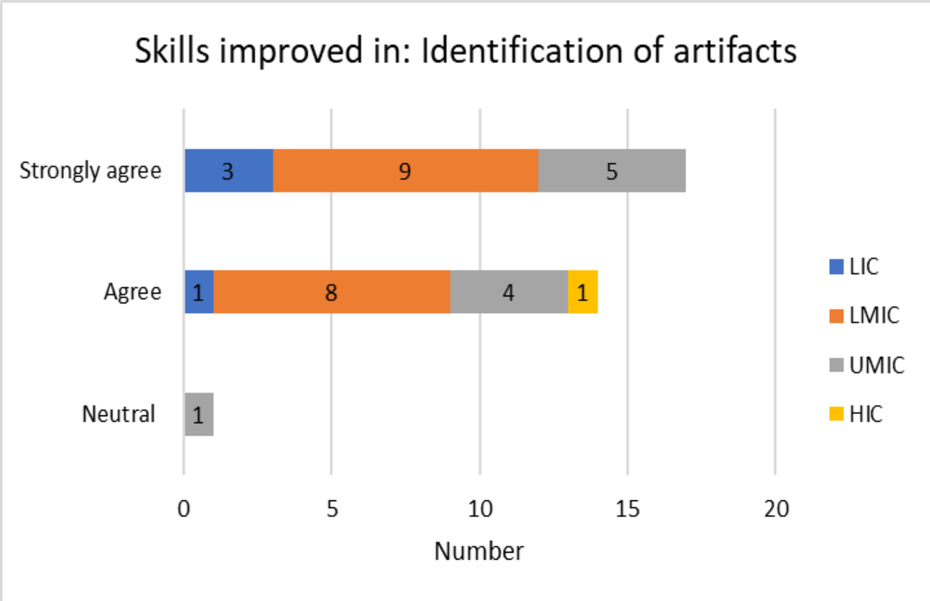
Supplementary figure 4.1: Countries with colour coding for number of non-responders (red 1-2; orange 3-4; and dark green 11-12).



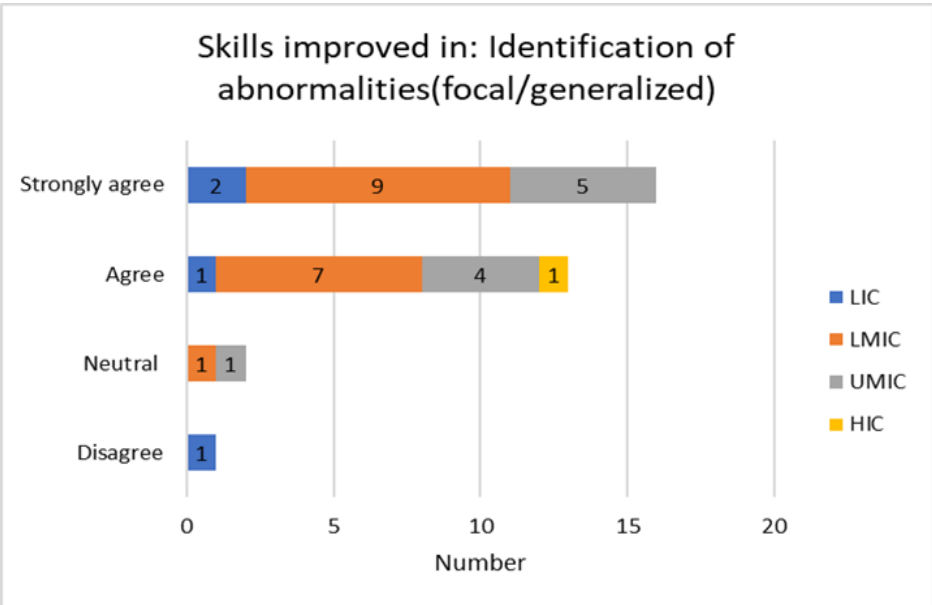
Supplementary figure 4.2: Completion of online course by the country income grouping of the survey participants.



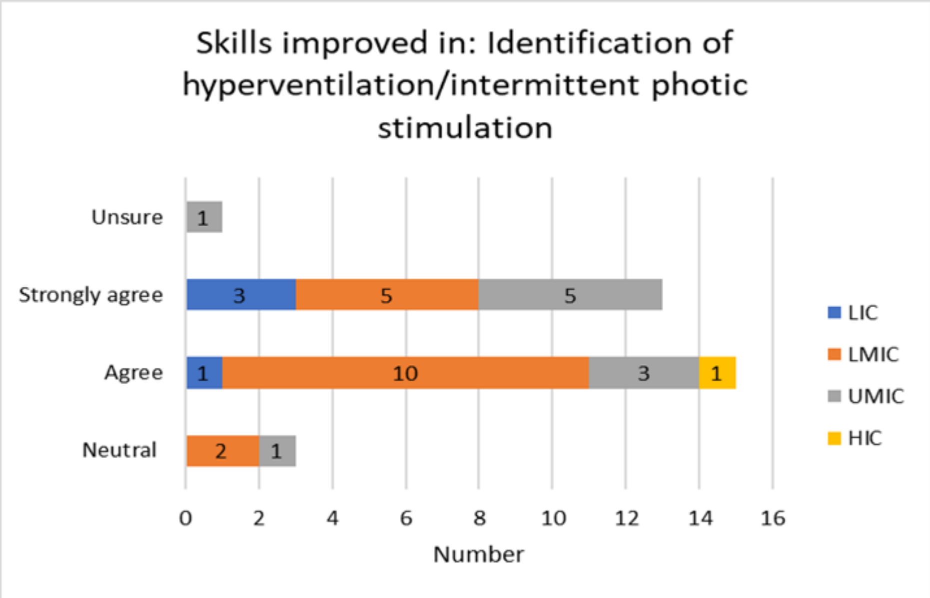
Supplementary figure 4.3.1: Identification of normal waveforms n= 32.



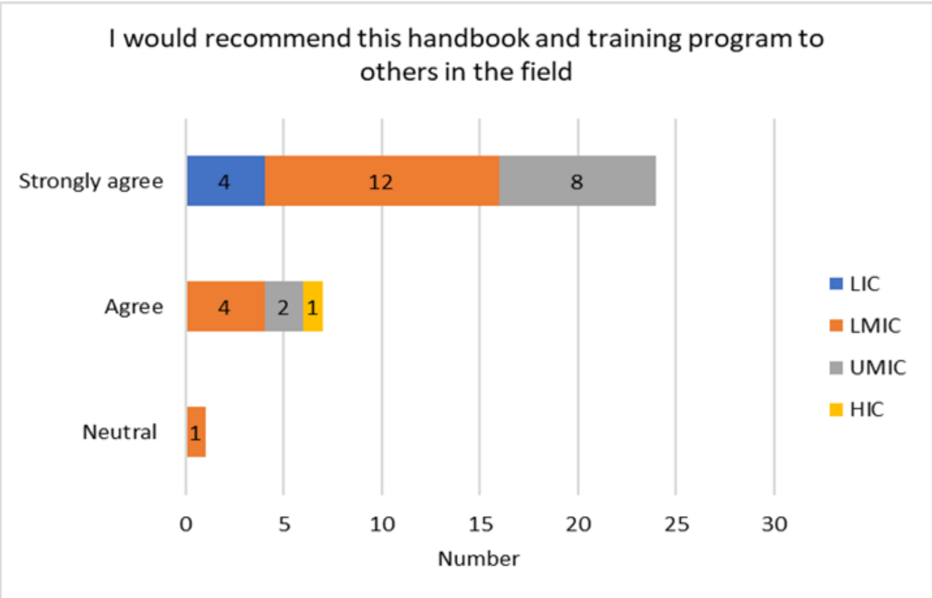
Supplementary figure 4.3.2: Identification of artefacts n= 32.



Supplementary figure 4.3.3: Identification of abnormalities n=32.



Supplementary figure 4.3.4: Identification of activation procedures n=32.



Supplementary figure 4.4: Recommendation of handbook and training program n=32.

CHAPTER 5 – Expert opinions

This qualitative study looked at opinions of EEG experts in advocacy and/or education from high to low-income countries, on training non-epilepsy specialists in paediatric EEG interpretation.

Journal: Epileptic Disorder

Title: Expert opinions on paediatric EEG training for non-epilepsy specialists in sub-Saharan Africa

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Running title: Developing Paediatric EEG curricula for non- epilepsy specialists

ABSTRACT

Ideally, paediatric electroencephalograms (EEGs) should be performed by accredited neurophysiology technologists and interpreted by specialists trained in epileptology. However, low-and middle-income countries (LMICs) lack such specialists.

Aim: To collate expert consensus on essential curriculum content for non-epilepsy specialists in EEG interpretation and safe post-training practice.

Method: A qualitative study on paediatric EEG training curricula needs was developed in collaboration with an adult education specialist. Data were collected via interviews from 15 epilepsy experts with training experience across high to low-income settings. Thematic analysis was used to identify sub-themes. The experts voted on the key statements in a two-round Delphi to ascertain consensus.

Results: Twelve aspects on paediatric EEG training were identified and categorised thematically: relevance; exposure to paediatrics; focus on paediatrics; barriers; resource limited setting; entry skills; best pedagogy; assessment; critical skills; re-enforcement of skills; training model and recommendations.

Conclusion: This study was driven by the inadequate access to training in paediatric EEG for non-epilepsy specialists which is further exacerbated by the lack of epileptologists and neurophysiologists. The outcomes from the expert consensus opinions promoted consolidation, adaptation and evolution of existing models that are viable for practice and to be used worldwide. The Delphi consensus demonstrated alignment among regionally located specialists towards promotion of effective and maintained training for non-epilepsy specialists, as well as highlighting barriers which should be considered and addressed.

INTRODUCTION

Sub-Saharan Africa (SSA) has the highest burden of neurological diseases and prevalence of people with epilepsy [49]. This is especially relevant in paediatrics, where incidence of neurological diseases are the highest in SSA compared to other regions of the world [51].

There is a significant shortage of neurologists and neurophysiologists [57]. Access to electroencephalography (EEG) and the skills needed for interpretation are scarce in resource limited countries (RLCs) [51, 53]. This diagnostic tool is often used inappropriately by clinicians without the expertise to interpret the results. Our group has explored paediatric EEG training programs for non-epilepsy specialists [52]. Training this group is critical to improve epilepsy care in settings with limited resources, where epilepsy specialists (i.e. epileptologists) are lacking.

In SSA, people with epilepsy are initially seen by primary health care providers. Various models have explored methods to improve diagnosis of epilepsy, enabling care at the entry point by primary care practitioners [58-60]. Artificial intelligence EEG (AI-EEG) was used by McInnis *et al*, to assist healthcare workers lacking epilepsy training [61, 62]. A systematic review assessed qualitative and quantitative aspects of curricula, teaching methods and effective educational EEG programs for non-experts to screen adult EEG patterns for critically ill patients [63]. The report concluded that different point of care providers can be educated [64-66].

This qualitative research drew on the skills of experts embedded and invested in the field of EEG training from diverse regions. It is important to understand the ideal requirements and to critique existing training guidelines for EEG for both specialists and non-epilepsy specialists in low income (LIC) and high-income countries (HIC) as seen in Table 5.1. Our belief is that it is possible to train any motivated and capacitated doctor at this level of practice working in a setting where they are managing children with seizures. This information will be used to strengthen an existing paediatric EEG training program [affiliated to the African Paediatric Fellowship Program (APFP)] for clinicians across sub-Saharan Africa. Further, it is envisioned to be an aid for other regions who could gain from using or adapting the model.

In this study, we sought to gain expert consensus via a Delphi process on the essential components of an educational curriculum needed to effectively educate non-epilepsy specialists on the interpretation of paediatric EEG. Specific aims were to: -

- Identify level for effective and safe practice for non-epilepsy specialists
- Identify and describe support for the role of non-epilepsy specialists in EEG practice

METHODOLOGY

Data gathering, ethics and procedures

Experts with high-level EEG practice and skills were identified across all six World Health Organisation Regions (WHO) to provide a broader insight of the challenges to deliver ideal paediatric epilepsy care in different regions. Fifteen out of sixteen clinicians with expertise in the field of neurophysiology from high to low-income countries agreed to participate in the project. The experts had expertise in the fields of epileptology, paediatric neurology, adult neurology, and neurophysiology (clinical physiology) (Table 5.2). All experts were experienced in training. Demographic participant data were extracted from pre-supplied curriculum vitae and interview questions were sent in advance to permit consideration and time to prepare for the responses. The participants were asked to consider their own range of experiences, as a trainee, as well as their current trainees needs. A qualitative study consisting of 11 key questions on paediatric EEG was designed with the support of an adult education specialist. These key questions related to gaps in training and knowledge identified through a systematic review[52], survey on EEG services in SSA[53], and relevance of a paediatric online tool[67] done by the same authorship team. All experts were asked the same 11, open-ended questions and, in closing, were asked if they would like to expand on any of their answers (appendix 5). A qualitative approach to the data analysis was adopted to address how the concept of training for non-epilepsy specialists is understood. A thematic analysis enabled uncovering of shared understandings from participants, which was further focused and returned to the group via a Delphi process.

Interviews were performed over May-June 2023 via an online platform, lasting 20-30 minutes. All 15 experts consented for the interview and to collaborate on manuscript preparation. Interviews were recorded and transcribed verbatim by a trained transcriber. All names were de-identified. A two stage Delphi method was adopted to explore consensus of the themes derived i.e. where there was over 80% agreement. All data were stored securely. The study was approved by the ethics committee of the UCT, Cape Town, South Africa (481/2018)

Findings and discussions

This section addresses the themes arising from the 11 questions, from which we identified, analysed, and interpreted data patterns of meaning that arose with each question. The 11 questions were analysed using a thematic analysis which enabled identification of various themes.

Experts' demographics (Table 5.2)

Forty percent of the experts n=6, either worked in Africa n=4 or had significant collaboration with Africa n=2. Of the 15 experts n=7 (47%) were paediatric neurologists, n=4 (27%) epileptologist, n=5 (33%) adult neurologists and n=1(7%) clinical physiologist (neurophysiologist). Whilst all were committed to high level service provision in the field of epilepsy, there were additional focus areas of work such that twelve (80%) were involved in teaching of electrophysiology and n=3 (20%) were advocates on the subject. We recognized advocacy as a key role for respondents who had promoted for the safe and effective utilization of the resource of EEG.

Findings

Twelve main themes relating to the questions were identified (Table 5.3) with common sub-themes reoccuring illustrated in the interview quotes (supplementary thematic data). These key themes were converted into statements which were re-presented to the experts in a two stage Delphi survey.

Delphi process:

Overarching themes and sub-themes were identified (Table 5.3), from the extracted interview responses (supplementary thematic data). The main researchers (VK,JW) generated the consensus statements. This process was independent from the respondents to avoid bias. Experts responded to a two stage Delphi method. The first stage Delphi process, the group reached consensus on the following statements. It is relevant for non-epilepsy specialists to be trained to perform and interpret paediatric EEGs. Non-epilepsy specialists need access to epilepsy specialists and to be trained to ensure consistency in practice. Training on paediatric EEG is necessary for any clinician and whose practice includes treatment of children with epilepsy. Paediatric EEG training should be a separate and standalone area of study. Barriers to providing adequate paediatric EEG services in LMICs are compounded by inadequate training resources for non-epilepsy specialists. In the setting of lack of access to technologists, nurse training should be considered. In the setting of lack of access to epileptologists, clinicians involved in the care of children with seizures should be encouraged to access training. Face to face teaching with clinical application is required and not only on-line.
Training skills should be maintained and reinforced**.** Assessment of skills is required. Members of the group emphasised the lack of capacity for dedicated time to establish required skills and consensus was not reached (73%) that non-epilepsy specialists can be trained in paediatric EEG at a basic level. On the first round a consensus (with >80% agreement considered consensus) was reached for 21 of the 22 statements[68].
These statements,the percentage consensus and the key comments from the experts are relayed in Table 5.4. The only statement that did not reach consensus (73%) pertained to entry skills and the ability to train individuals. In the second stage of the Delphi

process, we addressed this statement by examining perspectives from individuals, institutions, health or government levels, and exploring the concept of task sharing. The second stage Delphi explored solutions and reached consensus that individuals should be invested in developing and maintaining EEG skills, that institutional support should ensure adequate infrastructure, and that national or regional policy should be in agreement with service need. Ultimately, all experts reached consensus on the four statements regarding the success and sustainability of non-epilepsy specialists. Barriers acknowledged by the expert group emphasised the challenges of busy and inadequately supported clinicians already committed to multiple service needs leading to attrition of the EEG service and individual skill maintenance.

Discussion

This study explored expert consensus on the relevance, need and potential for the training of non-epilepsy specialists in EEG interpretation. Whilst the study provides valuable insights into the training of non-epilepsy specialists, the study is limited and does not cover all possible variables. The important findings related to some of the themes are highlighted below.

Relevance (lack of experts)

This was driven by the fact that there are limited numbers of epileptology experts and EEG training programs in high and low income countries. There was consensus from the experts of the inevitable adverse healthcare consequences from inadequate training[69].

Exposure to paediatrics (lack of training)

Speciality training is often not available, or sparse, in resource limited settings [57]. Neurologists and child neurologists have limited time in their training to reach high levels of EEG interpretation skills [11, 52]. Additional time for training in these areas is especially important in LMICs, where these trainees may be the only clinician available to report EEGs [13]. As such fellowships are required to gain competency in interpretation of EEGs.

Focus on paediatrics (lack of interpretation)

For an adult neurologist without substantial additional training, paediatric EEG patterns can be difficult to interpret [64]. Interpretation of paediatric EEG requires instruction in and exposure to the different EEG changes that evolve during brain maturation and the abnormalities present in specific paediatric epilepsy syndromes [6]. Recognition of certain patterns is critical for appropriate management and to minimize neurological and developmental deficits for e.g. status epilepticus or developmental epileptic encephalopathy such as infantile epileptic spasms syndrome.

Assessment

The value of continous assessment to maintain learned skills by having consistent supervision was also emphasised. Hosting bi-weekly EEG meetings was seen as a favourable collaboration for training, re-inforcement of knowledge and skills, for different levels of expertise. This practice is used in our center at the Red Cross War Memorial Childrens Hospital. Ongoing collaboration between training centres and partner sites is crucial.

Barriers (lack of training)

Due to lack of neurology specialists in SSA, some experts were in favor of training non-epilepsy specialists who treat children with epilepsy in EEG interpretation while other experts doubted the feasibility that non-epilepsy specialists would be able/willing to invest the time needed for proper training to occur and for skills to be maintained. Most countries do not have the expertise to train non-epilepsy specialists and technicians, and widely accepted curricula for such training do not exist. One expert suggested training in their mother tongue as english is not very well understood for some regions in SSA. This would require qualified EEG trainers in those countries, which is currently lacking.

Misuse of EEG

During the interviews from experts in Iraq, Tunsia, Colombia, India and Zambia, it was reported that misuse of EEGs is a common issue amongst non-neurology personnel particularly among practitioners who receive financial incentives based upon EEG completion. EEGs are performed unneccessarily on patients with no clinical indication for EEG, leading to misdiagnoses especially when the reader is not sufficiently skilled in paediatric EEG interpretation.

Training model (apprenticeship)

Experts describe with clarity the importance of having both “apprenticeship as well as online resources”, as the best pedagogy to learn paediatric interpretation. However, some SSA countries do not have the capacity to send physicians away to train for long periods of time and a hybrid method was suggested. The expressions of recommendations from some experts describe the importance of accessing early EEG training and emphasing the important for sub-Saharan African trainees, as time is limited during their registrarship.

Entry qualifications, maintainance of skills and infrastructure requirements

Whilst most of the experts agreed with the concept of training non-epilepsy specialists, they raised important issues around capacity, commitment and sustainability. This question did not reach consensus in the first Delphi round. The second stage Delphi explored solutions to the challenges raised about sustainability of the training model concept, through different levels critical for the service to be functional. At the individual’s level, this person must be invested and capacitated to not only complete the training program but also to continue to maintain the skills learnt. Further to ringfence clinical duty time to be involved in adequate numbers of EEG analyses, as well as engaging with colleagues in the same field to critique and compare quality of work undertaken. This could be supported either by regular meetings or online calls with specialists who may be located in other regions. The experts noted the huge workload burden carried by clinicians who may be responsible for diverse areas of healthcare delivery. That these individuals need to be officially identified for their allocated time and role in the EEG service so that they are not drawn into other areas of care. At the institutional level, that the individual is based in, the centre should have identified the need for EEG services as a priority area and in line with this ensured infrastructure is adequate to develop, run and maintain an effective service with appropriate equipment and staffing. At a national level there should be policy support that EEG services are necessary to deliver high quality care for children with epilepsy. There was consensus that if these three areas, individual, institutional and national policy, were met then the concept of training non-epilepsy specialists was viable.

Recommendations

Filling the gap in countries where resources are limited, was expressed as a stepping stone to address the lack of pediatric EEG training. There are few non-specialist curricula which have been critiqued, whilst some show similarities with key concepts taught, in general, paediatric EEG training is virtually non-existent in most programs [52]. The first and last authors via the APFP program are supporting the training of doctors in the clinical interpretation and analysis of EEGs, and nurses to perform EEGs and recognised urgent intervention findings, by expanding their paediatric EEG skills set and maintaining skills with bi-weekly EEG meetings. The online course established by the first author covers the key concepts for learning paediatric EEG interpretation. This curriculum content and teaching method is accessible and applicable within Africa and aimed to strengthen pre-existing local skills. The handbook supports this niche skills area; such that participants found the handbook to be useful, both for their clinical practice and for the accessibility of the knowledge contained in the book [67]. Future training will promote and engage with the primary care curricula of the International League Against Epilepsy (ILAE). This EEG curriculum is aligned with the implementation of the Intersectoral Global Action Plan for Epilepsy and other Neurological Disorders (IGAP) to promote pathways to care for people with epilepsy [70]. This re-enforces the training and education of paediatric EEG interpretation in SSA.

The Delphi process was impressive for the consensus reached on the different qualitative statements from the international panel. Our purpose was to create a global international consensus-based recommendation, illustrating opinion cohesion and further learnings and recommendations that came through, as explained by the experts. However, our question on entry skills failed to reach consensus of 80%. Whilst the concept of training non-epilepsy specialists was accepted this response related to the conceptualisation of how it would be implemented and sustained. In the current resource limited setting, there was appropriate concern that effective and sustained implementation would be challenging for the non-neurologist. The stage two Delphi which expanded on this and resulted in consensus on all four statements (table 5.4). To date, our experience has been closely aligned with APFP work, specifically focusing on enhancing the skills of paediatricians and paediatric neurology trainees. It would be valuable to explore which other cadres could also benefit from such training e.g. medical officers, psychiatrists, adult neurologists, neurosurgeons etc. Expanding our focus might enhance overall interdisciplinary collaboration and improve patient care across different specialties.

Strengths and limitations

The study had similar representation from resource equipped and resource limited countries. Interviewer bias was curtailed by the fact that the first author asked the same questions across different interviews. Only one participant failed to acknowledge the email invitation to participate in the study. The themes and sub-themes were arrived at by the first author and the adult education expert. The 15 experts interviewed had special interest either in education and/ or advocacy. There could be some bias in that the experts were indeed passionate and experienced in the field, but the findings should ideally reflect common and broader acceptance and as such we cannot assume that the same views would be held by epileptology experts who do not have experience in LMICs.

Conclusion

There is a dearth of paediatric EEG skilled specialists in sub-Saharan Africa. To address this issue, the experts supported adapting training for non-epilepsy specialists (Table 5.1) with a focus on paediatrics. The findings of this study address this gap and promotes continuous teaching collaborations as well as being innovative in developing such programs. The purpose of the article is not to delay diagnosis and treatment of epilepsy until an EEG is obtained, but rather to reinforce the importance of an EEG as an ancillary tool to describe an electroclinical condition or syndrome.

Clinical skills remain the pillar of diagnosis in epilepsy. To reach a complete approach to epilepsy description, classification, follow-up and prognosis, a well done EEG is important, but it should not replace a clinical diagnosis. The consensus based stage one and two Delphi pecentages was successfully reached. These training recommendations are being incoporated into the EEG training program of the African Paediatric Fellowship Program which aims to provide sustainability to qualified paediatric neurologists and non-epilepsy specialists training in EEG. This EEG program works well under the APFP which typically trains paediatricans as the main group to benefit from the training but we believe that any doctor involved in the treatment of children with epilepsy would benefit from access to the curriculum. The culmination of this project would benefit epilepsy care for children in SSA as well as in other low and middle income countries.

Key Points

- Access to training of non-epilepsy specialists (Table 5.1) in paediatric EEG promotes better care for people with epilepsy.
- Paediatric EEG training models are needed that are effective, affordable and sustainable in the African setting, as well as in other LMICs.
- Effective examples are evident via the training and education for paediatric EEG interpretation in SSA via the African Paediatric Fellowship Program.
- Delphi stage one and two statements (Table 5.4) demonstrated strong consensus in training recommendations across regions and experts.
- Adequate support and investment in EEG services is necessary at the individual, institutional and national level.

Ethical approval

This study protocol was passed by the Red Cross Children's Hospital Research Committee and the University of Cape Town Ethics Committee REC/REF 481/2018. This article is based on the research Conducted for a Doctor of Philosophy Degree in Neurophysiology.

Acknowledgements and disclosures

Gloria Cooper is a qualified research transcriber who provided the service of transcribing all the interviews. None of the authors has any conflict of interest to declare.

Legends for tables

Table 5.1: Terminology applied to clinician roles in Low- vs. High-Income Countries

Table 5.2: Demographics of experts and focus area of interest i.e. education or advocacy.

Table 5.3: Themes and sub-themes relating to interview questions. Demonstrating the 12 main themes relating to the responses from the participants as well as common sub-themes that emerged from the analysis. For example, relevance of the need for EEG training was strongly emphasized with sub-themes focused on the lack of access to training was raised by 5 of the 15 experts

Table 5.4: Delphi stage one and two statements and consensus

Supplementary files

Supplementary file 1: Appendix 5

Supplementary file 2: Thematic data

Table 5.1: Terminology applied to clinician roles in Low- vs. High-Income Countries

	Low Income Country	**High Income Country**
Paediatrician	Specialist	Primary care physicians
Epileptologist / Epilepsy specialist (adult or paediatric)	Adult or child neurologist with 1-2 years of epilepsy training	Adult or child neurologist with 1-2 years of epilepsy training
Non-specialist	Medical officer	Physician who is not an epilepsy specialist including those trained in general medicine, internal medicine, paediatrics and adult or child neurology when no additional training in EEG beyond that encompassed in core training has been completed
Healthcare practitioners	Medical officer Clinical officer	Physician Physician assistant Nurse practitioner

*To acknowledge that there are regional variations in entry point, focus and duration in training but the end point would be specific expertise at high level in epileptology

Table 5.2: Demographics of experts and focus area of interest i.e. education and/or advocacy

Participant	**Continent**	**Region**	**Expert**	**Profession**	**Gender**
1.	South America	UMIC	Education	Paediatric Neurologist	female
2.	South America	UMIC	Education	Paediatric Neurologist	male
3.	North America	HIC	Education	Paediatric Neurologist	male
4.*	North America/Africa	HIC/LMIC	Education	Paediatric Neurologist	female
5.	North Africa	LMIC	Advocacy/education	Paediatric Neurologist	female
6.	Asia	UMIC	Advocacy/education	Epileptologist	male
7.	South Asia	LMIC	Education	Adult Neurologist	male
8.	East Asia	HIC	Education	Paediatric Neurologist	male
9.	Africa	LMIC	Education	Adult Neurologist	female
10.	Africa	LIC	Advocacy/education	Adult Neurologist	female
11.	Europe	HIC	Education	Epileptologist	male
12.	Africa	LMIC	Education	Adult Neurologist	female
13.*	North America/Africa	HIC/LMIC	Education	Adult Neurologist and Epileptologist with Fellowship Training in Paediatric Epilepsy	female
14.	North America	HIC	Education	Paediatric Neurologist and Epileptologist with Fellowship training in Paediatric Epilepsy	male
15.	Europe	HIC	Education	Clinical Physiologist	female

*Collaboration work in African region. Abbreviations: USA, United States of America; UMIC, upper middle-income country; HIC, high income country; LMIC, low middle income country; LIC, low-income country.

Table 5.3: Themes and sub-themes relating to interview questions

Demonstrating the 12 main themes relating to the responses from the participants as well as common sub-themes that emerged from the analysis. For example, relevance of the need for EEG training was strongly emphasized with sub-themes focused on the lack of access to training was raised by 5 of the 15 experts

THEMES	SUB-THEMES	NUMBER OF AGREEMENTS
Q1. RELEVANCE	Lack of training	5
	Neurophysiologists	4
	Lack of experts	7
Q2. EXPOSURE TO PAEDIATRICS	Lack of training	5
	EEG interpretation	11
	Collaboration	3
	Neurophysiologists	1
Q3. FOCUS ON PAEDIATRICS	Lack of training	13
	EEG interpretation	5
Q4. BARRIERS	Lack of experts	9
	Lack of training/exposure	8
	Non-specialists	2
Q5. RESOURCE LIMITED SETTING	Non-specialist	15
	Epileptologist	7
	Lack of experts	6
	Neurophysiologist	4
	Technician/telemedicine	3
Q6. ENTRY SKILLS	Non-specialists	11
	Epileptologist	2
	Misuse EEG	1
Q7. BEST PEDAGOGY	Apprenticeship	12
	Combination of training	9
Q8. ASSESSMENT	Continuous assessment	10
	Combination of assessments	7
	Collaboration	1
Q9. CRITICAL SKILLS	EEG interpretation	13
	Lack of experts	1
Q10. RE-INFORCEMENT OF SKILLS	Continuous assessment	7
	Collaboration	5
Q11. TRAINING MODEL	Lack of training	6
	Misuse EEG	2
	Apprenticeship	5
	Collaboration	1
	Continuous assessment	2
Q12. RECOMMENDATIONS	EEG interpretation	4
	Misuse EEG	4

Table 5.4: Delphi stage one and two statements and consensus

Theme	Statement	Sub questions	Consensus %	Focused comments
Delphi round 1				
Relevance	In an ideal setting paediatric EEGs would be performed by accredited neurophysiology technologist and interpreted by epileptologists. However currently LMICs lack experts or specialists in the field of paediatric neurology and paediatric electrophysiology.	**(a)** In order to meet the need for access to paediatric EEG, it is relevant for non-specialists to be trained to perform and interpret paediatric EEGs **(b)** The training should be at an adequate standard to ensure consistency in practice.	87% 100%	**Key message:** Emphasis that although non-epilepsy specialists can be trained to do the EEG, they still must have access to a specialist.
Exposure to paediatrics	Training curricula and training programs should have time specifically focused on paediatric EEG for any clinician whose practice will include paediatric EEG in their future work		100%	
Focus on paediatrics	Training in paediatric EEG should be a separate and standalone area of study as the field carries unique aspects that are separate and different to adult EEG and require specific skills to be competent.		80%	**Key message:** Paediatric neurology and by default paediatric neurophysiology in many parts of the world is still a new and evolving concept. Development of services is layered on the legacy of how services are constructed. One person who disagreed with the statement explained that "a person should only learn paediatric EEG if this is an area of practice, however, everyone needs basic EEG training".
Barriers	Barriers to providing adequate paediatric EEG services in LMICs extend beyond the lack of specialists but also are compounded by the lack of adequate training resources for non-epilepsy specialists		80%	**Focused comments from the Delphi process:** "But the availability of paediatric epilepsy specialist is a good catalysing point".

Resource limited setting	The optimal healthcare practitioners to be trained in paediatric EEG skills in resource limited settings should align with the most equipped and best placed practitioners in the region.	**(a)** In the setting of lack of access to technologists, training nurses should be considered. **(b)** In the setting of lack of access to epileptologists, clinicians involved in the care of children with seizures e.g. paediatricians, child neurologists, general doctors should be encouraged to access training.	93% 87%	**Focused comments from the Delphi process:** There should be a standard qualification for non-epilepsy specialists. One expert was sceptical about training non-epilepsy specialists. **Key message:** Although 87% of the group were in agreement with the statement, they really highlighted the fact it must be done properly and safely. You have to recruit the correct person to do it.
Entry skills	Non-epilepsy specialists with interest in the care of children with seizures can be trained in the field of paediatric EEG at a basic and non-invasive level.		**73%**	**Focused comments from the Delphi process**: From two experts who disagreed with the statement, based on "Depends on how much time and effort is the individual prepared to devote to epilepsy and EEG" and "it depends on the type and duration of training. Agree that paediatricians could be trained in EEG interpretation but needs very careful training course". This question failed to reach 80% consensus and required a 2nd round of Delphi with questions adjusted according to group response. **Key message**: The EEG trained paediatrician must be fully focused, dedicated, supported, and capacitated to enable full commitment. Consensus was not attained as some experts did not believe that this was a feasible goal given the competing demands on the time of a paediatrician in a LMIC setting
Best pedagogy	Whilst training should follow a flexible teaching method which is most viable for local region, face to face teaching or apprenticeship is required and not only on-line.	**(a)** Training should have clinical application to reinforce knowledge translation and relevance. **(b)** Training skills should be maintained and reinforced.	93% 100%	**Focused comments from the Delphi process:** "For the exceptional candidate who has no in-person training option, there should still be a way to train". **Key message:** The aim of this process is to identify mechanisms to solve the paradigm in Africa where the challenges are huge, compounded by burden of disease and lack of resources. **Focused comments from the Delphi process:** "There should be a plan to provide intermittent long-term

				supervision. However, there should be an end goal. Thereafter, consultation when needed can be provided". **Key message:** Our Kenyan / South African bi-weekly meetings provide reciprocal educational gains for the trainees. Eventually when centres become established and should become the hubs for training i.e. there should be a progression in the stages of capacity. Entry point - establish a setup at centres providing a service, provide collaborative work together, evolves from training evaluation to stand alone facilities who provide support for other regions and expand the network!
Assessment	Assessment of skills learnt is required. This should have a continuous assessment component to detect early training deficiencies and refocus attention to areas of training need.	**(a)** An exit examination is also important to ensure consolidation of skills learnt over the training period. **(b)** At the entry point a pre-skills assessment is needed to have insight into entry level of the trainee. **(c)** A post-training assessment provides further information across skills progression.	100% 100% 100%	
Critical skills	Critical EEG skills are basic EEG training on pattern recognition and interpretation but should include:	**(a)** Insight into different patterns related to brain maturation and unique aspects of paediatric EEGs in general. **(b)** Additional critical skills are the ability to undertake EEG practical activities from electrode placement to knowing how to record an artefact free EEG.	87% 93%	**Focused comments from the Delphi process:** From one expert who disagreed with the statement, based on "critical skill is performing a good quality EEG first as interpretation is wasted if EEG recording is suboptimal". **Focused comments from the Delphi process:** The same expert who disagreed above, based on "these are not additional skills they are the most important still. If this step is wrong, the rest is a waste of time".
Reinforcement of skills	It is important to establish methods for maintenance of skills.	**(a)** This should be via theory assessments and case discussions	87%	**Focused comments from the Delphi process:** From one expert who disagreed with the statement, based on "I do not agree with maintaining skills through theoretical assessments; but I agree that this should be done via

		(b) but supported using mentorship and building collaborations with centres regularly training in EEG and providing clinical services for EEG in children.	87%	case discussion. but you put it together, so I chose to disagree".
Training model	Training for non-epilepsy specialists should be standardised to ensure consistency.	**(a)** Quality of training models should be critiqued using monitoring and evaluation tools.	93%	**Focused comments from the Delphi process:** "I think we have differing definitions of "specialist" here…In Zambia, a paediatrician is a specialist" and "However, these tools may vary depending on specific settings or regions and availability of resources".
		(b) Those providing paediatric EEG services should meet an adequate level of competency as approved by local authorities before being allowed to practice.	80%	**Focused comments from the Delphi process:** "This assumes a local authority would have the technical expertise to make this determination. I believe this is better handled by a central authority unless the technical expertise clearly exists locally to make this evaluation"; "If there are no local standards then international validated standards should be followed" and "In LMICs, there is often a lack of local authority which is competent to do this". **Key message:** The one person that disagreed and emphasized local authority limitations. It may be idealist to expect local authority to be able to undertake this role. So, whilst an important approach to follow, if local authority isn't equipped to provide the competency assessment, then alternate options are needed e.g. international groups.
		(c) Access to specialist training is still required, in addition to non-epilepsy specialists, to attain high level paediatric epilepsy and EEG services.	93%	**Focused comments from the Delphi process:** "So high level services will not be available to everyone unless telemedicine comes into play" and "Fellowship trained Epileptologists are necessary to oversee EEG Training to non-epilepsy specialists and maintain EEG reporting standards".

				Key message: There is a need for specialists in resource limited environment. This speaks to the fact that if one tries to set up this kind entry level basic care safe practice service you should have an access point and somebody in the country who would lead it (Wilmshurst et al., 2016).
Recommendations		**(a)** Clinicians training in child neurology in LMICs need to acquire more advanced paediatric EEG skills than their colleagues in resource-equipped settings. Skills include practical equipment related as well as interpretive, so that when they establish and build services in their home settings, they are equipped to do this. **(b)** These trained clinicians should also take an advocacy role to raise awareness of the risks of misinterpretation and misuse of EEG in the hands of untrained practitioners in their local settings.	87% 100%	
Delphi round 2				
Expanded training requirements	What would be needed for a non-epilepsy specialist to be able to use, sustain and maintain EEG training skills?	**(a)** Individual perspective - the non-epilepsy specialist should want to train and have long term commitment for use and maintenance of skills. **(b)** Institution perspective – the centre / region should provide	93% 100%	**Focused comments from the Delphi process:** "The interest of the individual is very important" and "Also that the non-specialist should have a responsible number of epilepsy patients (otherwise if s/he sees only few patients, s/he might not be motivated to continue the training". **Key message:** Non-specialist healthcare providers should be invested in attaining and maintaining basic skills to be able to care for children with epilepsy and to optimise their use of EEG. **Focused comments from the Delphi process:** "Institutions must provide the basic equipment and

		support for the operational infrastructure for the service delivery.		materials to operate and maintain an electroencephalography service, given that epilepsy is a public health problem with a high probability of control with an accurate diagnosis" and "Institutional involvement is important to give value to training and advancement in professional rank and to provide learners with the necessary equipment". **Key message:** Institutions investing in proper resources and professional training not only ensures better patient outcomes but also contributes to a more knowledgeable and skilled healthcare workforce.
		(c) Health policy / Government or Ministerial level – recognize and support the development and sustainability of this service, ultimately improving healthcare outcomes in children.	93%	**Focused comments from the Delphi process:** "I agree with this statement, although sometimes government public policy is born because awareness and work were raised by the patient and medical community and not by the politicians in power" and "It is necessary to raise awareness between public health officials about the need to offer these services". **Key message:** Advocacy from patients, non-government organisations and the medical community can inspire public officials. Increased awareness amongst those officials can lead to proactive measures and policies that enhance service availability and quality.
		(d) Task sharing - in settings which lack paediatric EEG specialists, provided points a-c are met, appropriately trained and supported non-epilepsy specialists can undertake paediatric EEG interpretation.	80%	**Focused comments from the Delphi process:** "This is important in poor resource settings with no access to specialists" and "The interested person must demonstrate an update through virtual or in-person training in variable periods, for example every 3 years". **Key message:** Health systems can better meet the needs of their populations, even in contexts where resources are scarce by prioritizing accessibility to services and emphasizing continual professional education.

5.1 Supplementary file

THEME 1: Relevance

The *lack of epileptologists* was raised by seven (47%) participants.

"I think, training epileptologists, is very complex, it takes, sometimes, one to two years, and the resources may not be available" – **participant 4.** "To have, or make an epileptologist, really, is a great ambition, and it is a great job, when it is possible. But you know, this is not always possible" – **participant 6.** "Epileptologists, he must have an in-depth knowledge" – **participant 1.** "If you're in a university hospital or in a large city, maybe you are training for being an epileptologist, and a good, qualified epileptologist" – **participant 2.** "In the most resource limited settings, we need access to expert epileptologists" – **participant 14.** "There's, certainly, a need for epileptologists in tertiary care settings" – **participant 13.** "Epileptologists, high level education must be necessary" – **participant 8.**

Nine (60%) participants thought *safe practice* was very important for non-specialists in having knowledge of basic EEG patterns.

"We have the gap and the insufficient resource in our country, all the person who are not specialists, can well take care to patients. So, the safe practice is the most important thing for this person, which are not specialists" – **participant 10.** "Need for safe practice in community practice, for seeing patients and for patient care. The level of training depends on the area where it's required" – **participant 13.** "I think the first goal should be to establish a safe practice, when I say safe practice, meaning, they should know the basics of what is normal" – **participant 4.** "Safe practices are for all, but for unskilled persons, not dedicated only to epilepsy, you have to assure that safe practice is always there for making EEGs" – **participant 2.** "Understanding that EEG is an important supportive tool, I think we need to train people to have safe practice. So, to at least understand what EEG is used for, and what are the indications" - **participant 12.** "For the technician, EEG epidemiological technician, or some nurse practitioner, safety of the practice is the most important thing" – **participant 8.** "I think it's, not only, delivering effectively, but it is delivering, as you said, safely, which is safety of patient, safety of clients, safety is extremely important. Ethics is extremely important. And the economics are extremely important" – **participant 7.** "A non-specialist or a child neurologist, should have adequate knowledge of electrophysiology for safe practice" – **participant 3.** "For non-specialists, he must know key aspects" – **participant 1.**

Severe *lack of training* and those not correctly trained stood out as a theme with five (33%) participants.

"In third world countries, there's, basically, a total lack of expertise. So there, basically, anything you have, more than zero, is useful, because virtually, you don't have anything like this" – **participant 11.**

“We need to be mindful that specialists and sub-specialists are in real demand and are extremely limited in many of the resource limited settings in sub-Saharan Africa, as well as some parts of Asia, as well as South America” **– participant 7.**
“I believe that, if trainees are not trained correctly, it can be unsafe, because patients may be treated incorrectly, as a result of an inadequate EEG report” – **participant 15.**
“I think that this is a very interesting project, it’s very relevant, of course, because, we Africans, particularly sub-Saharan Africans, we have to cope with all what is related to epilepsy. You know epilepsy is a very prevalent pathology, in particular, in Africa and in sub-Saharan Africa, so, developing skills to manage epilepsy, I think, is something that is interesting, but is very necessary” – **participant 9.**
“And then there is a second level of, actually having capacity to read and interpret electrophysiology studies, with confidence” – **participant 3.**

Four (27%) thought *electrophysiologists/neurophysiologists* should be performing EEGs. This was represented equally from HIC (2) and RLC’s (2).

“Clinical Neurophysiology Board, where we give them four years of study, to give them a Board Degree” – **participant 6.**
“There should also be electrophysiologists, that are providing some basic, but important, EEG access, but they need to be able to refer to higher levels of expertise, when needed, and they need guidelines about when that is” – **participant 14.**
"In those countries where EEG reading is part of a speciality, which is called clinical neurophysiologist, their neurologists only need to train basic EEG features, just to become acquainted, become familiar with when to refer, or how to read the report” – **participant 11.**
“So, with the speciality functional exploration, we can work, as a neurophysiologist, we can work in hospital. So, this is the problem. All neurophysiologists or physiologists in Tunisia, choose to be, even, neurophysiologists, and they work in functional exploration department, in hospital, and also in medical school. Or they can specialise for other exploration, such as respiratory or cardiac exploration” – **participant 5.**

Two (13%) experts felt *neurologists* need to have adequate knowledge on EEGs, however, many countries lack specialists.

“Generally, in Africa, we’ve got very few neurologists. So, well, doctors, to start with, are very few, and neurologists, as a speciality, is even fewer”– **participant 12.**
“However, in some country’s EEGs are read by neurologists. In those countries, it’s imperative that they learn, also, the EEG patterns, and recognise them, and make a report” – **participant 11.**

THEME 2: Exposure to paediatrics

In house paediatric exposure during their registrar training was raised in 11 (73%) responses.

Training times varied across regions. It was noted that some centres have limited qualified trainers to teach paediatric EEGs.

“We have exposure to EEG, very early, in our training as child neurologists, at least, in our program. We have a two to three month, usually three months, of EEG exposure for child neurologists” – **participant 3.**
“Paediatric neurologists and neurologists doing training, the residents, will attend the epilepsy ambulatory, twice weekly, and an electroclinical discussion of some cases with epilepsy and EEG, with their staff, will precede this ambulatory” – **participant 1.**
“In Boston, the child neurology trainees will get exposure through being able to access and review their own patients’ EEGs, as well as when they’re rotating on services, they are expected to review ICU EEGs, etc., but they do not read and report them”– **participant 4.**
“We have a laboratory of EEG, in which, some seniors, like me, are practising EEG; they have been trained, they have been abroad to be trained in EEG. They did specialisation in EEG, and they are practising it; and while practising it, they teach some young protégé which are in training for general neurology” – **participant 9.**
“We have a paediatric neurology residency program, and spend, usually, two-month blocks of epilepsy rotation, where they will be exposed to EEG reading as part of their clinical training” – **participant 14.**
“In Sfax Medical School, our department is specialist in EEG, because it is a child neurology department, and we focus, in our daily practice, we focus, mainly, in epileptology” – **participant 5**.
“I think, most particularly, will be the neurologists who’s received, or taught the proper research, in the same institution. That is my course. So after, I did not receive any EEG education course” – **participant 8.**
“EEGs are reported by neurologists, or paediatric neurologists, after their full training in paediatric, or in neurology too, a two-and-a-half-year fellowship, in clinical neurophysiology. Now, during the neurology training they also have six months in clinical neurophysiology. So, altogether, they are exposed to three years of clinical neurophysiology” – **participant 11.**
“In our setting, specifically in Zambia, there’s one centre in State, where you can get paediatric EEG. And so, in terms of interpretation, it’s those who are training in paediatric neurology - currently there’s one - and then we have two paediatric neurologists; those are the ones who would get the most exposure to EEG interpretation” – **participant 12.**
“There’s, also, at least a one week didactic on neurophysiology, with a focus on child neurology paediatric recordings” – **participant 13.**
“Our trainees, the experience they get, is just from reporting lots and lots of paediatric EEGs, and also neonatal EEGs, because, obviously, neonatal EEG is part of the paediatric group. our philosophy is that, in order to be able to report an EEG on a child, we need to be able to do an EEG on a child. And if you don’t do one, you can’t interpret one. So we insist that all our fellows, actually, are able to apply EEG electrodes - I can’t emphasise how important that is - because interpreting paediatric EEG is challenging enough, and if you don’t appreciate the kind of things like, artefacts, or all the things that can influence the EEG interpretation, I think you truly don’t get that appreciation, until you actually do it” – **participant 15.**

Lack of training is a recurring sub-theme in particular, for paediatric exposure, in EEG interpretation as reported by five (33%) experts.

“Colombia is a country with a heterogeneous distribution of the healthcare system. You haven’t got all the technology that is available in the first or developed world, or countries, and you have most of the population, with unserved settings. In my city, in Medellín, you have a lot of places where you can get the paediatric EEG interpretations, but outside the city, it is not available” – **participant 2.**
“As a child neurologist, you get three months in your three years of training, which is, I don’t think it is enough for many of them. The exposure after the three months, is very case-by-case, individualised” – **participant 3.**
“We have a problem in our countries, which are the French speaking countries in West Africa, that’s a part of the sub-Saharan region of Africa. In this country, we first see the problem of the lack of supervisors. We have no supervisors, formal supervisors, for EEG training, so we have to learn at the same moments, we’ve other duty”– **participant 10.**
“There are some hospitals have the equipment, but do not have the competent people or the specialised people, to read, interpret, analyse the EEG. So, the paediatrician found himself need to read this. So, he will read, she will interpret, and has narrow, or possibly, insufficient, or even wrong knowledge, that he had. That’s a problem in our region” – **participant 6.**
“We have one paediatric neurologist; we just have one paediatric neurologist. And he also joined us about ten years ago. So, you can imagine, ten years ago, we used to report paediatric EEGs, and you can, actually, imagine what would have been the standards of reporting, and we had no training” – **participant 7.**

Six (40%) experts commented that neurology trainees can access further exposure to *paediatric EEG interpretation* via courses, fellowships, and additional degrees.

“In Sfax Medical School, we have proficient master’s degree of Epilepsy, and we have a module of EEG in child, also in adult, so they can have training in interpretation. We have theoretical and also practical seminar, and during this practical seminar, they can have the competency and also knowledge, to improve their knowledge in EEG interpretation” – **participant 5.**
“There are several courses, to teach in EEG, are available, which are based on special institutions, like epilepsy. There are based in epilepsy hospitals in Japan. And also, some society, like Japan Epilepsy Society, or Japan Electrophysiological Society, provides educational course for EEG” – **participant 8.**
“Some of the trainees have also enrolled on the online course, EEG online; so, again, it teaches basics of EEG, not specifically addressing paediatrics so much, but it gives you general principles. And I’m not sure if any of our paediatric colleagues have registered on your paediatric handbook training course. But that’s, essentially, how they get training, it’s training from external rather than internal expertise”– **participant 12.**
“If they decide to pursue an EEG, or epilepsy training, or a fellowship, you must stay at least one year on the EEG units, and if you wish, one year in the video EEG. The video EEG is optional for those that want to go to epilepsy surgery. But the EEG, one year is mandatory, attending the epilepsy ambulatory” – **participant 1.**
“We have a training program, of course, for neurophysiology, which is one year, and we can do an extra year for intracranial neurophysiology or intracranial EEG, with epilepsy surgery” – **participant 3.**
“They can do an optional selective or electives, to make up for the six months, if they wish to write the EEG exam, over and above their Royal College exams” – **participant 14.**

Three (20%) experts reported that *collaboration training* occurs amongst the neurology trainees for exposure to EEG interpretation during their training. In particular, there was mention of the difference in availability of training between their home and work region.

> "In Zambia, our child neurologists, during their training, did get some exposure and some course work on it, and we continue to work with them in workshops, to help them read and interpret EEGs" – **participant 4.**
> "So, with regards to training, I think there is the weekly meetings that you host at UCT, and so that paediatric neurologists and trainees can join that, with online meeting" – **participant 12.**
> "I'm going to go with the Zambian setting on that, and in the Zambian setting, there is, for all the trainees in neurology, both adult and child neurologists, there is a weekly EEG reading session that is dedicated to paediatric recordings. But it is very well attended by those who are interested in epilepsy and neurophysiology, and those who are going into child neurology; so that's weekly" – **participant 13.**

Rare but available in some African countries are qualified *neurophysiologists* performing and interpreting EEGs as reported by one (7%) expert.

> "But they are, also, not the ones who read them; we have certified neurophysiologists doing it for themselves" – **participant 4.**

THEME 3: Focus on paediatrics

Interestingly, but not surprisingly, 13 (87%) experts agreed that there should be a separate focus on *paediatric training*.

> "In those countries where you have paediatricians to read children's EEG, then definitely" – **participant 11.**
> "I think there should be a separate. Many of my colleagues, I know, would never look at a paediatric EEG; they just feel uncomfortable. But I think it's really important. And maybe people should specialise in paediatrics, because it is very different in many aspects" – **participant 15.**
> "Yes, of course. I think the training and the EEG management and interpretation is quite different from adults. The child doesn't follow, always, your orders, and you have to be very skilled and trained for that" – **participant 2.**
> "Absolutely, I have no doubt about it, because, as I said, at a stage, we used to report paediatric EEGs, because there was no paediatric neurologist, and we have seen a wonderful difference it makes, if there is a paediatric specialist. So, I have no doubt about that" – **participant 7.**
> "That's also something we have not done here, because child neurology is not well developed; it seems to be not existent here" – **participant 10.**
> "There are countries where paediatricians evaluate children with neurological disorders, meaning they do child neurology, and they don't have access to child neurologists. In this

setting, I think the paediatrician should be trained in EEG, and we have done that, also, in our institution" – **participant 3.**
"Absolutely, yes. A particular focus on paediatrics is mandatory; yes" – **participant 1.**
"Of course. Sure. Definitely" – **participant 6.**
"Of course, because, I suppose it's the same everywhere else, but in our laboratory, infants, the paediatric population, are the main part of our patients. We have daily number of EEG, in which paediatric EEG are a great part" – **participant 9.**
"In Japan, in our opinion, we should focus on paediatric EEG, because there are very few people to see, both adults and children. Most paediatricians can focus on the children, so we can focus on the paediatric EEG training" – **participant 8.**
"Yes, so I think" – **participant 12.**
"Yes, hundred percent" – **participant 4.**
"Yes, absolutely" – **participant 5.**

There is a significant difference between paediatric *waveforms* and adults as mentioned in eight (53%) experts.

"Paediatric EEG is quite different from adult EEG, so you need paediatric experience, to become comfortable with it" – **participant 14.**
"If you can see paediatric EEG, you can also see other EEG. But it is not vice versa. But the doctors who can see other EEGs, cannot see paediatric EEGs, so they can focus on paediatric EEG" – **participant 8.**
"We absolutely need to have training, EEG specific training, for EEG for paediatrician, and for a child. It's very important, especially for the infant; it's very different from adult, and from other age" – **participant 5.**
"When we think about epilepsy in general, there is very unique features about epilepsy in children. So, I think it's important to have a general understanding of EEG, but within that, there should be a subset that focuses on children" – **participant 12.**
"I certainly think that there needs to be a recognition that, to be comfortable with paediatric EEG, particularly in the younger age groups, you have to go beyond the basic EEG training that might be sufficient for adult records" – **participant 13.**
"I think that it has to be the main focus, when training people as neurologists and why that, during maturation, brain maturation, you have a very rich pattern of EEG" – **participant 9.**
"If you have adult neurologists who train in general EEG reading, including children, then, specifically, they need to train in the EEG patterns in the paediatric epilepsy syndromes" – **participant 11.**
"In our setting, most EEGs are for children, but it depends on the purpose. For paediatric neurologist, it would our perfect to receive a focal zone, paediatrics, not only epilepsy, ICU patterns. Now, considering neonates, it's a different word. I don't think that they need to know, in that, neonates, because not all epileptologists know the maturational aspects and everything else. But epilepsy, there are natural clinical syndromes, that will occur, that have onset in infants, neonates, childhood and adolescence, they must know bilateral clinical correlation, for sure" – **participant 1.**

Initial EEG usually involves learning basic knowledge for adult EEG interpretation; however, extra training is required for *paediatric EEG interpretation* as their waveforms are unique and differ with brain maturation. This was mentioned by five (33%) experts.

"I wouldn't want it so siloed out, that we really isolated it too much. But clearly, you can't just do the basics of adult EEG, and then be looking at neonatal records" – **participant 13**. "When you get trained, you first start with an adult to see all the organisation, so on. And later on, you get involved into paediatrics, because there are developmental issues, there are environmental issues" – **participant 2**. "I think you need the general principles, first; you need to understand adult EEG. I think we all started there. And then, when you're comfortable there, then you can start looking at the different age ranges, because, as you know, they vary so much" – **participant 15.** "For EEG training, usually, the skills, or the training for EEG, encompasses both adults and paediatrics" – **participant 14.** "I think paediatricians should not have a specific exposure to EEG, because they are not going to use it, and EEG is something you have to practice, to remember it" – **participant 3.**

Misinterpretation is very common in EEG when the person interpreting the EEG is not properly trained, as stated by one (7%) expert.

"We have a lot of problems for false interpretation and misinterpretation. And unfortunately, in Tunisia, several neurologists, and several psychiatrists have in his private office, an EEG, without training, without skill, and without competency; so, misinterpretation is very high" – **participant 5.**

THEME 4: Barriers

The theme of *lack of experts* was just one of many barriers experienced by nine (60%) experts.

"Unfortunately, there are few centres in the central and north-east regions, and none in the north. We do not have staff in the latter"– **participant 1.** "We have a strange distribution of our neurophysiology specialists in Denmark. So, there is a large number of person specialists, who will retire within the next five to ten years" – **participant 11.** "We don't have enough child neurology specialists, epileptologists. The second problem is a lack of expert. A few experts in EEG, paediatric EEG interpretation. This is the main barriers – **participant 5.** "When the awareness is present, there is no resources; I mean, there is no people who are experienced and competent, in this region"– **participant 6.** "I think the first and foremost barrier, is the limited number of paediatric neurology, or paediatric epilepsy consultants"– **participant 7.** "The first barrier is our system, which is focused on the training of adult neurologists, and the training on epilepsy; there is nothing for EEG itself" – **participant 10.** "The biggest barrier is the lack of trainers, which really comes down to, as I said, the whole country. We have two paediatric neurologists, and so they are dealing with all the paediatric issues relating to neurology"– **participant 12.**

"The barriers are that we do not have enough EEG units, and enough people who are involved and would like to train and to teach EEG and paediatric EEG" – **participant 2.**
"Our postgraduate training program is new enough, that we're still lean on numbers, and we aren't encouraging people to jump right into fellowships, because we need to have a sufficient number of postgraduate, fully trained neurologists, to help train the trainers, bring up the new generation"– **participant 13.**

Eight (53%) experts highlighted an overall *lack of training* and exposure to EEGs and one of the major observation was lack of time during training.

"They come to be trained in neurology, and it is during this period that they have to learn, also, EEG, so sometimes, they don't have enough time to care about EEG. But we try to make it easier for them, so that they can spend enough time, because practising is a very important part of the training" – **participant 9.**
"The second barrier in a high-income country, is that we are very service specialised. So, we have epileptologists and neurologists, who read the EEGs at a very high level of training with a fellow. So, the child neurologists don't have enough exposure" – **participant 3.**
"I think that it takes a lot of exposure, you need to have consistent exposure; and the time dedicated to, not only, reviewing the EEGs, but actually reading and reporting them out; I think that's the only way they, actually, gain their confidence in interpretation" – **participant 4.**
"Many patients with epilepsy, come to outpatient clinics. So, younger fellows, mostly spend their time in the ward, not in the outpatient clinic. So, they have very few chances to see the patient with epilepsy. Also, if I don't teach EEG, and they don't have the chance to see paediatric EEG, or just EEG of a patient with epilepsy" – **participant 8.**
"The main barrier is time, because, ideally, you need one-on-one training with an experienced, certified EEG person, who can, then, sit with the trainee and go through EEG, one-on-one, and explain findings, and review the EEG together" – **participant 14.**
"The other barrier is also just the access to EEG. So, as I said, in State, we've got the one centre for paeds. Then in private, we've got about one or two centres of doing paediatric EEGs. So already, just the access to the tests is limited, and so, that further limits access to understanding it and interpretation" – **participant 12.**
"The second barrier is our perception about the EEG interpretation. For us, EEG is something so difficult, and that, which we can go to" – **participant 10.**
"From our perspective, I think, sometimes, it can be challenging to see the full range, and that's why we have always ensured that our fellows spend time in the other hospitals that see more of the rare diseases, the rare conditions" – **participant 15.**

Another two (13%) experts indicate that they do not have training courses nor the skills to teach *technicians or non-specialists.*

"And the other way, you have, apart from the doctors, you have to train the technicians. These technicians do not have some structural school where to learn it, so we have to train them directly, by our own means, our own scanners; it's not from conventional if I can say that" – **participant 9.**
"We do not have, really, EEG training for other specialists. EEG training is only for neurologists, neurophysiologist, and child paediatricians. We do not have courses, or

training courses, for general practitioners, or other kind of medical specialists. And the other point, is that we do not have that many units to train, and time to train. Training needs skills for training and for teaching" – **participant 2.**

THEME 5: Resource limited setting

The experts opinion on this questions revealed numerous themes on whom should be best trained in a resource limited setting (RLS). All experts indicated mixed feelings about whether a *nonspecialist* (nurse/medical officer/paediatrician/general practitioner) should be trained or not. One (7%) expert mentioned that in resource limited setting, training should be better received in their own mother tongue.

"I have had experience of training people to do EEGs in resource limited settings, we were able to train the nursing team, very well; they were excellent, and very committed, and were able to, actually, apply the EEGs, really well; as long as we had a very clear protocol, and that worked really well" – **participant 15.**
"In this situation, it depends on the country, and it depends on what is available in the country. I think, any doctor, and also in some countries, nurse, but we need to have a very engaged medical doctor and nurse" – **participant 5.**
"But considering my scenario, middle income country, I don't think that medical officers and nurses would be interested in EEG training, at this moment. But, perhaps, we may change the situation with, for example, the paediatric epilepsy training, now that we have more paediatricians. And in the future, I believe some are also attending to the paediatric epilepsy training" – **participant 1.**
"But I don't think that medical officers or nurses will work this" – **participant 6.**
"I think, every personnel that is already evaluating children with neurological disorders, especially epilepsy, should have, as a minimum, the basic concept of EEGs; they should be trained, ideally, should be paediatricians or medical officers. There are some settings where they don't have medical officers, and the nurses are available, and I think they, in these cases, they should be trained" – **participant 3.**
"I do think medical doctors should have awareness, and an ability to understand reports for basic epilepsy syndromes, which is a standard for paediatric training in many high resource settings, and I think it should be the same here" – **participant 4.**
"So, because Japanese people can't speak English so well, like me. I think it's the same situation in the limited resource settings; they can speak mother tongue, but most people can't speak English. they can be taught by EEG education training, then you can teach EEG training skills to your hometown medical practitioner, or technicians" – **participant 8.**
"I think that all the people who are interested in caring about infants, have to be trained on it" – **participant 9.**
"Paediatricians should know how to manage epilepsy, they should know how to manage seizures, particularly febrile seizures" – **participant 7.**
"I don't believe the general paediatricians have the neurology or neurophysiology; they would need a lot of additional training before you could start training them in EEG" – **participant 13.**
"Paediatricians, generally, are very broad in their knowledge. To learn EEG, is over and above what I'd expect a paediatrician to understand"– **participant 14.**

“But when it comes to a general understanding of what EEG is, and what EEG should be used for, that should be directed to any doctor, and I think it should start at the level of a medical student” – **participant 12.**
“I think this must be site specific. And then, depending on what the setting is, try to find the adequate tools. Let me answer it more specifically. If you go down to zero, where you maybe have one neurologist per country - and there are countries in Africa with just a handful of specialists in the whole country – then, probably, you will rather go for training nurses or healthcare workers, and give them tools, like applications. Now, in countries where the situation is better, probably, a focus could be on post-graduate training, for example, if there is a sufficient number of neurologists or paediatricians interested in learning how to train EEG, then, for example, online courses, which are very efficient, you can bridge the distances, you can have participants from several countries” – **participant 11.**
“I think everything is based on training. If you have the good training, you can do the job” – **participant 10.**
If you are very interested in epilepsy and in EEG training, it doesn’t matter what kind of degree you have. It can be a technician, a nurse, a GP, a paediatrician, or a child neurologist, or even an epileptologist. The topic is if your genuine interest in that, and that you are very well qualified, trained for that” – **participant 2.**

The expectation that an *epileptologist* is an expert in the field of epilepsy and EEG was mentioned by seven (47%) experts. Two (13%) experts commented that epileptogists lack EEG training.

“I think that, of course, epileptologists, they must have training. I cannot understand when an epileptologist does not have EEG training; it does not exist” – **participant 1.**
“There may be some unskilled epileptologists, that, maybe, interpret very bad, the EEG recordings” – **participant 2.**
“You need epileptologists to lead and train people; you need key leaders in the field” – **participant 14.**
“In an ideal world, I would say, epileptologists, because those are the best” – **participant 11.**
“In some countries, we need to have epileptologists, because we need to have clinical expertise and also EEG expertise" – **participant 5.**
“I think a few epileptologists must be necessary, there; and they can teach other general paediatrician, or medical officers, or nurse practitioners” – **participant 8.**
“I think, career intended epileptologists, is first, is always the first option” – **participant 6.**

Six (40%) experts indicated *neurologists and child neurologists* should be the preferred clinicians to focus training on.

“I think, when we talk about EEG interpretation, I think those who are training as neurologists or paediatric neurologists, should get that training” – **participant 12.**
“I think it should be paediatric neurologists, first and foremost. Because paediatric neurologists should be specialised" – **participant 7.**

"I think that child neurologists should have EEG training, at the maximum, they should be able. I mean, I think in a resource limited setting, they should be reading and interpreting, and that should be part of their training" – **participant 4.**
"In that training, I think of paediatric neurologists, and neurologists, that are not a career intent epileptologist, would be of great interest" – **participant 1.**
"The child neurologists" – **participant 13.**
"I think, general neurologists would be the next level to train, whether they community, or private, or public healthcare" – **participant 14.**

The suggestion that *neurophysiologists* can be trained was mentioned by four (27%) experts.

"In Zambia, we don't have a training track for neurophysiology, which I recognise exists in Europe and other places. Should we have that, I think I would be delighted to have neurophysiologists take that on. We just don't have that cadre of people, right now" – **participant 13.**
"In the limited resource setting, I think the most important focus must be done - if you talk about EEG training - to the technologists. They can make a record, and interpretation, also. And because the duration of this kind of training is shorter than the duration for medical doctor, neurologist, epileptologist, and they are also familiar with patients" – **participant 10.**
"Another realm is a neurophysiology person, who may have master's or PhD in neurophysiology, who then becomes an expert neurophysiology reader. In my experience, that's the rare exception" – **participant 14.**
"I think that any other paraprofessionals should, actually, just understand the role of EEG, but not, necessarily, the interpretation" – **participant 4.**

Three (20%) experts emphasised that there is good potential for training *technicians* with the assistance of telemedicine for interpretation.

"Maybe, there could be very good technicians, that make hallmarks on topics or points. So, the point is, to get very, very well-qualified, for that. It doesn't depend on the degree you have" – **participant 2**.
"I also think it's very important to train people who can acquire EEGs, So, training people to be technicians, even if they are not necessarily technologists. So, if there are certain nurses who can be trained to acquire EEGs, I think that would be a useful way to use our resources, because you can have many acquirers and fewer interpreters" – **participant 12.**
"Training the local teams as well, supplementing that with telemedicine and telehealth. And I think this is really doable. I do think, for resource limited settings, what we did, was we actually provided the interpretation remotely in Cork. I have first-hand experience of reporting paediatric EEGs remotely" – **participant 15.**

One (7%) expert was very firm about *psychiatrists* not being trained in EEG interpretation.

"I would definitely, and I can tell you, I also don't believe the psychiatrists should be trained" – **participant 13.**

THEME 6: Entry skills

Ten (67%) experts felt that a wide range of *non-specialist personnel* with an interest in epilepsy can be trained.

"I think, if you have somebody who has a good appreciation of the local healthcare setting, and is used to that population, so works with children, I think it is very possible to train teams to do EEGs" – **participant 15.** "In my opinion, you need to be a neurologist or paediatrician, and you already need to have some basic knowledge of epilepsy" – **participant 11.** "The first, is the interest; you must have very good interest. It's not only EEG, you must have, also, information skills about epilepsy at all. What is epilepsy? What are you looking for it? It's not only of the technical points but knowing all around the clinical aspects of epilepsy and, maybe, in some respects, also, the treatment aspects, because some drugs have, also, an importance in the EEG" – **participant 2.** "I certainly think that you could take somebody who's a neuroscientist, who knows a lot of neurophysiology, and give them some of the additional developmental biology, and stuff they need, and they might be able to do that. We just don't have that training track" – **participant 13.** "In some situations, in order to have a rapid diagnosis, and accurate diagnosis, in some epileptic syndrome, it can be general practitioner, or paediatrician, or general neurologist, or even nursing, some settings" – **participant 5.** "It depends on, if you are just thinking of basic level, then, I think, people with paediatric neurology experience should be able to" – **participant 7.** "I think it has to be doctors first. If it is possible that they are trained in neuroscience, it's better. But we can see that paediatricians are not necessarily trained in neuroscience, but they care about children, so they can be included, I think" – **participant 9**. "It would really just be someone in the healthcare system, so, basic understanding of healthcare" – **participant 12** "For a physician to read EEG, I think you need to have an understanding of neurology. And it's time and mentorship, because you learn it's pattern recognition. You need to sit and read, and have access to raw EEG data, which is then recorded accurately, so that you can learn from the mentor, in an apprenticeship program" – **participant 14.** "The entry level should be MDs who are interested, on condition that they are interested, in this part of speciality; it, always, will do, and will give a good gain" – **participant 6.**

Having *basic knowledge of EEG* and a scientific background was indicated in eight (53%) experts.

"Entry level skills, as you say, they may develop from education. Our recognition of the essential background abnormalities, first; variants of normality, because they are frequently reported as abnormalities, leading to treatment, is one of the pitfalls of the EEG" – **participant 1.** "I said that, for me, they have to get a background in neurophysiology. That's very important, to be able to identify artefact, to know why artefact happened, to know what is the wave from the brain, why they have different signification, they have to have an idea about sleep, sleep record, they have to get an idea about other biological function; for example, why I have to record, at the same time, muscle response or health. So, I think, the background of physiology is important to have" – **participant 10.**

“I think the main level is, what I call, basic level. So basic level is, probably, the most fundamental part of neurophysiology, to recognise what is normal and the most common abnormalities, or the most basic - that is a way to call it – abnormalities, for the practitioners to recognise, as a minimum, what is abnormal, what is an epileptiform discharges, what is the different easily recognisable slowing, or cerebral dysfunctions, and recognise what is a generalised epileptiform abnormalities, in a focal one. And that’s, probably, the first step” – **participant 3.**
“And then, when it comes to using the EEG, I think it’s a basic understanding of what an EEG actually is, and indications in which we can use an EEG. I think those would be the basic things that someone should understand” – **participant 12.**
“To be very, very qualified, and specific, in all the technical parts. The technical parts of an EEG recording are of utmost importance, because it will guide in a very good manner, if they are well done, the interpretation of the recording” – **participant 2.**
“I think you have to have the baseline clinical knowledge, and then you, also, do really need a basic neurophysiology course, in understanding the basis of EEG and how it is interpreted” – **participant 4**.
“You need to have an understanding of basic neurophysiology and neuroanatomy; and to understand the brain, neurobiology, would be important, as well. It’s important to have some understanding of the way electric circuits work, and technology, more now, at the level of an EEG technologist” – **participant 14.**
“The most important thing to see, to read EEG finding, is the differentiation, differentiate abnormal findings from normal findings. It’s hard to discriminate abnormal or a normal EEG, from the normal background. Particularly, for paediatric EEG” – **participant 8.**

Two (13%) experts felt *epileptologists* are required for accurate diagnosis and when more invasive montitoring is required.

"If you want to go at, particularly, the very early EEGs, or if you want to go into research surgical work-up, then, I think it has to be for career you’ve used the term, career intended epileptologist, so it has to be that” – **participant 7.**
"We need, really, to be epileptologists, in order to have a very accurate clinical diagnosis; because, EEG, alone, it’s not sufficient to make the diagnosis of epileptic syndrome” – **participant 5.**

One (7%) expert indicated that certain people are trained and *misuse EEG* testing for other disorders and not necessarily for epilepsy.

“We are seeing, if that, some persons who get trained in EEG, are using EEG for other things, that do not have to do anything with epilepsy. So, ADHD disorders, dyslexia, cognitive disability, psychiatric diagnosis, even migraine; all those are using, in some parts of my country, EEGs. And there is not a filter, for saying, no, that is not an indication for doing that, and you are misusing EEG” – **participant 2.**

THEME 7: Best pedagogy

The experts were very clear on their thoughts on the best pedagogy for EEG training. Of interest this question revealed two additional themes as well as multiple common concepts. *Apprenticeships* are pivotal for EEG training and this was reiterated by 12 (80%) experts.

"Apprenticeship is always the best way to learn, to do, and to work, and to have, the problems daily, and you will learn from your problems, from your mistakes, that you will do now, today or tomorrow, is the best way to learn" – **participant 6**. "You need apprenticeship to actually learn EEG" – **participant 14.** "You have to add, either, face-to-face courses, but ideally, shorter internships" – **participant 11.** "Practical training" – **participant 9.** "It's necessary to have on-site training, and in this sense, I am old-fashioned school, I think. You must have an intense training because EEG is a new language" – **participant 1.** "I think it is very important to do a face-to-face training, and one-to-one training. Because there are a lot of manual skills, that have to be trained and repeated, everywhere and every time, for doing really good EEG recordings" – **participant 2.** "It's very expensive, and almost impossible, try to train a low-income country, especially Africa, in person, it's almost, not achievable goal, if you don't have the resources. So, I think, if possible, an apprentice level, meaning, face-to-face training, should be part of the experience; so, a combination" – **participant 3.** "I think it needs somebody there, on-site, to help staff. Because it's so important to train teams to be able to get those EEG recordings, in the right way" – **participant 15.** "Where possible, I think there should be some in-person interaction. And this can either be, the trainee visiting an established centre, or say, an experienced trainer visiting a centre where there are several trainees for a period of time and having that in-person interaction" – **participant 12.** "When people do online, we try to pair it with some in-parallel apprenticeship, as well" – **participant 13.** "I think the way we have done EEGs, is apprenticeship, as students and registrars we will report EEGs, and other consultants will come in the evening, just about before we are leaving home; they would go over the EEGs along with us, and that was a good learning experience. And I, personally, believe face-to-face is always better than online" – **participant 7.** We have two or three face-to-face meetings, in our master's degree. And it's very important to have" – **participant 5.**

Online training revealed similar responses from 12 (80%) experts, whilst there were some mixed views, the majority felt online is not enough.

"Online, is interesting for theoretical aspects, on theory; it may improve things. I think this online system is something that a good part of pandemic. but only online training, will provide the superficial knowledge" – **participant 1.** "I think online training is very good. I don't think it's enough on its own" – **participant 15.** "I feel it's very useful to have a component which is online" – **participant 12**. "Online is not enough. online, you can learn all the theoretical aspects, but if you put them in practice, you may get a lot of troubles, more in children. It is quite different to do an EEG for an infant, than from an adolescent, or a person who has a different shape of his head. So, you have to be very, very well-trained in the technical aspects, and it is a practical point" – **participant 2.**

“With the caveat, that, I think apprenticeship and EEG could be done online” – **participant 4.**
“I think it should be a combination of apprenticeship modules, and they can be easily done online. I think we are going to do, actually, a course online, by the International League Against Epilepsy, we’re designing the module in Latin America. And modules that are online, can be structured in a way that are very practical, and can be some control; and we should use that technology, we should use it, because it’s less expensive” – **participant 3.**
“Online is not enough, not in the ideal world. We settle for online, when we have to” – **participant 13.**
“Online courses are excellent, and again, if you don’t have an alternative, then you can really make a difference, also, with the online courses” – **participant 11.**
“The problem with online, is that I’m sitting in my room, and trying to do it, and there are many competing interests, at least, in my mind” – **participant 7.**
“Absolutely, no We tried in our Masters Degree, our Masters Degree, it’s online” – **participant 5.**
“Online, is good to sustain the already known knowledge; in other words, my knowledge, to sustain this knowledge, to possibly, to go further, I may need the online. But to create a specialist by online, I think it is not possible, not practical, at all” – **participant 6.**
“I know I have tried to have some of skill proof, in online one; it’s not enough. You have to have someone in your side, who show you things, who help you to place correctly, the electrode. I think you have to have someone on your side; it’s very important”– **participant 10.**

Nine (60%) experts felt the combination of *apprenticeship and online* was profound for re-inforcement of EEG knowledge and training.

“I think this is two mandatory parts of the training” – **participant 9.**
“I think it has to be a mixture of apprenticeship and common didactic” – **participant 7.**
"It has to be done in a mixed manner, but always, always, there should be a face-to-face, essential training” – **participant 2**.
“I think, both apprenticeship and modules” – **participant 10.**
“You need both” – **participant 14.**
“Both” – **participant 4.**
“This is possible with, both, e-learning, and I think it needs somebody on-site, to help train, in person, ideally. I’ve now tried to do that over telemedicine, but maybe that’s possible” – **participant 15.**
“Both” – **participant 13.**
“Well, ideally, you would need both” – **participant 11.**

The sub-theme, *modules*, revealed six (40%) responses and whose concerns were expressed about limited practical exposure only using modules for learning EEGs.

“Practice is very important. Theory, alone, theory course, alone, is not sufficient” – **participant 5.**
““You have to have theoretical training” – **participant 9.**

> “We have developed a neonatal EEG e-learning course, which is free, it’s available for anybody who wants it; but it’s just, basically, all the basic principles of neonatal EEG, but you still need some hands-on experience” – **participant 15.**
> The modules can give you didactic teaching” – **participant 14.**
> “If competent by, modules, you know, to lighten the dark picture, will be very, very good” – **participant 6.**
> “There are extremely good EEG courses, these days, available at the ILAE Academy. As well as the Cleveland Clinic, they have about one month of EEG training. So, I think it helps to have a formal module” – **participant 7.**

Two (13%) experts found that *continuity of training* was important with frequent follow-up’s and learning was reinforced by daily EEG readings.

> “As you know, you are doing your neurophysiology fellowship, which takes one year, probably, for us to train to recognise patterns, and we continue doing it almost every week, if not, every day of our life; so that’s how we build experience, and that has been the problem with EEG. We may train somebody with a module, we may train somebody apprentice, but then we don’t follow on them, and that would be important” – **participant 3.**
> “I don’t think, apprenticeship or modules are not so important; just read lots of EEGs, is the most important thing” – **participant 8.**

Lastly one (7%) expert found that a *flexible teaching method* would work best for their country.

> “I would support a hybrid way of training, and this is really speaking to us, specifically, in Africa. We don’t have many people to train, so you can’t expect everyone to have in-person training exclusively” – **participant 12**.

THEME 8: Assessment

Assessment methodology produced two new aspects to positively impact training from one expert. There were significantly mixed views on *exit exams* from 12 (80%) experts.

> “I think there needs to be a baseline exit exam, to say, you’re now a qualified interpreter, particularly in resource limited settings, where there’s not a lot of regulation around that. So, I think there should be something there, to say that they are actually certified” – **participant 4**.
> “The exit exam will do, for a short time, and he will, then, try to forget, try not to go through the knowledge” – **participant 6.**
> “You have to assess their theory aspects, that can be done by a written form, like exams. But I would not let it, with a final exam, and after that, not doing anything; it is not advisable” – **participant 2.**
> “I think an exit exam is very helpful, because, without it, people don’t reach a certain level of expertise; it’s important to set standards” – **participant 14.**

“In Japan, just exit exam is necessary to read EEG” – **participant 8.**
"In Denmark we have a checklist with around sixty items, this is very resource demanding, because you need lots of tutor time to do this assessment, so, the alternative could be, just taking an exam” – **participant 11.**
“The way I would envision it, would be to have exams, but to do them as levels. So, to generate or develop a curriculum, where you’ve got, say, level one. So, at level one, you acquire these skills and have an exam. Then you acquire level two skills. So tiered exams, maybe say, every six months, or every year. I think that might be a more practical way of doing it” – **participant 12.**
“Exams, I feel, put people under too much pressure” – **participant 15.**
“There is very similar to the exam that you have for board certification; the exam works like a learning process” – **participant 1.**
“Exit exam is important” – **participant 10.**
“As students, we always tend to really read and study when we have an exit exam” – **participant 7**.
“We need to have writing evaluation” – **participant 5.**

Eleven (73%) experts supported *continuous assessment*, however, some felt having a mentor or doing the assessments themselves would be more beneficial. There was contradiction in one expert whom felt continous assessment would not work in their setting.

“To have someone in his side, who help him to understand, to go through the difficulties, maybe, this kind of interpretation of EEG, every day, can be taken like a continuous evaluation. I have someone with me, who can help me to go to EEG, to see my own difficulties” – **participant 10.**
“I feel that continuous assessment can be quite difficult. it might be difficult to continuously assess someone, especially if they are distant from the trainer” – **participant 12.**
"There has to be a continuous assessment” – **participant 7.**
"Also, practical evaluation” – **participant 5.**
"Continuous assessment is the best way to know how effective your teaching process is. And then you can correct possible mistakes. My mistakes, when I am teaching, and your mistakes, when you are learning, or our mistakes in our language, how I am expressing myself, are you understanding what I say?” – **participant 1.**
"You have to look of the continuous sustained maintenance of skills, that should be done on a practical point of view; I would suggest every two years, something like that exam. It’s better if you go, so you can see what they are doing, what is the unit over there, and to see how they do that. And you can get a certificate that you are doing the things good, or that you are not doing the things good” – **participant 2.**
"Continuous assessment is the best way possible” – **participant 6.**
“I think, always, continued education is important” – **participant 4.**
“I think you can determine a lot, from continuous assessment, so that would be my preferred method” – **participant 15.**
“Beyond that, ongoing review can be helpful, like continuing medical education (CME)” – **participant 14.**
“The continuous assessment is totally important. That’s a problem, totally a problem” – **participant 8.**

Only seven (47%) experts felt both exit *exam and continuous* assessment was important.

"I think, in both exit exam and continuous assessment, very important" – **participant 8.**
"Both" – **participant 13**.
"I think they are both valid" – **participant 1.**
"I think it's a mixture of both" – **participant 7**.
"I would say, both, as well" – **participant 4.**
"I think, both" – **participant 2.**
"Both evaluation" – **participant 5.**

One (7%) expert stated that *pre and post testing* was important to test knowledge and learning. The same expert also felt that collaboration was imperative for the personnel or groups that are going to be trained.

"I think, a pre and post-test examination should be mandatory, for multiple reasons. Number one, you can assess background knowledge. And number two, you can assess interest and learning experience, from the trainees. So that's important. I think, it should be in every course" – **participant 3.**
"I think, what we need later, each has to support the groups, support them in a practical way" – **participant 3.**

THEME 9: Critical skills

The most important critical skills the experts emphasised was *basic EEG training* covering pattern recognition and interpretation skills, this was mentioned by 13 (87%) respondents.

"To distinguish normal, or normal variant, or other mimicking normal variant, to discriminate it from the abnormal finding; because that is very important, I think" – **participant 8.**
"Gaining the skills to read and report routine EEG, accurately, would be a primary goal" – **participant 14.**
"The interpretation of, of course, no doubt, age appropriate, normal findings, abnormal findings. Non-epileptiform abnormalities. And, last but not least, artefacts. if you have to add paediatric EEG, I guess it's the maturation of the EEG, which is extremely important. And that is something which most of us, as adults, we are not able to appreciate; and that is where we have the maturation of EEG, that's where we all have problems" – **participant 7**.
"I think that the medium is that, for the doctors, they have to be able to interpret an EEG on awaken and also on sleeping. They have to recognise the patterns of EEG. Be able to see if there are some epileptic patterns, or not. And if there are some serious pathologies, or not. If they can give some criteria for the medical treatment" – **participant 9.**
"In our setting, I think that people need to recognise ominous patterns in inpatients, so those can, appropriately, be managed. So that if there is a delay between the formal

reader being able to see that - which is not uncommon, because lots of our readers are in different time zone" – **participant 13.**
"The critical knowledge, at least, to be able to interpret an EEG; at least, to be able to report EEG. we want safe interpretation, safe reporting" – **participant 6.**
"The EEG training must be comprehensive, and in that, knowledge is necessary for epileptologists and neurophysiologists, everywhere. We must speak the same language" – **participant 1.**
"I think, recognising the basic aspects of EEG reading. Again, looking at what is normal, and that's not an easy task. As you know, paediatric neurology, an EEG features, they are changing every time. Modules have to be designed, with that in mind and same with abnormalities, or the different syndromes, basic syndromes, that are important to recognise" – **participant 3.**
"In terms of interpretation, I think there needs to be some basic interpretation, recognising seizures, recognising artefacts that mimics seizures, and how to eliminate major kinds of artefacts" – **participant 15.**
"To understand the role of EEG, so, that they can interpret artefacts, adequately, to that extent, if the neurophys, you think they need, and then they should be able to read routine studies and understand normal versus abnormal" – **participant 4.**
"The second thing would be the ability to report a routine EEG. So, for me, for a centre starting, I would really focus on routine, a standard EEG, before going to complex types of EEG acquisition" – **participant 12.**
"'Must know', EEG patterns. But basically, you have patterns from normal EEG, that you need to know, and of course, here comes the influence of age, and then both wake and sleep, normal patterns. Then you have the abnormal patterns, inter-ictal/ictal patterns, and then you have a long list of artefacts and normal variants" – **participant 11.**
"To have interpretation, at least, for the most frequent epileptic syndrome" – **participant 5.**

Seven (47%) experts emphasised the importance of knowledge of *EEG practical skills* inclusive of electrode placement. Application to knowing how to record an artefact free EEG was indicated as being an important theme.

"This is, for the specialist, the child neurologist - I would say that they need to understand how EEG is performed" – **participant 4.**
"I think, for me, would be, how to set up an EEG laboratory, and then, also, how to acquire an EEG properly. So that is one of the first things" – **participant 12.**
"So now, while doing EEG, perform it, have a good EEG recording, and be able to do the proper manipulations, according to the clinical context" – **participant 9.**
"Just for EEG electrode application, understanding, and I think, what we'd need to be able to do, is to apply EEGs in the right way, be able to get a good quality recording. Things like, how to set up a system, we all know, a lot of people can record EEGs, and they have all the filter settings wrong, or they have the settings incorrect; just basic principles of recording" – **participant 15.**
"I imaginate a unit of EEG lab, the person who will be inside, have to be able to place the electrode, to identify, how to start the machine, to entry patient data, to initiate the record, to be able to make an activation, to be able to identify artefact and correct them" – **participant 10.**
"We need to be able to know the technique of EEG" – **participant 5.**

“I think, in paediatric EEGs, we need to begin with the EEG lab, and how to set up electrodes, how to, in very young children, how to adapt the montages. So, setting up the electrodes, making the child comfortable. I think it’s important that the clinician should also have a fairly good idea about it, and, again, that is not just by going to the EEG lab, and just watching, but by doing some of the work themselves. So, I think, all of those things are extremely important, and that would be the first level of critical skills” – **participant 7.**

The general *understanding of abnormalities* and how to react to conditions that can have an impact on the child’s development if there is a delay was another sub-theme that emerged in three (20%) experts.

“We have to emphasise main critical aspects, such as background abnormalities, variants, pitfalls, and epileptiform patterns, interictal, mainly, not necessarily, it is more complicated, but I think that the training must be the same” – **participant 1.**
To identify, also, the epileptic activity, and then to give an answer to the person who sent you the patient, for EEG” – **participant 10.**
“If you’re talking about the non-academic non-epileptologist - to recognise, even amongst outpatient patterns, those that treatment matters a lot, so, a hypsarrhythmia pattern, for example, please don’t miss that, we need to get onto that quickly. You would want to make sure that they could make the distinction between idiopathic epilepsies and localisation related. So, I think I would focus on those where we have treatments available, and recognising those patterns, have an implication for treatment” – **participant 13.**

The *lack of experts* was a recurring sub-theme.

“We do not have a lot of people that are interested in teaching it. The most critical barrier, is to have the persons that can give all the training, but if you have, that’s the most important point, if you do not have, you cannot do anything” – **participant 2.**

THEME 10: Re-enforcement of skills

Seven (47%) experts found that *continuous assessment* was the mostly likely way to re-inforce concepts already learnt.

“I think that’s extremely important, because the human mind is trained, as such, that it keeps forgetting what it does not do, often. And there is always the need for continuing EEG education, just like you have continued medical education, so it is extremely important” – **participant 7.**
“I say that it’s, for the doctors, I think that they have to keep being in training. Continuous training keep in the exchanging with colleagues. And for technicians, it’s daily, for technicians, it’s a daily process” – **participant 9.**
“In some countries, there’s absolutely no mechanisms to make sure that the competency is kept on the same level, or perhaps, also, improved. In some countries, you need to collect a continuous medical education point. very difficult to say. I think the minimum requirement, is that you are active within that field, and you collect some CME points” – **participant 11.**

“I think, practically, in our situation, it’s more, continuously working together, so that everybody keeps their skills up. I think, also, if you’re involved in training the next generation, you’re pushed to keep your skills up” – **participant 13.**
“It depends on the person and depends on where the person is work. If it is in private, it is very difficult to follow them. And if it is in hospital, it is easy, because especially if they are in the academic hospital. So, we have continuous training and continuous seminar” – **participant 5.**
“There could be CME credits, for ongoing attendance at didactic modules; that’s probably more practical and realistic. So, I think, more practical, would be to do didactic CME” – **participant 14.**
“Continuous assessment, and the CME hours may be helpful, in that respect. But it is not easy, really. It’s one of our problems and challenge, also, and not only in our field, but even in the fields of other specialities” – **participant 6.**

Six (40%) experts felt that *theory assessments* were important to keep the knowledge and understanding of maintaining skills post-training, irrespective of format; exams/survey’s/quizzes/evaluations or projects. Not all countries have the tool for re-examination.

“We do not have any periodic evaluations, at least, in India’s instance” – **participant 7.**
“In other countries, you simply need to sit a new exam. But again, one can also consider having an exam specifically for this” – **participant 11.**
“It would be nice if people had to do some maintenance or certification for that, whether they reset an exam, where they have a series of online quizzes that are timed, that they’re expected to do. But if someone’s practising in isolation, I think some sort of pragmatic assessment that is timed, then, that is linked to their certification, would be helpful” – **participant 13.**
“I would say that, for continued certification, so there should be a certification, in every – I don’t know - three to five years, they have to, then, submit and show that they are still able to read EEGs, across the lifespan, with good accuracy” – **participant 4.**
“I would suggest doing a follow-up exams or surveys from the theoretical point of view to technical point of view” – **participant 2.**
“Sometimes, you have to you gather technicians from our own laboratory, or the laboratory of Dakar and other regions - so project is to find time to gather them, and to teach, in order that things that have been what have been acquired, will be preserved, so that they don’t forget all what they have learned, and so on” – **participant 9.**

Five (33%) experts found that *collaboration* with previously trained colleagues was Powerful in re-inforcing skills. However, one expert found that collaboration was lacking and needs to be implemented.

“You have a good model in South Africa. I think your bi-weekly meeting online, is a good one. . But I think that that’s something, in this meeting, you have a different level of participant, you have a very experimented person, you have the new one. you can find, in this group, someone who is most new than you. So, it’s a mixed group, which, each one can, with his case, and we can debate; during this discussion, you talk to all the questions,

which are very important, to sustain your knowledge, to sustain your lab. I think this kind of meeting is very important for the sustainability" – **participant 10.**
"I think, one thing that would be useful, which I observed, that you are doing at Red Cross and the University of Cape Town, is where you've got people who have trained with you, but then you have regular interactions with them, like regular meetings. And I feel that, that way, it can be a way of monitoring by the trainers, and also a way of ensuring that the people who were trained, are keeping up to date with what they are supposed to present. So, I feel that's quite a useful way of doing it, having regular interaction" – **participant 12.**
"I think we're lacking in our societies, in our collaborations. Usually, the collaborations are high to low-income collaboration, but that doesn't mean that we may have low to low-income collaborations from countries. And I think, the model, I have ambition, is a model where the institution is engaged, and there is a formal schedule for trainees, to have that time devoted to help the other countries. So, institution has to be very supportive" – **participant 3.**
"If they could bring their case more often, or if we had some online meetings, this is something that, after a question, I was thinking about, to discuss their case. I think that we could help them more, and learn more, as a group" – **participant 2.**
"I think there needs to be, maybe, regular update sessions. And it could be just something like every six months, that you would say, for training, they review the online module that's developed. Because I do believe an online module is very beneficial; that could be your update" – **participant 15.**

Only four (27%) experts found *conferences/workshops and face to face meetings* useful. One (7%) expert felt lectures failed to impact skills.

"I think the EEG conference in the institution; or now we can use a website like this. So, EEG conference is, I think, the best way to sustain the maintenance of the skills" – **participant 8.**
"In the international side, we have some webinars, we have some training, some non-diploma but some certificate, or participating in congresses, or workshop. So, I think that it would be very interesting for them to keep in these kinds of trainings. It's maintenance if you can say" – **participant 9.**
"Some of the time, if there is a possibility to go to the physical meeting, like a congress, that also could be fine; or workshop, that can be fine" – **participant 10.**
"For our students, we try to have, example, a course, per year, and to invite all the students, all the previous students too; and also, for our face-to-face meeting, we usually invite previous students from previous promotion" – **participant 5.**
"Teaching currently, I think, with a limited number of participants, during conferences, is one way, because a child neurologist, epileptologists, attend conferences. We had this experience last year, and the Epilepsy Conference, we create some workshops, and they could review their concepts. Also, we had some case discussions, with no more than thirty people. Hands-on, courses for those with training; and again, online, cases, we can discuss that. They are all valid instruments. But what I don't believe, that works, is, lectures showing EEGs for large audiences; I don't think we teach something, only the basics" – **participant 1.**

Lastly two (13%) experts promoted that *site visits* would be beneficial to sustain maintenance of skills post training.

“I think what it needs to be, is, I think there needs to be constant update sessions, with sites, I do think; because it depends on the site, sometimes they will see a lot of children, and sometimes they may have very few; and if they’re in the situation where they have very few skills unless you’re doing it all the time, it is difficult to keep skills going. Because, even when it comes to operating the machine, I know people forget how to use an EEG machine, if they don’t use it all the time” – **participant 15.**
“If it could be done in a practical point of view, it should be done. I think we should go to the places where EEG are done, and not expecting they’re coming to us to the cities. First, to ensure that, what are they doing, it’s there; with what kind of EEG recorders are they working; how is that unit and assessment at all; and looking what they are doing in their own place. That will give you a real local aspect of what is being done” – **participant 2.**

THEME 11: Training model

The final question on how one would promote better EEG training in SSA, interestingly but not suprisingly revealed many different opinions thus creating the most sub-themes. One of the clear messages that stood out was *training* for both specialists and non-specialists from six (40%) experts.

"To create, or, say, build competence, good competence for the specialist, and not to create the half education. The half education is always dangerous” – **participant 6.**
"My experience has been, when you train the teams, they’re so diligent. Once they’re trained, were very committed to ensuring that they got good quality recordings” – **participant 15.**
“To train leaders in each country, is the best way to propagate knowledge or EEG reading” – **participant 8.**
“I think we should also promote, is training trainers. So, when we’ve got people who visit centres which are established, and they’re trained, I think we should encourage and promote that they then go and train the people back in their own home countries” – **participant 12.**
“For our neurologists, like me, they do not have to be afraid by EEG; it is a science, like other science. And if they want, they can go, and they can become great EEG interpreters” – **participant 10.**
"I think that the main difference that I see, comparing the high, middle and low income. Middle and low in one group, and high, is that they have a non-medical staff that is better prepared, and it’s so helpful. So, for sub-Saharan Africa and Brazil, I think that we have to pay more attention to this group, in particular, and for epileptologists and neurophysiologists. As I said, we must raise the bar and we must have the same training, all” – **participant 1.**

Five (33%) experts indicated that *online or apprenticeships* would be useful.

“The establishment of apprenticeship time, either specific training, either epilepsy fellowships, would help for neurology candidates, so that they can learn EEG. Or dedicated time, like a three month or six-month epilepsy rotation, where you could learn the skills. And then, a dedicated EEG exam” – **participant 14.**
“If you want to talk about real training skills, I think we’re doing a pretty good job of selecting people, having them go do proper training on site, in the meantime doing online,

etc., and I think, just making more of those opportunities available, will be helpful, as we have more and more people who are able to take advantage of that" – **participant 13.**
"Online courses, combined with annual face-to-face training courses, would be an option" – **participant 11**.
"I think there's a lot of utility in online and distance learning programs, in our region, where we don't have enough teachers. So, I think promoting that, in as many countries as possible, is very useful" – **participant 12.**
"I guess the only recommendation I would have, would be to use as many multi-modal types of learning, to have, online. I know everybody has mobile phones now, particularly in Africa; they seem to be just everywhere. And I think, to make the training available, ideally on an app, or a phone, or a tablet, or something, that that training could be available" – **participant 15.**

Four (27%) experts emphasised that *standization of teaching/training* should be the same with different languages and income countries.

"I think we have to recognise them with a certificate that make them feel that they are going to have something that is valuable" – **participant 3.**
"We have to remember that EEG is the same, everywhere. So, considering that's the same everywhere, we may have fewer reserves in sub-Saharan Africa or in Brazil, but it does not equal less knowledge, or training, or strength. For example, I learned, as I said, EEG, in a high-income country, and the training here, middle income, is exactly the same" – **participant 1**.
"French speaking countries, in which, the value of the interpretation in EEG, are different from the English-speaking countries. We have to standardise, and then determine our program, and the content of the program, which will be the same for everybody. That, also, is very important" – **participant 10.**
"I'd like to see, if not continent-based, or regional-based, a little bit more than just country, of a standardisation and credentialing. I think that is a limiting factor in a lot of sub-Saharan Africa, that if you're not for a specific type of training program, you can't get qualified, because we try to do it whichever way is acceptable. But if there is a standardised exam process, at least we know there's a unified kind of end to it" – **participant 4.**

Some countries have issues with *non-neurological personnel* misusing EEGs. Lack of training and knowledge of interpretation EEGs can lead to mis-diagnosis which is detremental for the patients especially paediatrics indicated by two (13%) experts.

"In India, there are a number of non-neurologists, who would set up an EEG; so they would be psychiatrists, so, in their practice they will, probably, do EEGs. And I think that is where the huge standard deviation comes in from, in terms of the standards of reporting" – **participant 7.**
"In our setting, the Medical Registration Council needs to start monitoring who's allowed to read an EEG. Right now, every …… who can get four-channel EEG and a piece of paper, is setting up a private practice facility. We have an issue, in Zambia, that we need to start regulating who's allowed to charge for EEGs. But in terms of improving services, we're at a place where we really need regulators to shut down some of these charlatans who are

making a fortune and hurting patients, and they really are hurting patients" – **participant 13.**

Two (13%) experts illustrated that *continous assessment* was important.

"To have more seminars, and more workshops, in our Congress, in Paediatric Congress, Neurology Congress. It's very important. And to include EEG training and interpretation, as a course, and a pre-Congress course" – **participant 5.**
"To assure, the continuous assessment and the CME always" – **participant 6.**

Two (13%) experts felt *teachers* need to make the subject more interesting to get more people trained.

"For our teachers, I don't know of all the supervisors, which already exist in our country, they have to begin - I don't know how to say - they give a half-image of EEG. When they want to show EEG, they have to make it more soft, they have to say to the students, that it is something which is accessible for them" – **participant 10.**
"You are very well involved, but very, very interested in learning this. But if your teaching is qualified, but maybe, authoritative and strict and, otherwise, maybe you will lose your interest in doing that. So, it's, without losing quality, how to close human relationships. That's, I think, the most important fact, to get persons interested in, in sub-Saharan Africa, and everywhere" – **participant 2.**

Similarly, two (13%) experts felt that *policy makers* should consider making EEG training separate from epileptology and highlight the benefits of an EEG service in assisting patients.

"For our authorities, which is the university and also the government - they have to separate EEG trainings from the epileptology, because EEG is very important, it can be a part of EEG, if you want to have people who will be very good in capacity to interpret EEG in the future. Yes, of course, EEG and epileptology goes together, but if you talk about the training, they have to be separate. That's my most important recommendation; separate" – **participant 10.**
"First, at least, to say, make it a priority, to prioritise the awareness of EEG services importance, among the policy makers. I have to put in the minds of the policy makers, that EEG is a priority, EEG services, because it's important, because it is needed, because it is a new field which we will have to go through" – **participant 7.**

Two (13%) experts indicated that in SSA *local leaders* need to be involved and trained in a language that would make sense to them.

"You can have the best intentions, if there's no engagement of the local leaders, there is no way to achieve your goals. You have to understand that local leaders are very busy, clinically; sometimes, there are, number one, only one paediatric neurologist in the country. Number two, they are overwhelmed with clinical things, to sit with you and have these courses, it's very difficult for them. So, understanding that, we can design, I think, models that can adjust to data schedule, and can cause less interference with their clinical flow" – **participant 3.**

"A lot of people think, okay, all these electrical points, all these situations of interfaces, and the milliamperes, and so on, those are not languages that clinicians, or people engaged in healthcare, are used to. So, if you can explain that, in a regular, simple fashion, you are closing those barriers and closing those gaps, and getting, maybe, more interested people. And the other point is, how to learn to get involved in the local necessities, and to understand that local necessities, and to adapt my training in a qualified way, to those local necessities. The way you can make it in another part, because the location is quite different, and the languages, and so on, are quite different" – **participant 2.**

Collaboration was a sub-theme that arose previously.

"I think they are going to commit, knowing that they are going to be supported, on an ongoing basis, by that institution" – **participant 3.**

One (7%) expert's approach to this question was *finding a gap* and how one can assist in fillfulling this concept.

Promote it; I think that, do evaluation on the field, like what you are doing, an evaluation of the situation. What the situation, right now, which are the gaps, and try to fill it, to increase the level. Where the bases are, or where there's, try to enhance the level to reach the goal of the developed countries; it's the main goal. It's not for tomorrow, but I think that if we try to move, it will be done one day" – **participant 9.**

THEME 12: Recommendations

Twelve (80%) experts took up the option to provide additional information at the end of the interview. The main sub-theme was *EEG interpretation training*.

"We are trained in institutions that are training child neurologists that are going to go and work in low income countries, we should make emphasis, from the get-go, since we are training them, having a focus on EEG for them, and they can learn EEG, actually, while we are training them, because once they go to the country, they become busy. And I think that's how we, also, fail. I think we have to go to the root of the problem. I think, we're trying to create models based on what we have in high income countries. So, and we should have a goal, in institutions, that help training doctors working in poor research areas, to train them, from the beginning, in EEG. And if we can do it, if that's, also, a resource available, they should be trained, an extra year, in EEG and clinical neurophysiology, before going back to their countries" – **participant 3.**

"I will end by saying people have to work in workshop. I think it's easier for a sub-Saharan country to try to improve, by implementing what is done in another country, than to try to reach, directly, what is done in the United States. By changing their experience, I think people can little-by-little, step-by-step, can reach some levels that will ensure the fact that they are really progressing" – **participant 9.**

"It's a little cycle of knowledge, so perhaps we should, considering your questions, and thinking about providing a better training for child neurologists, in general, and for non-

medical staff, about key aspects. But, again, all epileptologist is the same everywhere" – **participant 1.**
"I just want to suggest that there are other alternatives for non-expert readers of EEG. So quantitative EEG, can be helpful for non-expert physicians to detect seizures, in a critical care setting. We've used that in our hospital, and it's been very helpful" – **participant 14.**

Three (20%) experts supported *research* and what the researcher is trying to achieve in SSA.

"Some significant gaps that we must address, in my opinion, are non-medical staff, as I mentioned, usually they are unprepared to obtain a high-quality EEG recording, if they don't have a very close supervision" – **participant 1.**
"It's very important that the project that you are doing, and important to collect everyone's views, so that we can actually have a strategy of how we can improve electrophysiology training" – **participant 12.**
"I am very supportive of this, because it is something that I do think we need to try and make sure that EEG management is possible, in any setting, I believe, if the training is delivered in the right way; and it needs to be adapted and tailored to different settings. The teams are there; they're well able to do EEGs. And I think we need to just, maybe, support a bit more, with the use of telemedicine, and use remote monitoring, to help support interpretation, until the local staff are fully trained" – **participant 15.**

An EEG can provide answers in the diagnosis of epilepsy, however, it can be *mis-used* because of its limitations.

"We also need to make people aware of the limitations, at least, in the interpretation of EEG. And the expectation, often, is that, if a patient is sent for an EEG, we would provide a diagnosis, a treatment, and the epilepsy would be perfectly well-controlled. So, I think that is also a very important message that needs to be conveyed. Where, is it really necessary that EEG needs to be done in every child? And every time the child has a seizure? Or every so often, in paediatric practice? So that is also something that probably needs to be clarified. And that is also something that needs to be communicated to the practising physicians" – **participant 7.**
"EEG is frequently misused, and it is misused, because the indications are done for other kind of things, and because a lot of people are not well trained, and make EEG reporting's, in a very bad way. And in that, I think we should protect EEG training, EEG doing, everywhere, in a good, qualified manner, and with strict criteria for doing it. People should know, what is the indication, what is the technical aspects, what can you expect, and what, maybe, you should not expect, from an EEG, and how to make a good Interpretation of the EEG recordings" – **participant 2.**

Patients in some countries undergo EEGs for inappropriate indications by *non-neurological personnel* seeking monetory gain.

"We have, a problem, in Arabic region–- possibly in yours–- there are non-competent people, who don't understand this field, but they are practising this profession, they are

practising EEG, reporting, EEG videography. But they are non-competent; this is a problem, because they are harmful. Not only the problem that we have no specialists, but we have wrong or non-competent specialists, who insist to work in this job" – **participant 6.**
"Places like Zambia. Patients are terrible judges of good quality, right? They go where it's accessible, and somebody who's putting ……. billboards up about their great services, may get sought out, who really shouldn't be allowed. So, for us, I think that's becoming the biggest threat to proper care for our patients, is just, for profit. I won't even say sub-par. There's no neurophysiology there; it's just a joke. Zambia has gotten enough middle class, able-to-pay, patients, that's evolved into a real challenge for us. So, until we address that, it's like the other problem that we have in our arena, in terms of trying to provide the best services for our population" – **participant 13.**

One (7%) expert felt that having a *standardised exam* is needed.

"I would emphasise that, I think there should be an exam basis, but not, necessarily, a standardised training, because I think that is a limiting factor in a lot of sub-Saharan Africa, that if you're not for a specific type of training program, you can't get qualified, because we try to do it whichever way is acceptable. But if there is a standardised exam process, at least we know there's a unified kind of end to it" – **participant 4.**

Lastly, the indication that *artifical intelligence* is the way forward was mentioned by one (7%) expert.

"I can see that most of the questions focused on training, let me reiterate that I can see a huge potential for including artificial intelligence-based apps, in the future, exactly in these under-served, or underprivileged areas" – **participant 11.**

CHAPTER 6 – Conclusion

Sub-Saharan Africa and South East Asia have the highest global burden of neurological diseases in children [71]. Many of these neurological conditions are the sequelae of prematurity, birth insults, trauma and infections of the central nervous system in children. The disability of children (5-14 years) living with this burden has increased during the last 25 years. This highlights the need for expertise in the management and diagnosis of these disorders in areas of the world where resources are limited.

Epilepsy is a frequent sequel to these neurological conditions. An EEG is an inexpensive tool to assist with the diagnosis and management of epilepsy. Special skills are required to obtain an accurate EEG in a child and experience is needed to interpret the EEG. Paediatric EEGs are complex, compounded by variance in brain maturation and the presence of common artefacts in moving or unhappy children. Accurate reporting is important to avoid misdiagnosis and unnecessary use of antiseizure medication. However, expertise is limited in under resourced areas of the world.

The overall aim of this study was to understand who performs and interprets paediatric EEGs in sub-Saharan Africa and to develop a pedagogical model to improve this service. The specific aims of this study were: - 1) to establish what paediatric EEG training was available and to review the literature relating to EEG training worldwide over a 30-year period; 2) to understand which practitioners perform and interpret paediatric EEGs in SSA and whether they have had training in paediatric electrophysiology; 3) to critique the paediatric online course constructed by the researcher in order to understand whether the participants found the information useful for their practice and lastly, 4) to explore the relevance and viability of training non-epilepsy specialists in SSA, by asking epileptology experts their views and opinions. These studies addressed the hypothesis that non-epilepsy specialists can be trained to fill the gap in performing and interpreting paediatric EEGs in low income and low middle income countries where there is a shortage of trained personnel.

6.1 Study endpoints and applicability

The four papers presented in the body of this thesis address these aims directly and are summarised separately here. Following this, a section on the strength and limitations of these chapters is reported and general conclusions for the whole thesis are discussed.

6.1.1 Systematic review

A comprehensive search of the international literature covering a 30-year period is outlined in chapter two, looking at the efficacy of curricula and whether they can be adapted or are applicable to resource limited settings. There was limited data and only 15 studies met the study question.

Two groups of practitioners were identified by the literature study: one group learnt to interpret EEG for diagnosis of seizures and epilepsy; the other group learnt EEG as part of their speciality. The former group was addressed in five studies, and the latter in the remaining 10 studies. Only two studies were performed in LMICs, and the rest were in HICs. Only one study was undertaken in paediatrics. The studies included a range of disciplines and types of clinicians (medical officers/paediatricians/neurology residents, neurologists/ medical students/ internists/ anaesthesiology residents/ critical care physicians/ fellows (pulmonary and neurosurgery) and ICU nurses). The sample size of the studies was small, ranging from one to 33, except for one report with 108 participants.

Curricula content varied and was not comprehensive for learning clinical EEG and study designs varied. A consistent finding was that whether training was given by a clinical neurophysiology technologist, or by an epileptologist, there was no difference in the outcome of training. There was a huge variation in duration of training, lasting from 10 minutes to 41 months. Training included face to face, (lectures and practical), podcasts, online, (handbook/program) and lastly an automated program. Furthermore, the EEG epochs used for training ranged from 10 seconds to 20-30 seconds and the total number of EEGs between 10 and 50. Most studies were performed on adult EEGs only.

Pre-and post-training assessments were performed by using either multiple-choice, by reporting EEGs or by online surveys. An important conclusion after review of the literature was that existing curricula have inadequate paediatric neurology content [52]. These curricula do have similar key concepts, and many could be adapted to create a curriculum to teach paediatric EEG in LMIC and HICs.

There were limitations to interpretation but also areas of generalisability of the findings in this systematic review. Firstly, the authors reported different curricula and methodologies used making the inter-study comparisons difficult. Secondly, reading full EEGs was more advantageous than reading epochs consisting of 10-23 seconds. Thirdly, some participants could have had EEG experience prior to training, compared to some who did not. Future studies are needed to evaluate current or existing training programs for adaptation to achieve consistency of teaching worldwide. This could lead to safer EEG practice and could fill the gap in Africa and other LMICs.

6.1.2 Electrophysiology services

In chapter three, we reported the results of a web-based survey of paediatric electrophysiology services and training, from 73 healthcare practitioners managing children with epilepsy in 18 African countries. The responses covered all levels of healthcare from primary/district/secondary to tertiary institutions.

Amongst the responses we identified two groups: those with access to an EEG machine and with or without access to a trained EEG technician, and those without an EEG machine and with or without a technician. The vast majority of respondents came from primary and secondary hospitals, who had no access to an EEG machine, technologist (66%) or neurologist in 52%, with only a handful coming from a tertiary setting. This reflects the provision of health care in the region, where most patients are managed in primary or secondary level centres and access to tertiary care is limited by the scarcity of such centres.

The demographics of the respondents were mostly general paediatricians (55%), followed by child neurologists (14%), adult neurologists (8%), other (7%) and some unknown (16%). We found some variability amongst the respondents, with older healthcare practitioners performing more EEGs (>100) annually than the younger age group (<100). Differences in number of EEGs (>100) performed with or without a neurologist in a tertiary setting (44% vs 0%) highlighted specialist utilization of EEG when a neurologist. However, this difference was not evident at a secondary hospital level (50% vs 60%) or in private practice level (76% vs 75%).

In the manuscript we reported that there was a lack of technicians and paediatric EEG training amongst healthcare workers working with epilepsy in SSA. This highlighted the need for an apprenticeship in paediatric EEG, which reached a 77% agreement amongst respondents. Three themed patterns emerged from the qualitative data responses in relation to how an apprenticeship would benefit the healthcare practitioners: - 1) "professional development will improve their skills and enhance quality of EEG interpretations"; 2) "better care so that they can make quicker diagnosis" and lastly 3) "help paediatric patients and neurologists by having a trained paediatric EEG technician who could assist by diagnosing emergency conditions, resulting in improvement of paediatric epilepsy management and increasing expertise by educating others".

Two issues may have compromised this research. First, there were 14 countries with no responses, the majority being LIC and LMICs. The missing data could have increased the knowledge of paediatric EEG training in SSA. Secondly, there was participant bias, as the survey was sent mostly to paediatricians (55%) who treat children with epilepsy in SSA, some of whom trained with the African Paediatric Fellowship Program (APFP) or visited the department for short attachments to increase their knowledge in paediatric neurology and EEG interpretation.

The most important finding of this study was the strong support indicated for an apprenticeship program, which will be developed as a subdivision of the African Paediatric

Fellowship Program, which trains Africans for practice in Africa [4]. Since 2008, the APFP has trained 12 paediatric neurologists from Africa, with an additional four due to qualify in 2025. The focus of the apprenticeship program will be on technician level skills training, equipping healthcare practitioners, such as nurses or medical officers, to assist the newly qualified paediatric neurologist to provide safe EEG practice in their country.

6.1.3 Paediatric EEG online tool

In chapter four we reported the results of a qualitative review of the efficacy of the researcher's online handbook. This entry level handbook was originally developed for healthcare practitioners in sub-Saharan Africa. It has been used as a resource allied to the International Child Neurology Teaching Network, (ICNTN), making it accessible across the world in both high and low-income countries. In this manuscript, we reported the responses of 50 participants (HIC=8, UMIC=16, LMIC=21 and LIC=5) from 25 countries, with the majority of responses from resource limited countries. Thirty-five of these individuals obtained a certificate after completion of the handbook.

The demographic findings of the respondents were mostly paediatric neurologists (46%) working in tertiary institutions (35) and with a female preponderance (56%). We identified that 47 respondents managed children with epilepsy but only 52% reported on paediatric EEGs. There was variability in their training ranging from < three months to 13 years with most having pre-training (20) through a fellowship program (12) followed by some online courses (11). Amongst the respondents, only three had training during their sub-speciality paediatric neurology registrar rotation.

The study included participants enrolled for the online handbook course over a six-year period (2017-2022) with a huge variation of completion time, ranging from under a week to eight months. The reason for delay was described as "busy schedules". There was equal representation across resource limited countries with the participants completing the handbook, however, only two were from HICs.

The validated screening tool, (Likert scale), was used to measure participants' opinions on the handbook. Our main findings in this paper were that respondents' experiences and opinions endorsed using the handbook. Prior experience varied amongst the respondents and 53% of them did not have any paediatric skills before using the handbook, with a higher percentage being those from LMICs. Eight themes with sub-themes derived from the qualitative data and a consistent positive theme was the ease of accessibility to knowledge of EEG interpretation provided by the handbook.

The study had potential limitations: - firstly, over half of the participants, (54%), failed to complete the survey, despite having consented and receiving weekly reminders over a six-month period. The additional feedback would have given better information about the use of the handbook. Secondly, pre-and post-testing was only performed in the pilot study and therefore the knowledge gained from using this tool was not objectively quantifiable [8].

This qualitative subjective study explored the usefulness of the handbook. Our findings in the paper are that the participants reported that they found the handbook significantly useful, both for their clinical practice and for the accessibility of the knowledge contained in the book. Our findings are consistent with a trend from the previous pilot study performed on the handbook [8]. The handbook supports this niche skills area, and the EEG curriculum is a successful tool to improve and increase interpretation skills amongst those treating children with epilepsy in SSA.

6.1.4 Expert opinions

In the three previous chapters, I have described the need for uniformity in EEG training; evidence of lack of paediatric EEG training for non-specialists and technicians, and the effectiveness of the handbook as a tool to learn basic paediatric EEG principles for performing and interpreting paediatric EEG. In this final chapter, I now describe the opinions of 15 experts from both HIC and LICs with training experience in the field of epileptology, on training non-epilepsy specialists in EEG interpretation.

The vast majority of the experts were either involved in teaching (12) and/or were advocates for the subject (3). The experts' demographics included (47%) paediatric neurologists, (27%) epileptologists, (33%) adult neurologists and (7%) clinical physiologists, (neurophysiologist), with 40% either working, (27%), or having some collaboration, (13%), in Africa.

The findings from the experts' responses using thematic analysis enabled identification of various themes arising from the interviews. These 12 themes and recurring sub-themes were further verified by the researchers using blind analyses. To ensure the validity of the findings we returned the key concepts to the experts in a two stage Delphi method to access consensus across the group. All experts reached an 80% agreement across the final themes.

There were more strengths than limitations in this study. Firstly, only one expert failed to acknowledge the invitation to participate; secondly, all experts were asked the same questions thus limiting bias; thirdly, the experts were similarly represented from both HIC and resource limited countries; fourthly, both the researcher and co-researcher concurred on the themes and sub-themes and lastly, the experts were all experienced in training and/or advocacy on the subject.

This qualitative case study including the Delphi consensus supports the training of non-epilepsy specialists to interpret paediatric EEGs. This will help to address the shortage of skilled paediatric EEG interpreters across Sub Saharan Africa. The single statement that did not reach consensus, (73%), related to concern around the conceptualisation of how this training would be implemented and sustained. We then explored solutions on training requirements involving committed individuals, institutions supporting infrastructure e.g. EEG equipment and lastly policies from national and regional levels acknowledging the need for this service. By addressing the above areas, we presented a holistic training system that not only meets the immediate needs of individuals but also strengthens the broader community and economy. Presently, our bi-weekly meetings at the Red Cross War Memorial Children's

Hospital (RCWMH) offer collaboration with prior and current trainees to promote these types of support for training and sustainability in skills attained. The researcher, via the APFP program, has been supporting the training of paediatric neurologists and nurses by promoting continuous teaching collaborations (bi-weekly meetings), as well as by being innovative in developing a program incorporated in the curriculum content of the researcher's handbook.

6.2 Strengths and Limitations

A clear need for formal EEG training has been identified and should be adapted for broader use, based on the lack of paediatric neurology sub-specialists in our setting. Lack of training has been reported across HIC and LMICs [52]. The work in this thesis further confirms the presence of this deficit and as it is based in our paediatric department, it has offered training support to many interested colleagues in SSA. Since initiation of this teaching program, paediatric neurologists: - n=8 local (n=1 in training); n=13 international (n=4 in training); neurodevelopmental specialists: - n=2 local (n=1 in training); n=4 international (n=1 in training) and n=11 paediatricians, n=1 adult neurologist and n= 3 healthcare workers from SSA have been trained in paediatric EEG theory and interpretation. To further address this need, "The Handbook of Paediatric Electroencephalography: A basic guide to paediatric EEG interpretation" was developed and later established as an online resource. This curriculum has been used for face-to-face teaching since 2014 and from 2017 as an online platform (http://icnapedia.org/vle/). From a broader perspective, there is currently only one person performing this type of work in a resource-limited setting due to a shortage of an experienced paediatric neurophysiology technologists in South Africa.

Putting the data together, what has this information told us? Together, we have addressed a broad range of aspects of teaching, and we have done this using four different methodologies which were appropriate to the questions asked. Overall, the study addressed EEG teaching fourfold; firstly, by assessing curricula. The EEG curricula we reviewed had limited and insufficient paediatric content, which made comparisons between them challenging. Secondly, we assessed the needs of people working in the field. A larger cohort of respondents would have added more to the information gained. We only had representation from SSA and could have extended it to all LIC and LMICs, as this would have given an indication of wider training needs. Thirdly, in assessing baseline knowledge, we could only capture the kind of knowledge gained. Despite many attempts to encourage them, the responses from many participants who completed the handbook were incomplete. The result of the study warrants replication with pre-and post-testing. Lastly, we successfully obtained expert consensus in these areas of training and/or advocacy across HIC and LMICs. For the sake of consistency, one person collected the data by asking the same questions. The same goes for the themes and subthemes, where blinded analyses were performed by the researcher and co-researcher for verification.

The study outcomes suggest it should be possible to design a curriculum to address the lack of paediatric EEG training and interpretation worldwide and not only in resource limited countries. The handbook covers all the key points needed for paediatric EEG training [64]. The intention of the handbook is not to create specialists, but to enable safe practice and to recognise emergency study findings i.e. to equip clinicians with entry point skills so they can achieve further experience if necessary. The sustainability of the program is supported and aligned with the African Paediatric Fellowship Program, which has been training Africans for practice in Africa since 2008 [13]. The purpose of the paediatric EEG training is to assist with improved management of epilepsy in resource poor settings, thereby reducing the risk of further neurological deficit.

6.3 Future directions

By establishing a paediatric pedagogical model, the findings of this research will have a direct impact on the care of children with epilepsy worldwide and especially in low-income countries, (Africa and southeast Asia), where there is a deficit of paediatric neurologists as seen below in Figure 6.1 [57].

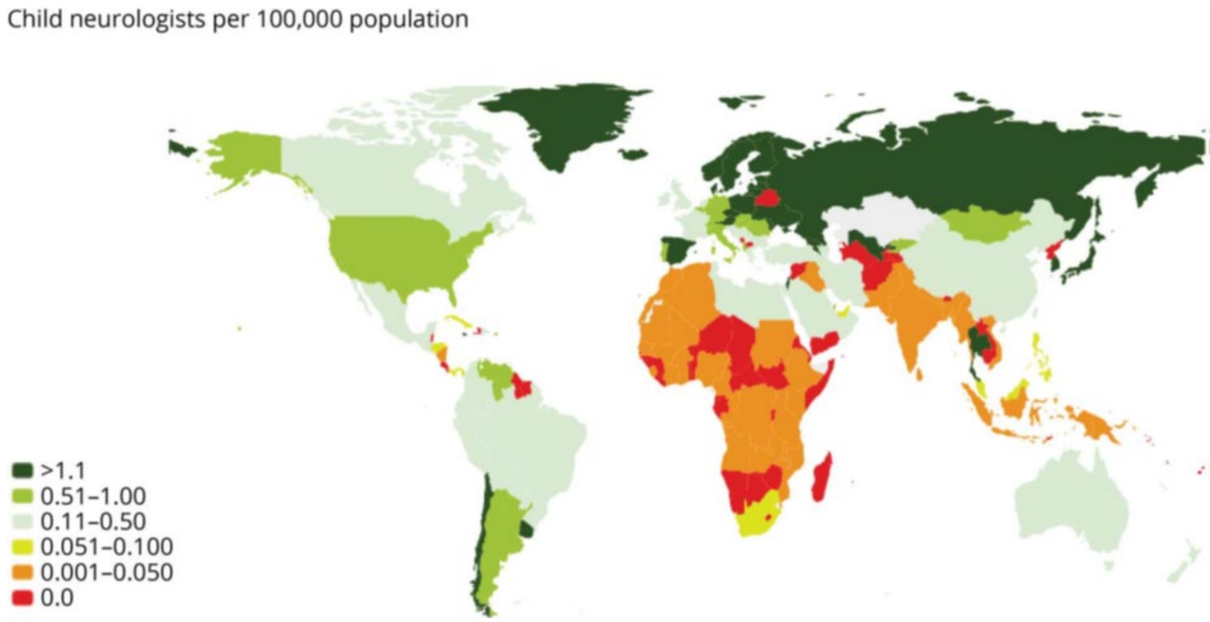

Figure 6.1: Child Neurologists per Country Populations Worldwide. [57]

EEG is a critical tool to aid in the diagnosis of epilepsy as it records electrical activity of the brain. However, specific training is required for the recording and interpretation of EEGs. Especially, in paediatrics, training can be complex owing to brain maturation and artefacts mimicking abnormalities due to the challenges of performing paediatric EEGs. Our findings in chapter two were unable to answer the question of whether there was an ideal curriculum for paediatric EEG training. However, there are future opportunities to work and expand on existing curricula, where key concepts include development of specific paediatric EEG training and working together with international collaborators. We have demonstrated lack of time amongst registrars as one of the most important barriers, but with the rapid advancement of technology, future teaching methods for training could include blended learning.

Expanding the understanding on how children with epilepsy are cared for in SSA, the evidence we found was that few doctors and technicians are trained in performing and reading paediatric EEGs. A reason for this is that there are inadequate numbers of training programs in SSA. This obstacle could be overcome as local training models can address the lack of skilled adult and paediatric neurologists in SSA (figure 6.2) [57, 72, 73]. This direction would enable better access to training for clinicians/non-epilepsy specialists and technicians in Africa in the paediatric field.

There is a model that has been devised and we can show there is change in practice with it. A curriculum on basic paediatric EEG training and interpretation is available. This curriculum has demonstrated both online and face to face that it is supportive for learning basic paediatric EEG and interpretation [8, 67]. In SSA, where there is a high burden of epilepsy, the handbook presents an exciting direction towards closing the gap for children with epilepsy. Another important project with the handbook will be to do both pre-and post-testing and to evaluate the participants over six month and one-year periods, which may further support the usefulness of the handbook.

There was a need for better understanding of the usefulness of training non-epilepsy specialists to fill the skills gap that reflects the current situation in LMICs. We wanted opinions from people who are highly invested and insightful in field. Fifteen such experts from HIC and LMICs who understood the challenges and the reality of the lack of skilled EEG personnel in SSA and LMICs participated. They fully embraced the need for adaptation of training and provided critical recommendations which were further critiqued to reach consensus among all participants via a two stage Delphi process. They were also insightful as to how clinical practice was expanding, adding further demands on practitioners and increasing need for training in this area. This again draws attention to the insufficient time clinicians have for EEG training. Although, our intentions are good, we need to advocate and be more proactive in training healthcare practitioners to empower them with the capacity to be able to deliver this service. The final consensus was supportive of training non-epilepsy specialists at a safe level of practice with the right level of support. The niche skill area of paediatric EEG is the specific role the non-epilepsy specialist will take on. However, a key concern was the expectation for the non-epilepsy specialist to maintain that level of skill without being capacitated to be able to do so. This was beyond the PHD to resolve but would be important to encompass in future work. We aim to roll out this EEG curriculum which is aligned with the primary healthcare curriculum developed by ILAE academy and the Intersectoral Global Action Plan (IGAP), to promote better care for people with epilepsy (figure 6.3) [70, 74, 75]. The study aligns with the objectives of IGAP: -

1) Objective 1 - Raise policy prioritization and strengthen governance – this study advocates for better care and providing safe practice for paediatric patients.

2) Objective 2 - Provide effective, timely and responsive diagnosis, treatment and care – our education and training in paediatric EEG would deal with not only pathways to care but the staff who would deliver the pathways to care.

3) Objective 3 - Implement strategies for promotion and prevention – we already have an established training program (APFP) in Africa for Africa and the paediatric EEG training would become an arm in the African Paediatric Fellowship Program.

4) Objective 4 - Foster research and innovation and strengthen information systems – rolling out the program and improving it by performing evaluations by assessing skills with (exams and continuous assessments) and lastly;

5) Objective 5 - Strengthen the public health approach to epilepsy – owing to the lack of qualified paediatric neurologists in LMICs, training non-epilepsy specialists mostly healthcare practitioners (medical/clinical officers) to improve epilepsy care in these regions.

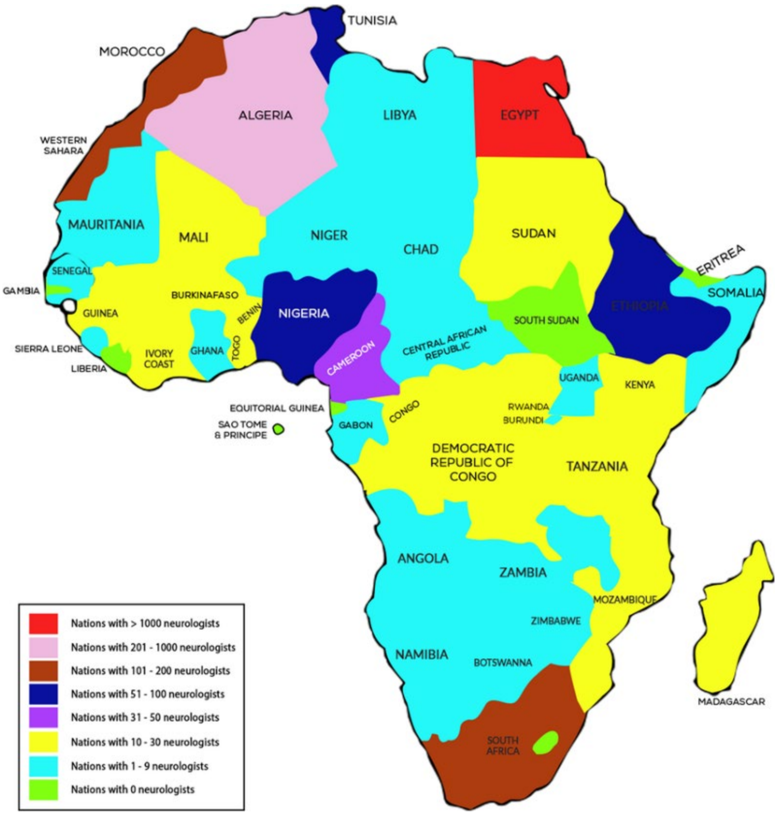

Figure 6.2: Map showing the number of available neurologists in each African country.[73]

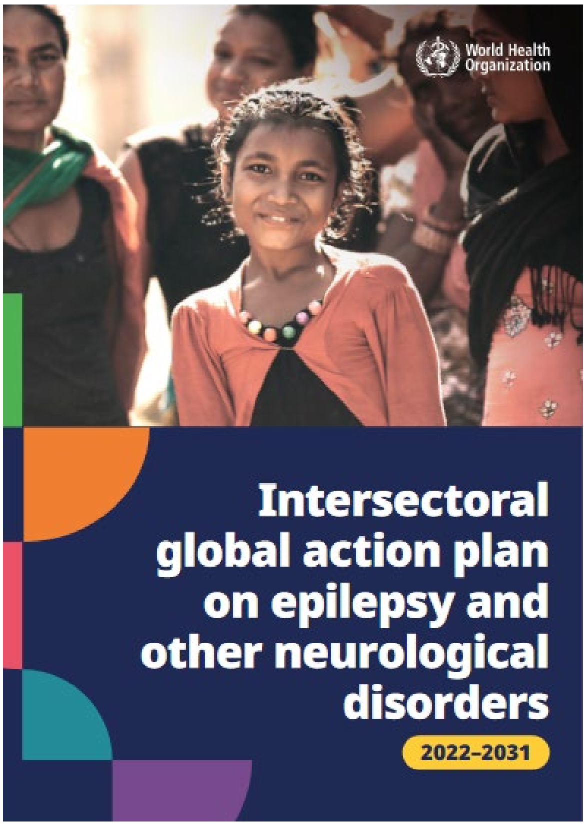

Figure 6.3: WHO Intersectoral global action plan.[75]

6.4 Conclusion

This dissertation describes the results of the first paediatric EEG research study looking at access to EEG services, EEG training capacity and curriculum models conducted in SSA. As such, this work makes an important contribution to the knowledge of paediatric EEG training and care on the African continent. The study outcome has emphasized insights and information which can help expand the training at a clinician and technician level and a program will be developed accordingly as an arm of the APFP. Future research and training in Africa, looking at optimising adult neurologist paediatric EEG skills and exploring tools to roll out paediatric EEG access will no doubt lead to improved epilepsy diagnosis and management. The use of podcasts could be a way to support and sustain access to knowledge gained. Neurochat, our bi-weekly EEG sessions hosted by the neurophysiology department at the RCWMCH, has been alluded to as being useful in monitoring the students' training. Using the infrastructure of the Neurochat, we could conduct research by looking at the outcomes of how the Neurochat impacts on the growth of learning. This can be used firstly, to check on the quality of the EEG recording (technicians/medical officers); secondly, with the paediatric neurology registrars in training, to critique their EEG presentation and how they approach cases and lastly to look at the variety of cases presented over a specific period. This observational type of learning will enhance EEG skills across different centres. In addition, new trainers can be added to the schedule for maintaining monitoring and sustainability. Further, the handbook will be revised, and new additions updated. The handbook will have quality checks with the users to ensure it stays user friendly and accessible for knowledge gained. As part of the post-doctoral activities in addition to developing the curriculum and updating the handbook there could be capacity to supervise master's students on aligned research activities. On the international front, it is hoped that this thesis will raise awareness and open further pathways for international footprints. This will lead to exploring avenues and engaging with the Intersectoral Global Action Plan, International League Against Epilepsy and International Federation of Clinical Neurophysiology.

6.5 Research Outputs

In addition to the publications included in this thesis, the study findings were presented at the following conferences:

6.5.1 Local:

Poster: A validation of a paediatric guideline on basic electroencephalogram interpretation for clinicians: A pilot study. Neurological Association of South Africa (April 2013), Protea Hotel, Stellenbosch

Oral (invited speaker): EEG- How can it help you! - relevance to EEG services in sub-Saharan Africa. 45th Annual UCT Paediatric Refresher Course (February 2022), Cape Town, SA.

Oral (invited speaker): “Curing epilepsy – yes, we can!” - relevance to EEG services in sub-Saharan Africa, Grand round, Red Cross War Memorial Children’s Hospital (June 2022), Cape Town, SA

Oral (invited speaker): Access to paediatric EEG training in Africa – relevance to EEG services in sub-Saharan Africa and online paediatric EEG handbook. International league Against Epilepsy Africa webinar (September 2022) - education and training.

Poster: Online paediatric EEG handbook: a survey on its usefulness – Department of Paediatrics and Child Health (October 2023), Annual Research Day.

Poster: Expert voices on non-specialist paediatric EEG training - Department of Paediatrics and Child Health (October 2024), Annual Research Day.

6.5.2 International:

Poster: A validation of a paediatric guideline on basic electroencephalogram interpretation for clinicians: A pilot study, 30th International Epilepsy Congress (June 2013), Montreal

Poster: EEG services for children in Africa: Pilot survey of capacity and needs 15th International Child neurology Conference (November 2018), Grand Hyatt, Mumbai

Poster: A Survey for EEG services in sub-Saharan Africa – 16th International Child neurology Conference and the 49th Child Neurology Association Meeting, (October 2020), San Diego, USA – virtual conference

Poster: Online paediatric EEG handbook: a survey on its usefulness – 17th International Child Neurology Conference (October 2022), Turkey, Antalya/ Annual Meeting of the Cognitive Neuroscience Society (March 2023), San Francisco, CA, USA

Poster: Expert voices on non-specialist paediatric EEG training – 18th International Child Neurology Conference (May 2024), Cape Town, SA

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Appendix 1: PES sign up (name and Email)

Sign-up (Name & Email)

Please complete your details to sign up. If you interested in participating in a research project about how effective this online handbook is on Paediatric electroencephalogram interpretation.

1) first name ______________________

2) Surname ______________________

3) email ______________________

Appendix 2: PES consent form

PES Consent Form

You are invited to participate in a PhD research study conducted by Veena Kander. The purpose of this research is to develop an apprenticeship training program for healthcare professionals from sub–Saharan

There are no known risks associated with this research. There are no know benefits that would result from you participation in this research. The records of this study will be kept strictly confidential. Research records will be kept in a locked file, and all electronic information will be coded and secured using a password protected file.

Your participation in this research study is voluntary. You may choose not to participate and may withdraw your consent to participate at any time.

If you have any questions at any time regarding this study, please feel free to contact Veena Kander at veena.kander@uct.ac.za or by telephone +27 021 658 5554

Please complete consent below.

Thank you!

---

1) I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.   ◯ Yes   ◯ No

Appendix 3: PES EEG services in sub-Saharan Questionnaire

PES EEG Services in Sub-Saharan Questionnaire

Dear Sir/Madam

As part of my PhD programme, I am undertaking a survey study to develop an apprenticeship training program for healthcare professionals from sub Saharan Africa in basic paediatric electroencephalography skills.

The aim of this study is to investigate and understand access to EEG studies, who performs and interprets EEG studies in Africa.

To this end, I kindly request that you complete the following short questionnaire regarding EEG services in Sub-Saharan Africa.

Thank you!

Participant Information	
Name of Institution	__________________________ (Please only fill in your institutions name in lower case)
Practice type	◯ Tertiary/Academic Hospital ◯ Secondary Hospital ◯ Primary/District Hospital ◯ Private practice
Please fill in your country	__________________________ (please only fill in your country)
Please fill in your age	◯ 25-34 years ◯ 35-44 years ◯ 45-54 years ◯ 55-65 years ◯ >66 years
Please choose your gender	◯ male ◯ female ◯ other (Please choose your gender)
Do you have a neurologist in your hospital?	◯ Yes ◯ No
If YES, what type of patients do they look after?	◯ Adult ◯ Children ◯ Both adult and children
If NO, who manages the neurological care of your patients?	◯ Paediatrician ◯ Psychiatrist ◯ Medical officer with an interest in neurology ◯ Combination of 1,2 and 3 ◯ Other
If OTHER, please specify who manages the neurological care of your patients?	__________________________

Do you have access to an EEG machine in your hospital?	◯ Yes ◯ No
Which department in your hospital performs your paediatric EEGs?	◯ Adult Neurology ◯ Child Neurology ◯ Psychiatry ◯ Other
If OTHER, please specify where your EEGs are being performed?	__________________________________
What is the waiting time to have an EEG performed in your hospital whether you have a machine onsite or not?	◯ < 1 week ◯ 1-4 weeks ◯ 1-3 months ◯ 3-6 months
Can you approximate how many EEGs are performed in your institution per year, whether onsite or its done offsite?	◯ < 100 ◯ 100-500 ◯ 500-1000 ◯ >1000

The next set of questions seek to gather information about the employment, training and qualifications of the technologist performing EEGs in your institution.

Do you have any dedicated people to perform EEGS?	◯ Yes ◯ No
If YES, who do they perform EEGS on?	◯ Adults ◯ Children ◯ Both adults and children
How many people offer EEG services at your hospital?	◯ 1 Person ◯ 2 or more

Please complete the next set of 7 questions for PERSON NUMBER 1 performing EEGs at your institution.

What type of employment do they have?
- ◯ Fulltime
- ◯ Partime
- ◯ Other

If OTHER, please specifiy their type of employment?

____

Where did the person train?
- ◯ Locally
- ◯ Internationally
- ◯ Combination

Please provide the name of the training institution of the person?

____

What type of training did the person have?
- ◯ Informal
- ◯ Formal
- ◯ Both

How long was the training?
- ◯ < 3 months
- ◯ 3-6 months
- ◯ 7-12 months
- ◯ > 1 year

Name the qualification obtained?
- ◯ Certificate
- ◯ Certificate and Degree
- ◯ Degree
- ◯ Bachelors
- ◯ Masters
- ◯ None

What was the training background of the person performing your EEGs?
- ◯ Nurse
- ◯ Doctor
- ◯ Clerk
- ◯ Other

If OTHER, please specifiy the training background of the person performing the EEGs?

____

Please complete the next set of 7 questions for the PERSON NUMBER 2 performing EEGs at your institution.

What type of employment do they have?	◯ Fulltime ◯ Partime ◯ Other
If OTHER, please specify their type of employment?	__________________________________
Where did the 2nd person train?	◯ Locally ◯ Internationally ◯ Combination
Please provide the name of the training institution of the 2nd person?	__________________________________
What type of training did the 2nd person have?	◯ Informal ◯ Formal ◯ Both
How long was the training?	◯ < 3 months ◯ 3-6 months ◯ 7-12 months ◯ > 1 year
Name the qualification obtained?	◯ Certificate ◯ Certificate and degree ◯ Degree ◯ Bachelors ◯ Masters ◯ None
What was the training background of the 2nd person performing your EEGs?	◯ Nurse ◯ Doctor ◯ Clerk ◯ Other
If OTHER, please specifiy the training background of the person performing the EEGs?	__________________________________

The next set of questions seeks to gather information about experience in EEG interpretation

If your answer is NO to the above question. Then complete this question so that we could determine how to fill this void in being able to provide an EEG service within your practice.	______________________
Who reads and interprets your paediatric EEGs?	◯ Adult neurologist ◯ Paediatric neurologist ◯ Psychiatrist ◯ EEG technician ◯ Combination EEG technician with specialist ◯ Other
If OTHER, please explain who interprets the paediatric EEGs?	______________________
What length of paediatric EEG training has the person that reads and interprets the paediatric EEGs had to interpret paediatric EEGs?	◯ < 3 months ◯ 3-6 months ◯ 7-12 months ◯ > 1 year ◯ other
If OTHER, please specifiy the time of paediatric EEG interpretation training?	______________________
Would having someone undergoing an apprenticeship in paediatric EEGs benefit your practice? On Completion of this Study, the apprenticeship would be an ARM of the African Paediatric Fellowship program training Africans within Africa.	◯ Yes ◯ No
If YES to the above, please explain how it would benefit your practice?	______________________

Appendix 4: PES Handbook Questionnaire

PES Handbook Questionnaire

Dear Sir/Madam,

As part of my PhD programme, I am undertaking a survey study to develop an apprenticeship training program for healthcare professionals from sub–Saharan Africa in basic paediatric electroencephalography skills.

The aim of the study is to understand the impact, change in knowledge and practice using an online paediatric course and whether chat/online support is important?

To this end, I kindly request that you complete the following short handbook questionnaire.

Thank you!

Participant information	
Please choose your gender	◯ male ◯ female ◯ other (Please choose your gender)
Please fill in your age	____________________ (Please only fill in your age in number format)
Please fill in your profession	◯ Adult neurologist ◯ Paediatric neurologist ◯ Medical officer ◯ Specialist ◯ Allied Professional ◯ Other (Please choose your profession)
Please fill in your speciality field, if relevant.	____________________
Please fill in your allied profession field, if relevant.	____________________
If OTHER, please specify your profession.	____________________
Please fill in your primary country of residence.	____________________ (Please only fill in your country)
What type of hospital or clinical setting do you usually work in?	◯ Tertiary care (healthcare specialist in a large hospital) ◯ Secondary care ◯ Private ◯ Community clinic/day hospital (primary care) ◯ Other
If OTHER, please specify the type of hospital or clinical setting you work in.	____________________

Do you treat children with epilepsy in your practice?	◯ Yes ◯ No
Do you report paediatric EEGs in your practice?	◯ Yes ◯ No
Have you had any previous paediatric EEG training?	◯ Yes ◯ No
If YES, during what time of your training (mark all that apply):-	☐ Registrar/residency rotation ☐ Fellowship program ☐ Online course ☐ Other
If OTHER, please specify in which settings EEG training was done?	__________________________
How long was the longest training period for?	◯ < 3 months ◯ 3-6 months ◯ 7-12 months ◯ Other
If OTHER, please specify how long was training for.	__________________________
What qualification(s) did you obtain? Mark all that apply:-	☐ Fellowship in EEGs ☐ Diploma in EEGs ☐ Online course certificates ☐ Other
If OTHER, please specify if any qualification was obtained.	__________________________

Current online handbook information	
Have you completed the full online course?	◯ Partially ◯ Yes ◯ No
If NO, what was the primary reason why you did not finish the handbook?	◯ Handbook was too difficult ◯ Did not have time to complete ◯ Lost interest in handbook ◯ Subject difficult to learn ◯ Other
If OTHER, please specify why you did not finish the handbook.	______________________
If YES, please give the complete date of completion	______________________ (Please fill in month and year)
How long did it take you to complete the handbook from registration?	◯ < week ◯ 1-2 weeks ◯ 3-4 weeks ◯ Other
If OTHER, please specify how long it took to complete the handbook.	______________________
What was the primary reason for delay if completion took longer than one month?	◯ Busy schedule ◯ New subject ◯ Not user- friendly ◯ Internet / accessibility ◯ Other
If OTHER, please specify what was the reason for the delay in completing the handbook after a month.	______________________
Did you use the online facilities available for the book?	◯ Yes ◯ No
If YES, how useful was the chat?	______________________
If No, why did you not use the chat? Mark all that apply:-	☐ Did not need it ☐ Did not understand how to use it ☐ Had no access to internet ☐ Was not aware of availability of chat

Please complete the following section regarding your experience and opinion of the handbook. Please note that this is a Likert scale ranging from 1 through 5, with an option of 6 if unsure or not applicable. The higher the number the more positive the experience/opinion.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable
Before using the handbook, I was skilled in reading paediatric EEGs.	○	○	○	○	○	○

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable
Using the handbook has improved my paediatric EEG reading skills overall	○	○	○	○	○	○

Please explain the reason(s) for the above rating: ____________________________

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Unsure or not applicable
Using the handbook has improved my paediatric EEG reading skills in: Identification of normal paediatric waveforms	○	○	○	○	○	○
Using the handbook has improved my paediatric EEG reading skills in: Identification of artifacts	○	○	○	○	○	○
Using the handbook has improved my paediatric EEG reading skills in: Identification of abnormalities(focal/generalized)	○	○	○	○	○	○
Using the handbook has improved my paediatric EEG reading skills in: Identification of hyperventilation/intermittent photic stimulation	○	○	○	○	○	○

Please explain the reason(s) for the above ratings: ____________________________

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable
The handbook is relevant to my current work.	○	○	○	○	○	○

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable
I am applying what I learnt from the handbook to my current work.	◯	◯	◯	◯	◯	◯

Please explain the reason(s) for the above rating: __________________________

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable
Using the handbook has improved the clinical care I am able to provide for my patients	◯	◯	◯	◯	◯	◯

Please explain the reason(s) for the above rating: __________________________

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Unsure or not applicable
I would recommend this handbook and training program to others in the field	◯	◯	◯	◯	◯	◯

Please explain the reason(s) for the above rating: __________________________

Please list or describe any suggestions for improvement of this course OVERALL: __________________________

Please list and describe any suggestions for improvement of this course SPECIFICALLY related to ONLINE interface: __________________________

Please list and describe any positive aspects of taking this course: __________________________

Appendix 5: EEG expert interview Questionnaire

Research Objective:

To investigate existing training guidelines for electrophysiology for specialists and non-specialists i.e., Neurologists and healthcare practitioners. To understand pathways to attaining skills in electrophysiology

Research Aim:

The aim of this section will be to understand what training guidelines exits between high income and resource limited countries and to collate the range of content, and styles of teaching, that currently exist for the discipline. As well as the entry level and outcome level of expertise/practice.

Section A: Background/demographic

a) (Establish Rapport and purpose) XXXXXX Thank you for agreeing to speak to me.

My name is XXX. I appreciate having the chance to speak with you. I am a senior neurophysiologist at the Red Cross Children's War Memorial Hospital. I am currently completing my PhD in access to ideal EEG training for non-specialists at the University of Cape Town.

b) (Motivation) I am conducting research into electrophysiology training and guidelines in high income and resource limited countries. I hope to use this information as it will contribute towards the adaptation and growth of our existing paediatric EEG training program in sub-Saharan Africa. Your response is valuable as an expert in the field.

c) [xxxx]Thank you for your CV/BIO?

d) I understand that this is a substantial investment of your time. The interview should take about 20 minutes.

e) [xxxxx] Please consider as part of your answer, your own range of experiences, from being a trainee through the senior management and systems level.

d) Do you have any questions about what I have said so far?

e) Do you consent to participate in this research?

i) Interview		ii) Collaboration	
Yes	No	Yes	No

Section B: Training

1. What is your opinion on the relevance and intended end points of training electrophysiology e.g., to make them epileptologists or to equip them for safe practice?

2. In your setting, in what way do your doctors get exposure to paediatric EEG interpretation, if at all?

3. Do you think there should be a separate focus for paediatrics?

4. What are the barriers in your setting in EEG training specially for paediatric EEG?

5. In a limited resource setting, who do you think would be the best clinicians to focus training resources on? E.g., career intended epileptologists, general paediatricians, medical officers, nurse practitioner etc.

6. What entry level skills do you think are needed?

7. In your opinion what would be the best style of training (apprenticeship/modules/both or is online enough)?

8. What assessment methods should be used for a more valuable outcome (exit exam/continuous assessment)

9. In your opinion what would be the critical skills to attain from the training i.e., units in LMIC that are initially starting?

10. How do you, or would you suggest, ensuring via monitoring and evaluation that there is sustained maintenance of skills post training

11. What recommendation would you have to promote better EEG training in sub-Saharan Africa?

111. Closing

a. (Establish a Conclusion) this information is quite significant and valuable. Is there, anything else you feel you might like to add, or expand on in greater detail before we conclude?

b. The above information will be used to write up the last chapter for my PhD and this will form part of a chapter for publication. If you agree to collaborate, you will be part of the co-author list.

b. Thank you for participating in this study.

c. Thank you for your valuable attention.

Appendix 6: Ethics Approval HREC 481/2018

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Buildin
Groote Schuur Hospita
Observatory 792
Telephone [021] 406 649
Email: sumayah.ariefdien@uct.ac.z
Website: www.health.uct.ac.za/fhs/research/humanethics/form

31 October 2018

HREC REF: 481/2018

Prof J Wilmshurst
Department of Paediatrics
Head of Department Neurology & Neurophysiology
Red Cross Children's Hospital

Dear Prof Wilmshurst

PROJECT TITLE: PAEDIATRIC ELECTROENCEPHALOGRAPHY IN SUB-SAHARAN AFRICA: ACCESS TO EFFECTIVE SERVICES, TRAINING CAPACITY AND APPLICABILITY OF TEACHING MODULES (PHD Candidate - Ms V Kander)

Thank you for your response letter, addressing the issues raised by the Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study, including the following documentation: -

1. PI generated synopsis
2. Research Protocol
3. Consent & Assent forms:
    - Appendix A-Entry form
    - Appendix B-Interview on EEG training guidelines
    - Appendix C-Survey-EEG services
    - Appendix D-Interview on existing EGG training centres
    - Appendix E-Handbook questionnaire
    - Appendix F- Pre-test questionnaire
    - Appendix G- Post-test questionnaire

Approval is granted for one year until the 30 November 2019.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the student: Ms Veena Kander will also be involved in this study.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix 7: Copyright certificates

SPRINGER NATURE

Clinical practice applicability and relevance to non-specialists of a paediatric EEG online learning tool

Author:

Veena Kander et al

Publication:

BMC Medical Education

Publisher:

Springer Nature

Date:

Jan 31, 2024

From: Becker, Emily <esargent@wiley.com>
Sent: Tuesday, November 28, 2023 11:31 PM
To: epilepsia <epilepsia@ilae.org>; Jo Wilmshurst <jo.wilmshurst@uct.ac.za>
Subject: RE: articles for thesis

Hi Dr. Wilmshurst,

Sorry for the delay in my response (I was, indeed, out for the Thanksgiving holiday!). There is usually a tool in the article itself, which Laurie was looking for, that can help authors go through the permissions process. It looks like that is missing from these articles, which is likely because they were published prior to the journal's move to Wiley. I'll see what we can do to get that added, and sorry for the inconvenience in the meantime!

That said, please assure Ms Kander that she is likely able to reuse her articles in her thesis with no special permissions. Under the terms of most Copyright Transfer Agreements (including Wiley's standard CTA), authors retain "The right to re-use the Final Published Version or parts thereof for any publication authored or edited by the Contributor (excluding journal articles) where such re-used material constitutes less than half of the total material in such publication. In such case, any modifications must be accurately noted."

Let me know if this does *not* describe Ms. Kander's work, and we can work on permissions if need be. However, I think we should be all set here!

Best wishes,

Emily

Emily Becker | Publisher | esargent@wiley.com

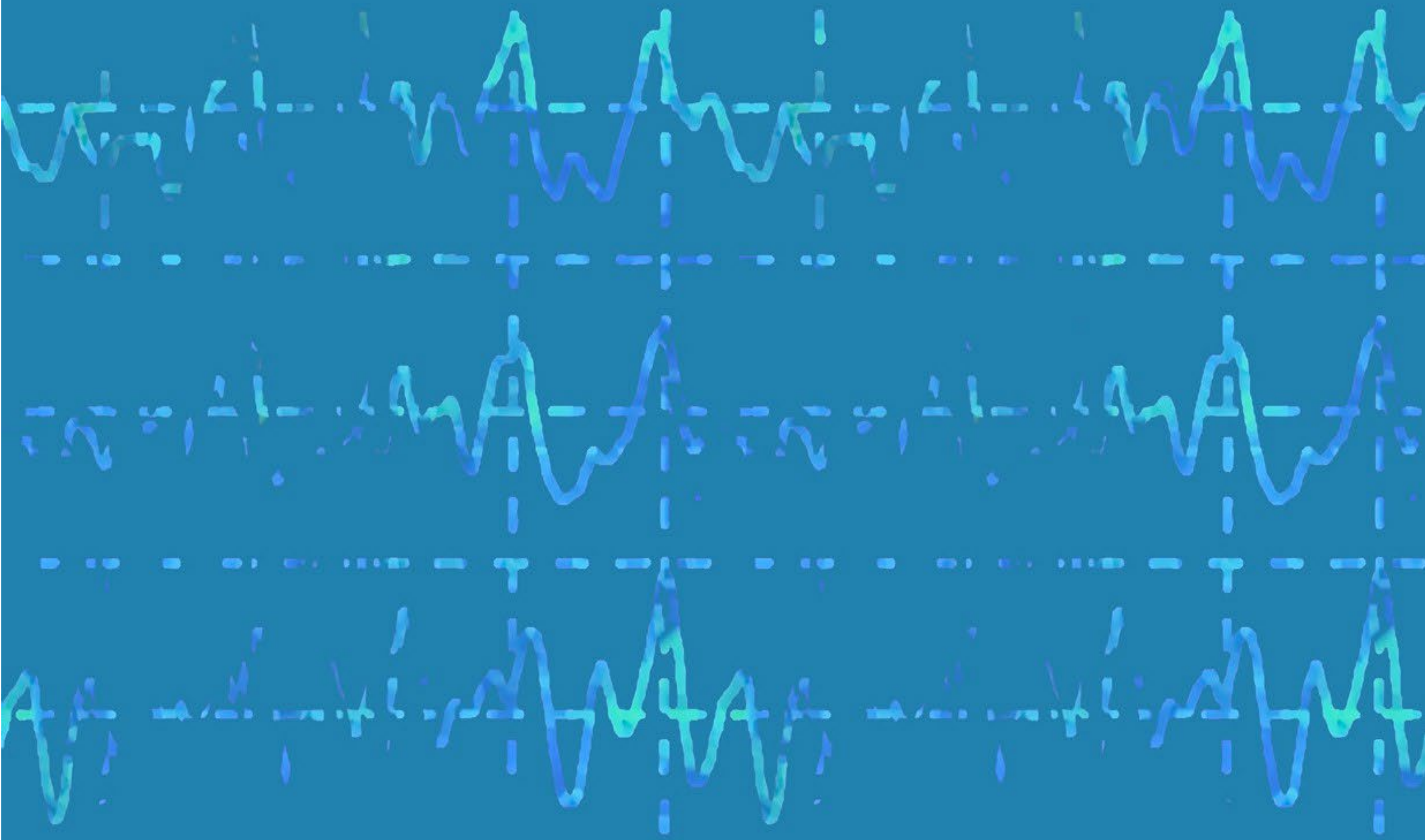
Appendix 8: Handbook of paediatric electroencephalography: A basic guide to paediatric EEG interpretation

NB: This is the initial version of the handbook (2016) i.e. the version used for the research. The Handbook is a fluid document which will be regularly updated – this is based on the findings of the PhD as well as the current nosology terminology.

--- HANDBOOK OF ---

PAEDIATRIC ELECTROENCEPHALOGRAPHY

A basic guide to paediatric EEG interpretation



Veena Kander

Warren T Blume

Jo Wilmshurst

HANDBOOK OF PAEDIATRIC ELECTROENCEPHALOGRAPHY

A basic guide to paediatric EEG interpretation

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This handbook is dedicated to my late parents and

Foreword

There is a great need to develop skills in electroencephalography in low middle income countries. Access to this tool is limited in Africa and must be used appropriately, inclusive of insight into when to request a study and how to respond to the findings. This data must be put in the context of the clinical presentation of the child. This text is unique in that it provides foundation skills to support safe practice for clinicians with access to, but no formal training in, paediatric electroencephalography. Whilst the text does not intend to provide a neurophysiology specialist level of knowledge, it does enable the practitioner to develop firm foundations which would facilitate further training in the area inclusive of increasingly complex international courses.

Jo M

Preface

There is a great need for basic understanding and interpretation of Electroencephalography (EEG) amongst clinicians who care for children in sub-Saharan Africa. Sub-Saharan Africa has limited resources in the field of neurophysiology, especially in paediatrics. The training unit at Red Cross War Memorial Children's Hospital has, with support from the African Paediatric Fellowship Program (APFP), had an increasing number of paediatricians attending the department to learn the basics of EEG interpretation, while completing their MPhil degree. The need for a suitable handbook to teach the basic concepts of paediatric encephalography to child neurologists and paediatricians became evident. The author has 26 years of experience in EEG interpretation of both adults and children. She has worked in many South African centers as well as at teaching hospitals in Canada and Australia.

Electroencephalography has revolutionized the understanding of epilepsy and its treatment in clinical practice. It is therefore imperative that practicing child neurologists and paediatricians interested in neurology have an understanding of some *basic* concepts of neurophysiology. This handbook meets those needs and would be the first published book in South Africa. It presents some insight into how an EEG is performed, what problems arise with children and interpretation of classic EEG patterns that can assist with correct diagnosis and management.

This handbook is designed to complement other training courses and materials used in the development of neurophysiology in sub-Saharan Africa. This project was performed as part of my Master's program. I am greatly indebted to Prof Blume for his editing of this handbook and to Prof Jo Wilmshurst for her contribution. I would also like to thank Judy Synders, Michele Barnard and Carmen-May Claydon-Fink for their graphic artwork. This handbook would not be possible for the EEG samples recorded by the author herself and with the assistance from Mr Louis Heyne for helping to access the EEGs directly from the computer. The EEG samples range between 1, 4, 8 and 16 channels. The qualities of the EEGs are not perfect as performing paediatric EEGs in South Africa is a challenge in itself. Lastly, I would like to thank my family, colleagues and friends who supported me throughout this project.

Veena

HANDBOOK OF PEDIATRIC ELECTROENCEPHALOGRAPHY:

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INTRODUCTION

There are many books and manuals on electroencephalography (EEG), but these tend to be too detailed for easy reference in a busy clinical setting. There is a need for a simple paediatric handbook offering basic electroencephalography skills for the clinician working in resource poor settings. This handbook is aimed at paediatricians interested in neurology, as well as training or practising child neurologists who have not had specific exposure to paediatric electroencephalography. It would also be useful for adult neurologists, many of whom interpret paediatric EEGs where no paediatric neurologist is available and for neurophysiology - technician trained nurses who typically perform such studies in the few equipped centers across Africa.

This handbook serves as a guide to the recording of basic paediatric electroencephalography; the related problems associated with children and interpretation of EEG patterns. It assists any licensed professional in competently recognizing epileptogenic disorders of childhood. Typical key electroencephalogram patterns are presented which, once recognized, assist in correct diagnosis and appropriate management of childhood disorders. These include the identification of typical absence seizures, hypsarrhythmia and sub-clinical status epilepticus. This may avoid inappropriate therapy choices and potentially improve neurological outcome in a child with epilepsy.

This training handbook is to help ensure that certain standards are met and reflects our vision for paediatric electroencephalogram monitoring and interpretation.

CONTENTS

CHAPTER 1
10/20 SYSTEM

In 1958 the 10/20 system to perform electroencephalograms (EEGs) was introduced and is based on the relationship between the location of an electrode and the underlying area of the **cerebral cortex**. The "10" and "20" refer to the distances between adjacent electrodes which are either 10% or 20% of the total front-back, right-left and circumference distances of the skull.

The first two anatomical landmarks used for marking are the **nasion and inion**. The nasion is the point where the top of the nose joins the forehead and the **inion** is the lowest point of the skull from the back of the head, normally indicated by a prominent bump, or indentation, if bump is not evident.

To measure an easy 10/20 system (Steps 1-6, below) requires a tape measure and a red china mark- er which can be purchased at any stationary shop. The patient should sit on a chair or lie on a bed for easy access to the head. Once the markings are done, abrade the skin slightly with an orange stick or neuroprep at the cross of each marking and place electrodes. Caps are also used for routine EEG's and have to be adjusted to fit the patient's head. A loose-fitting cap can cause artefacts and will not give accurate location of abnormalities.

In the paediatric setting we use silver disc electrodes with 10/20 paste such as *elefix* – a thick buttery conduction paste for EEG. Usually, cleaning the site for placement is not practical in children. However, electrodes need to be tested for impedance and maintained below 5 kilo ohms (to check press impedance button on head box and it will be done automatically). In a public health setting, sedating all children is also not possible given the service load and the risks attached to sedation. Sedation also affects the EEG.

Picture of patient with braids

Natural sleep is always encouraged, and parents made comfortable so that they can help get their children to sleep. When working with children you need to be relaxed, efficient and patient in what you are doing, in order to get the best result in the most difficult

NOTE: marking the 10/20 system on children can be difficult. Braids and other traditional or religious hairstyles increase the challenge as seen below. Patients' hair must be clean with no gels. Even numbers are on the right and odd numbers are on the left as seen in Figure 1.1. Competency of marking the 10/20 system comes with continued practice. Right-left markings are identified RL and anterior posterior markings are AP.

Skull defects and the 10/20 system: Modification

Retain the 10/20 system wherever feasible. Modifications for skull defects, cranial deformities and scalp lesions may be necessary and require precise annotation with diagram.

STEP 1 – Nasion to inion measurement (anterior to posterior)

- Measure the distance from the nasion to the inion and take 50% of the whole measurement, to mark the RL **Cz.**
- Place the tape measure at the nasion towards Cz and mark 10% of the whole (nasion-inion) distance to get RL **FPz**
- Place the tape measure on FPz to Cz, measure that distance and mark 50% to get the RL **Fz**.

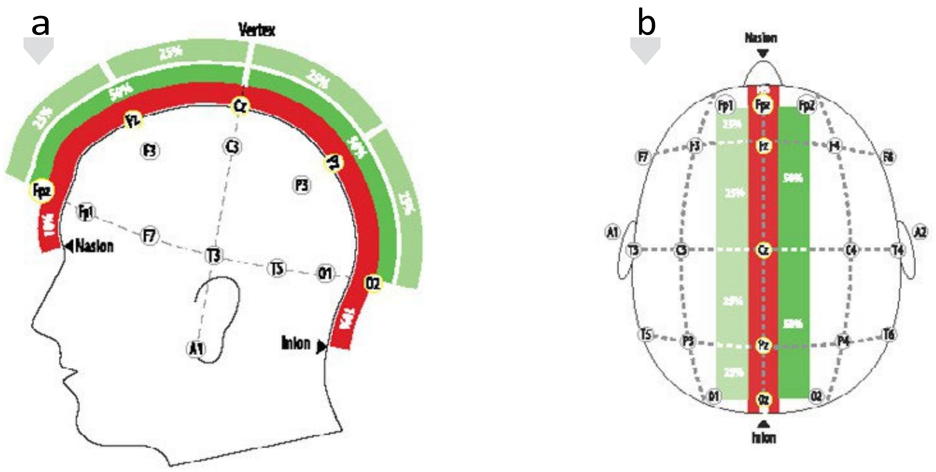


Figure 1.1: Step 1 diagram lateral view (a) and top view (b)

- Using the same distances as FPz to Fz and FPz to Cz, place the tape measure on Cz and place the RL marking of **Pz** and **Oz** respectively. The distance from the inion to Oz would be 10% of the whole (nasion-inion) measurement.

STEP 2 – Auricular crease to auricular crease (side to side)

- Measure the distance from one auricular crease (just anterior to tragus) to the other, (illustration below), 50% of this distance crosses and identifies **Cz.**

- 10 % of the distance between the auricular creases through Cz provides the AP mark of **T4** (if starting on the right).

- Place tape measure on the vertical mark of T4 to Cz; 50% of that distance provides the AP marking for **C4.**

- Repeat the same on the left to mark **T3** and **C3**. **NOTE**: the lack of side-to-side cephalic symmetry requires measurements to be made separately on each side.

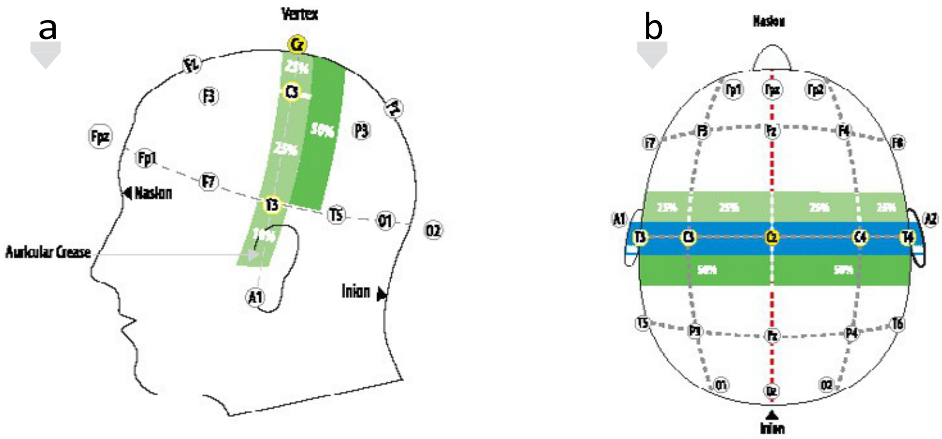


Figure 1.2: Step 2 diagram lateral view (a) and top view (b)

STEP 3 – Circumference (around the head)

- Using the nasion to identify the midline make an AP mark crossing the RL one to identify **FPz**. Placing one end of the tape at FPz determines the circumference of the head, i.e. take it around the head crossing over T4, Oz, T3 and back to FPz. 50% of that circumference identifies **Oz**.
- Using 10 % of the circumference, 5% on either side identifies (mark and cross) **O1** and **O2**.
- Repeat the same with marking and crossing **Fp1** and **Fp2** on either side of FPz.
- **NOTE: Remember to cross O1, O2, Fp1 and Fp2**

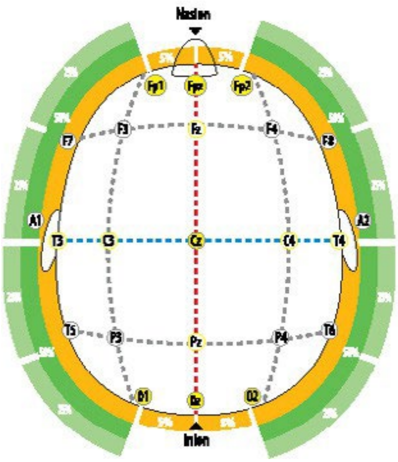


Figure 1.3: Step 3 diagram

STEP 4 – Double banana

(measuring parasagittal and temporal electrodes)

- Place the tape measure on FP2 to O2 crossing through the AP C4 mark; 50% of that total creates the C4 RL marking thus identifying **C4.**

- Place the tape measure on Fp2 to C4, mark 50% of that total to provide the RL marking of **F4.**
- 50% of the distance between C4 to O2, gives the RL marking of **P4.**

- Place the tape measure on Fp2 to O2 crossing through the AP T4; 50% of that total creates the T4 RL marking thus identifying **T4.**

- 50% of Fp2-T4 distance identifies **F8** (mark and cross).

- 50% of T4-O2 distance identifies **T6** (mark and cross)**.**

- **NOTE: repeat step 4 on the left side. Remember to cross F8, T6, F7 and T5.**

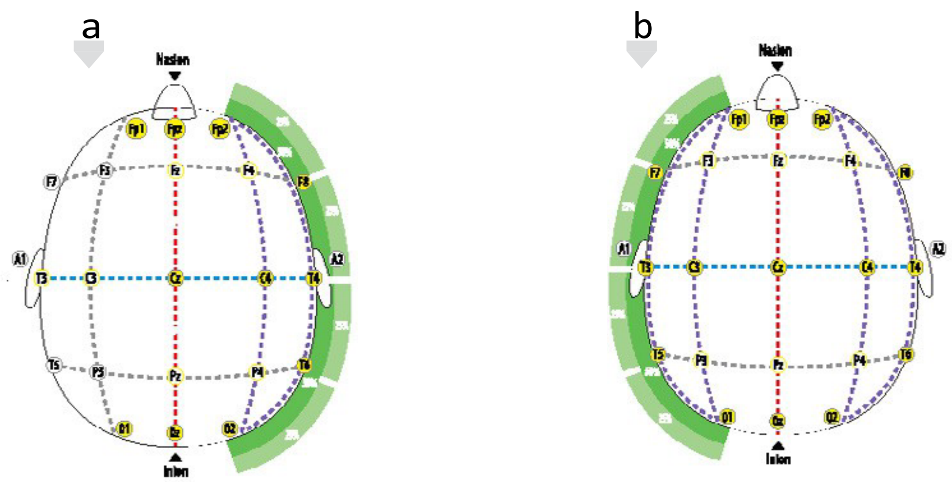


Figure 1.4: Step 4 diagram right side (a) and left side (b)

STEP 5 – Parietal

- Place the tape measure on T6 crossing over RL lines of P4, Pz, P3 to T5. 50% of that total identifies **Pz;** 50% from Pz to T6 gives the AP mark and identifies **P4**.

- 50% from Pz to T5 gives the AP mark and identifies **P3.**

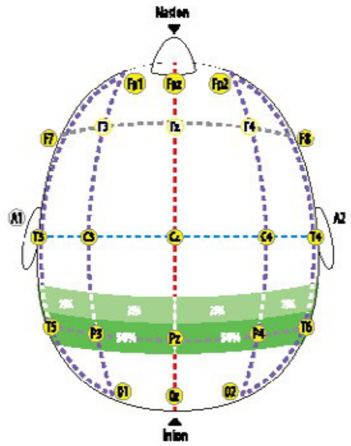


Figure 1.5: Step 5 diagram

STEP 6 – Frontal (temple to temple)

- Place the tape measure on F8 crossing over RL lines of F4, Fz and F3 to F7. 50% of that total identifies **Fz;** 50% from Fz to F8 gives the AP mark and identifies **F4.**

- 50% from Fz to F7 gives the AP mark and identifies **F3.**

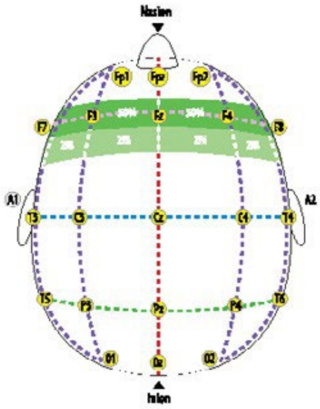


Figure 1.6: Step 6 diagram

NOTE: Each site has a letter to identify the lobe and the number to identify the hemisphere location. There is no central lobe so "C" is only used for identification purposes and also using "z" is a reference to the midline as seen in Figure 1.7. Knowledge of the hemisphere location is utmost important during interpretation of abnormalities (Table 1).

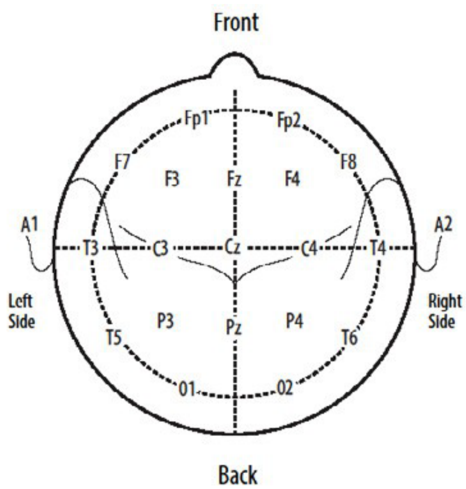


Figure 1.7: Composite steps of 1-6

Table 1- Lobe electrode relationships

Brain Area	Right	Midline	Left
Pre-Frontal	Fp2	Fpz	Fp1
Frontal	F4	Fz	F3
Anterior-Temporal	F8		F7
Mid-Temporal	T4		T3
Posterior-Temporal	T6		T5
Central	C4	Cz	C3
Parietal	P4	Pz	P3
Occipital	O2	Oz	O1

Outcome goals for Chapter 1 - 10/20 system

- Marking and placement of electrodes using the 10/20 system
- Adjusting electrode placement around anatomical defects/anomalies and with surgical procedures
- Relationship of electrode placement and brain anatomy
- Clean the head and make sure it is dry before electrode application
- Wrap child head with bandage around the head if child is restless or sweating
- Continued practice will yield perfection in marking and placement of the 10/20 system
- Attach electrodes on minimum of +/- 300 children in the following age groups (see Table 3 below)

Questions for chapter 1

1 Which of the following statements concerning the 10/20 electrode placement system is (are) correct:

1) Inter electrode distance is equal

2) F3 and F4 positions divide the frontal coronal line into quarters

3) The first measurement to be made is the head circumference through the nasion, pre-auricular notch, and the inion

4) C3 overlies the hand area of the motor cortex

a) 1, 2, 3 are correct

b) 1 and 3 are correct

c) 2 and 4 are correct

d) Only 4 is correct

e) All are correct

2. In the 10/20 system, which electrode is closest to the middle temporal gyrus?

a) C4 b) P4 c) F8 d) T4 e) T6

3. Which of the following corresponding electrode placement represents a lobe?

1) C4 2) F3 3) P4 4) O2 5) T3

a) 2 and 3 are correct

b) 3 and 4 are correct

c) 1 is correct

d) 4 and 5 are correct

e) None of the above are correct

4. The following are true concerning the international 10/20 system of electrode placement?

1) Determine electrode positions through measurement from standard landmarks on the skull

2) Label positions in terms of brain areas (frontal, parietal etc)

3) Even numbers represent the right hemisphere and odd numbers the left hemisphere

4) The distances are 10/20 mm apart from each electrode

5) Relaxed caps are efficient as well as the well attached caps

a) 1, 2, 3 are correct

b) 1 and 3 are correct

c) 2 and 4 are correct

d) Only 4 is correct

e) All are correct

5. All of the following preparations should be done for recording a paediatric EEG EXCEPT:

a) Clean the patient's head

b) Measure and mark the 10/20 system

c) Allow the patient to sweat

d) Explain the procedure to the patient

e) Make the patient comfortable

CHAPTER 2

ELECTROENCEPHALOGRAPHY INSTRUMENTATION

(filter settings, sensitivity, paper speed, electrical safety) and recording

EEG Machine (Figure 2.1)

Each EEG channel represents change of electrical potential difference with time between two electrodes on the scalp. The head box contains differential amplifiers which measure the voltage difference between the two signals at each of its two inputs. There are 21 electrodes attached to the head box, plus the ground. The manner in which pairs of electrodes are connected to each amplifier of the EEG machine is called a montage, as seen in Chapter 4. The exact sequence of waveform processing may be not available from suppliers; these data may be restricted for several reasons, patent protection being one. Fisch outlines the following sequence. Initially, waveforms pass through a differential amplifier and a second, single-end one. After passing through the above-described filters, the signal is further amplified by single-ended amplifiers whose outputs are controlled by the high frequency filter, low frequency filter, 50 hertz filter and sensitivity control.

Filters

Filters are used to exclude relatively high or low frequency waveforms from the EEG so that 1-30 Hz waveforms, the more clinically important ones, can be recorded clearly and without distortion. The purposes of low and high frequency filters are to block low and high frequencies that carry more noise than useful signals.

LFF

The low frequency filter (LFF), also referred to as a high pass filter, reduces the amplitude of slow waves but has no effect on high frequency waves. The LFF consists of a capacitor in the signal path and a resistor connection to ground. At low frequencies the capacitor impedance becomes very high so that the capacitor and signal source become excluded from the circuit, and the output *approaches* a short circuit to ground.

As mentioned above the LFF allows fast frequency activity through but attenuates waveforms of low frequency activity e.g. **sweat and delta activity (explained in chapter 5).** To decrease the amplification of low frequencies the LFF of 0.1s and 0.03s could be employed. In front of the EEG screen try altering the LFF's to exemplify their effects. This, combined with reduction in paper speed (half the normal speed) can better display focal delta.

HFF

The high frequency filter (HFF-low pass filter) consists of a resistor in the signal path and a capacitor connection to ground. HFF settings also represent the high frequencies that are reduced by 20%.

The HFF allows slow wave activity through but attenuates waveforms of high frequency activity (such as above 15 Hz) e.g. **muscle artefact and spikes.** Thus, altering the HFF from about 70 Hz to 35 or 15 Hz would filter out such high frequency waves exceeding these values. There is no need to increase the HFF as it is set at 70Hz. The high and low frequency filters set the window for which the EEG activity is recorded, and this is called the *bandwidth*.

50 Hz Filter

This filter reduces the most common type of electrical artefact, that from devices powered by alternating current. This filter substantially reduces 50 Hz activity but also to a lesser degree neighboring frequencies. It is used especially in ICU's where there are a lot of electronic devices which emit 50 Hz interference. However, if electrode impedances are low and equal, this filter may be avoided, even in the ICU.

Sensitivity

The sensitivity (μV/mm) controls the amplitude of the activity displayed. At times the sensitivity needs to be reduced if the waveform is greater than 100uv or 1cm deflection. The sensitivity can be reduced from 10uv/mm to 15uv/mm to view some abnormalities more clearly. On a paper machine the signal passes through a galvanometer which has a pen attached to the end and the pen draws the signal on the moving paper. The digital EEG system converts the waveforms into a series of numerical values, a process called the analogue to digital conversion. The speed at which the paper or digital EEG moves (mm/sec) will also affect the appearance of the waveforms.

The standard settings for paediatric EEG

- LFF=0.3sec (0.5 Hz)
- HFF=70Hz
- Sensitivity=10uv/mm
- Paper speed=10sec/page (digital machine)
- Calibration deflection=5mm

Electrical safety

The principles described below are adapted, with permission, from *Fisch BJ. Fisch & Spehlmann's EEG Primer Third Edition (1999) Elsevier. Amsterdam, Chapter 3 Digital and analog EEG instruments: parts and functions.pp 68-72.*

Direct electrical shock may occur from: a) failure of instrument or wall socket grounding, b) im- proper patient grounding, c) direct contact of electrodes attached to patient and strong electrical sources such as wall current. "Female" electrode connectors have interchanged with "male" connectors to prevent inadvertent plugging these into wall sockets, electrocuting the patient. The risk of exposure to electrical current depends on the path it takes through the body. Thus, a potentially lethal current arises with indwelling catheters, especially cardiac catheters.

Short circuit & ground failure: Under normal circumstances the chassis of an EEG machine is connected to ground. However, if a short circuit in the EEG machine occurs, current can flow to its outer covering (chassis). If the ground connection of the machine is intact, electrical current will flow directly to the ground and not through the patient. However, if the EEG machine connection to ground or the ground (green) input to the wall receptacle becomes disconnected, potentially lethal current may flow through the person touching the equipment. An ohmmeter would test the equipment ground, touching one probe to the EEG chassis and the other to the ground prong of the power cord plug.

Leakage current & ground failure: Unwanted current may also arise from capacitive and inductive sources. A power cord can develop capacitor-like properties as it contains three wires (*black*, carrying the main voltage to the EEG machine; *white*, carrying voltage returning from the instrument; and *green*, the contact between the EEG machine and the earth ground).

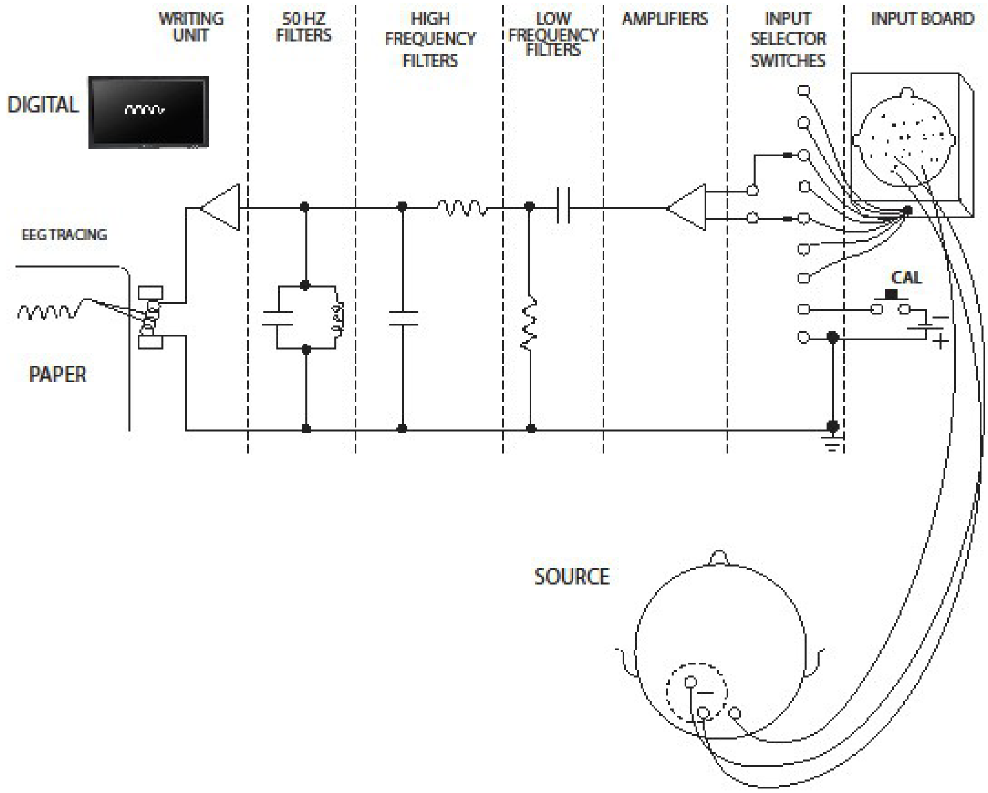


Figure 2.1: EEG machine

The longer the power cords with extension the greater the capacitance current and thus the greater leakage current. Thus, extension cords should never be used as such may raise leakage current to dangerous levels. Current through coiled wires induce an electromagnetic field that may also induce current flow in adjacent conductive materials leakage current could flow through the patient if instrumental or wall socket grounds are dysfunctional. Hospital biomedical engineers should periodically test instruments for leakage current.

Current flow between unevenly grounded equipment: If two separate instruments are attached to the same patient and their ground levels are not the same voltages, leakage current from one instrument may flow toward the patient via its ground electrode, through the patient, and into the ground electrode of the instrument with the lower voltage ground level. This circuit has been termed *a ground loop*. Adherence to four principles can avoid a ground loop:

1. Never attach a ground to the patient from more than one instrument at a time,
2. Attach all power cords from all instruments making contact to the patient into the same receptacle so they share the same ground level,
3. When performing an EEG on a patient attached to multiple instruments, use a current limiting device such as an isolation input panel,
4. If the patient's bed requires grounding to reduce interference, ground it to the same wall socket used by other equipment attached to the patient.

Recording of a paediatric EEG

There are many difficulties to be faced when performing an EEG on a child and the task requires more than simply skill in placing electrodes. Young children may be afraid and may not understand, even when an explanation of "putting on stickers" or "taking pictures" of their head is tried. Many are hyperactive and have limited capacity to co-operate with the procedure.

Sleep deprivation (*"stay awake until midnight and wake up at 4am, do not allow the child to fall asleep on the way to the hospital"*) and natural sleep, are helpful in activating epileptogenic abnormalities.

Sedation is never indicated for awake recordings as it will affect the recording. In rare occasions at the Red Cross War Memorial Children's Hospital, the use of melatonin is our drug of choice.

Our center has a full-time nursing sister, staff nurse and resuscitation equipment present in the department in case of emergencies. The children are required to "sleep off" their sedation before they leave the department ("*wake up, drink and pass urine*").

Outcome goals for Chapter 2 - EEG instrumentation, electrical safety and recording

- Use personal communication skills to achieve patient relaxation/co-operation
- Explain to patient and parent the test procedure including electrode application method and activation procedures
- Interact on a level appropriate to patient's age and cognitive ability
- Maintain respect and patient confidentiality
- Machine settings (LFF/HFF/sensitivity/paper speed and 50 Hz notch filter) and how waveforms are affected by these
- Never use your filters to enhance abnormalities
- Change HFF in ICU setting only if persistent external interference contaminates recording
- How to prevent electrical shock and patient safety
- Sedation given prior to performing EEG and its effect on recording

Questions for chapter 2

1 By decreasing the high frequency response of the EEG amplifiers with filters, the noise level will

a) Decrease

b) Be unaffected

c) Increase

d) Eliminate only the 50 hertz

e) Depend upon on the low linear frequency

2. The impedance of the electrode-scalp junction:

a) Is directly proportional to the frequency

b) Is the same as the resistance

c) Is inversely proportional to the frequency

d) Is not dependant on the scalp area covered by electrode

e) Is not dependant on the electrode material

3. Your EEG machine is set as follows:

T.C: 0.3 sec.

Sensitivity: 10uv/mm

Calibration signal: 50uv

HFF: 70Hz

The approximate pen deflection in calibration will be:

a) .15mm

b) 1.5mm

c) 5mm

d) 6.6mm

e) 8mm

4. Which of the following instrumental combinations will best reveal low voltage focal delta activity?

Sensitivity setting (uv/mm)	Time constant setting
7	0.3
5	2
10	0.001
10	2
5	0.001

5. Which of the following can be electrically hazardous to a patient having a portable EEG?

1) Extension cords

2) Radios and TV's

3) ECG machine and monitors

4) Electrical wall sockets

a) 1, 2 and 3 are hazardous

b) 1 and 3 are hazardous

c) 2 and 4 are hazardous

d) Only 4 is hazardous

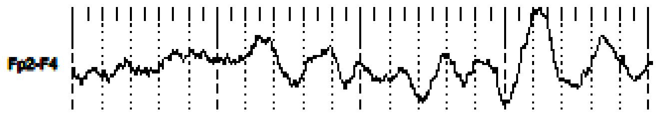
e) All are hazardous

CHAPTER 3
POLARITY

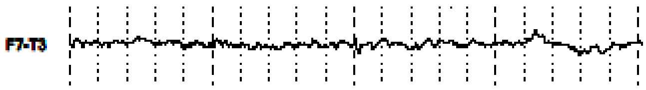
The EEG machine uses differential amplifiers to produce a single trace of activity. The differential amplifiers measure the voltage difference between the two signals at the two inputs. An electrode is connected to each of the inputs. A simple mathematical equation gives you the polarity and size of signal (G1-G2 = signal).

Here are some of the amplifier principles:

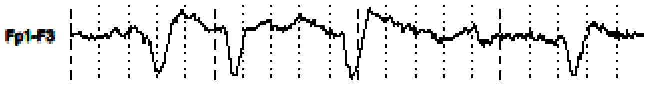
Upwards deflection- the input 1 (G1) is *negative* in respect to input 2 (G2) (on eye opening); *positivity* at input 2 will also produce an upward deflection. Thus, an upwards signal deflection simply reflects the *relative* polarity between input 1 and input 2. This simply indicates that input 1 is more negative than input 2 and that input 2 is more positive than input 1.



Equal and identical polarity between inputs 1 & 2 gives no signal deflection.

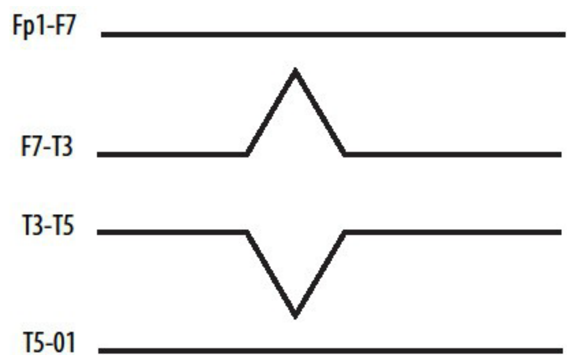


Downward deflection- occurs when input 2 becomes **negative** in respect to input 1 or input 1 becomes more positive than input 2 (on eye closure/blinks); as the **cornea** (+ve) is closer to Fp1 and Fp2 than to any other scalp electrodes.

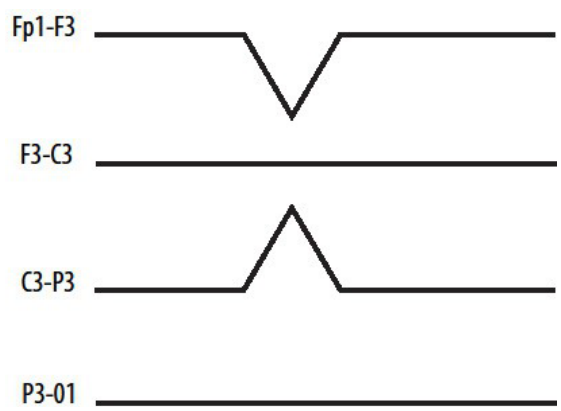


Here are some examples using the bipolar montages. These sequentially link electrodes together usually in straight lines from anterior to posterior or transversely. For example, the first amplifier may have electrodes Fp1 and F3 connected to it and the second amplifier F3 and C3 connected to it. The location of a focus in a bipolar montage is indicated by reversal of signal direction in adjacent derivations containing a common electrode in input 1 then 2 as illustrated below.

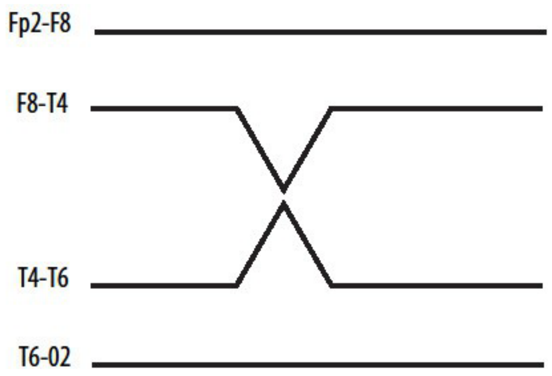
Example 1- Positive focus at T3 (out of phase)



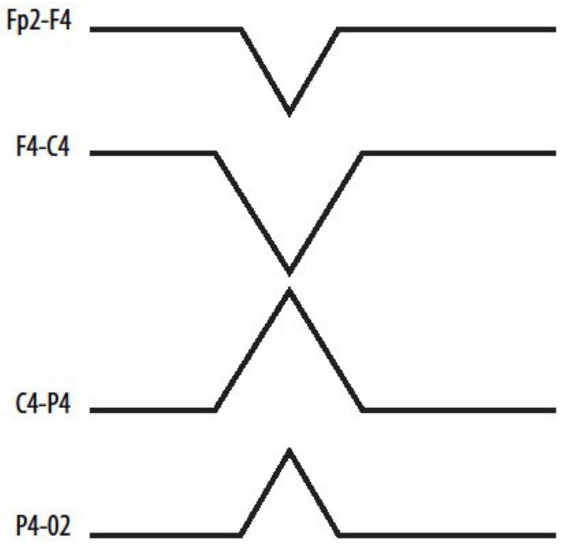
Example 2 – Negative focus between F3-C3 (in phase + no signal deflection)



Example 3 – Negative focus at T4 (in phase)

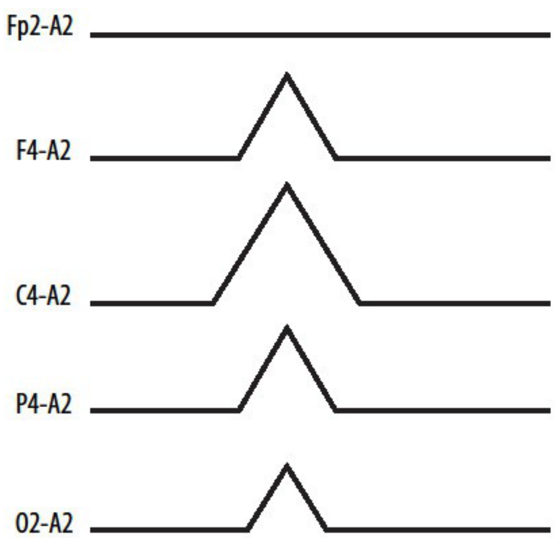


Example 4 – Negative focus at C4 (in phase with field spread to other channels)

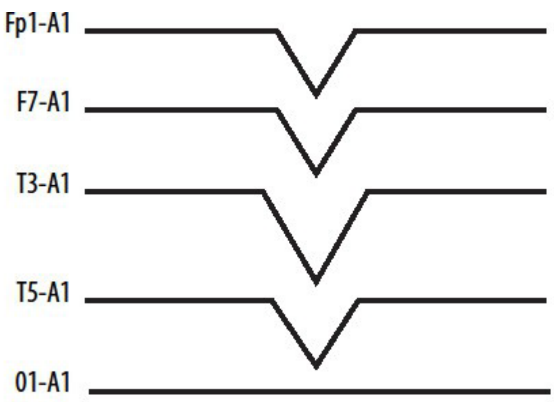


Here are some examples using the referential derivation. Referential montages are defined as those in which the input 2 is the same for most or all of the derivations. Such references are either A1/A2 or the Common Average Reference (AV). The focus in referential montages would be that electrode position attaining the highest amplitude of the EEG phenomenon in question.

Example 1 – Negative focus at C4 with field spread



Example 2 – Positive focus at T3 with field spread



Outcome goals for Chapter 3- polarity

- Understanding the logic of determining polarity of waveforms
- In bi-polar montages look for phase reversal which indicates location of abnormality
- In referential montages look for maximal amplitude for focus
- Recognize a positive focus(out-of-phase) and a negative focus (in-phase)
- A salt bridging of electrodes is not the same as equal and identical polarity (no signal deflection) seen with an epileptogenic focus

Questions for chapter 3

1 In an EEG a surface-negative wave will appear as:

a) Either an upward or downward deflection

b) An upward deflection

c) A downward deflection

d) A bi-phasic deflection

e) None of these

2. When looking to the right,

a) Fp2 is electropositive with respect to F8

b) F8 is electropositive with respect to T4

c) Fp2 and F8 will cancel

d) Fp1 is electronegative with respect to F7

e) F7 and F3 will cancel

3. In a bipolar montage a "phase reversal" signifies:

a) Inadvertent connection of the amplifies to a 3-phase power

b) An epileptic seizure

c) The point of maximum voltage

d) Two electrodes have been connected to one grid

e) None of the above

4. Two scalp electrodes placed over the same potential field of an underlying dipole and connected to channel 3 of an EEG machine will cause:

a) An upward deflection in channel 3

b) An upward deflection in channel 4

c) No deflection in channel 3

d) A downward deflection in channel 3

e) A biphasic deflection in channel 3

5. During an eyeblink or eye closure, the eyeball normally:

a) Rotates upwards

b) Rotates downwards

c) Moves laterally

d) Stays stationary

e) Converges

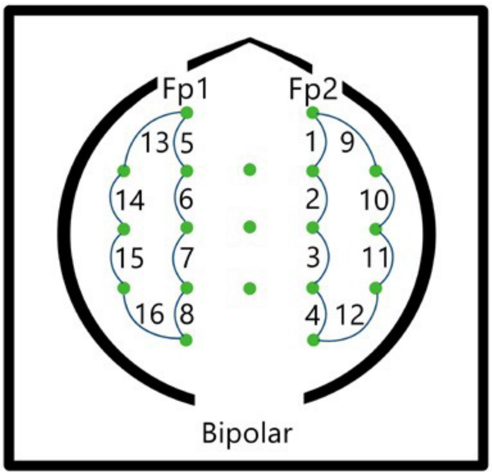
CHAPTER 4
DERIVATIONS/MONTAGE

Derivations

A *derivation* is created when a particular pair of electrodes is connected to a single amplifier. What combination of electrodes would be best to display a particular area of the brain's electrical activity? Between the 21 electrodes, one can have 210 different derivations; however, it is preferable to use derivations that have comparable inter-electrode distances.

Montages

A montage is a particular arrangement using several derivations simultaneously. A large number of different montages can be designed. The usefulness of the different montages is to make EEG interpretation as easy and accurate as possible. When deriving a montage, it should follow a logical, anatomical order or pattern. It should be simple and easy to comprehend. Certain guidelines have to be followed, and the American Clinical Neurophysiology Society has some recommendations in this regard (www.acns.org). Use standardized montages so that records from different laboratories can be easily compared. The following are some routine montages for a 16-21 channel machine. An ECG lead and EMG surface electrodes should be included on all montages. Ear electrodes are placed over the mastoids or on the ear lobes with ear clip electrodes.



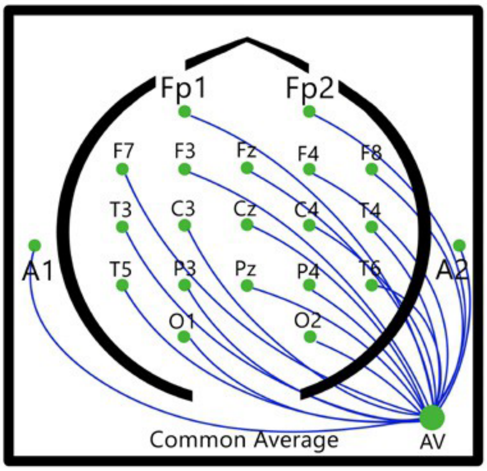
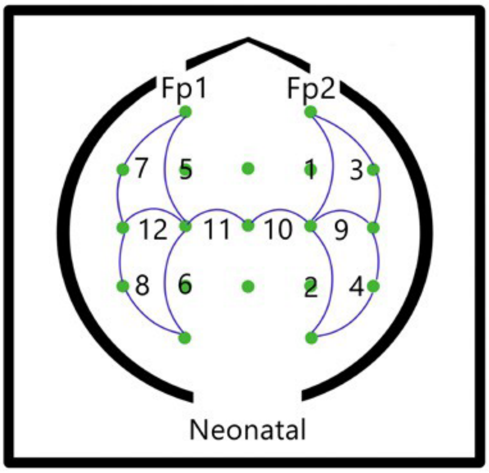
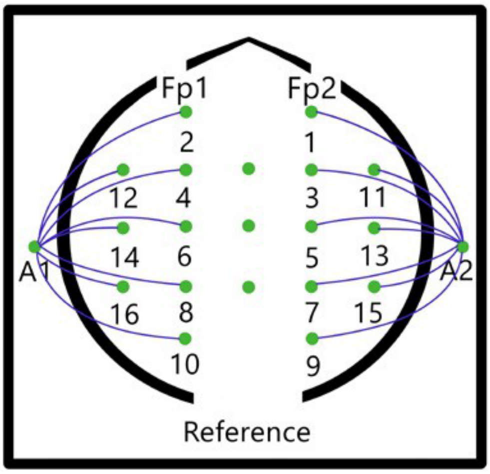


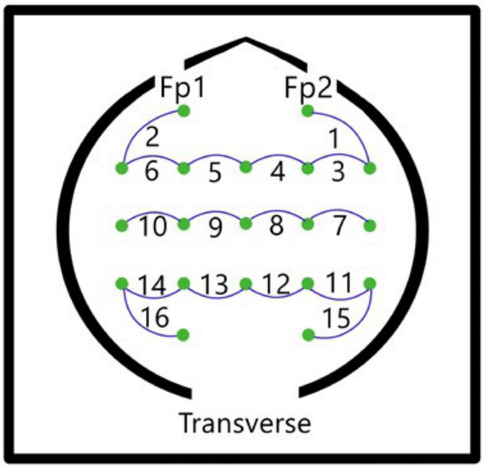
Table 2: Selected Montages

BIPOLAR MONTAGE	REFERENTIAL MONTAGE	TRANSVERSE MONTAGE	NEONATAL MONTAGE	COMMON AVERAGE MONTAGE
Fp2-F4	Fp2-A2	F8-Fp2	Fp2-C4	Fp2-av
F4-C4	Fp1-A1	Fp1-F7	C4-O2	Fp1-av
C4-P4	F4-A2	F8-F4	Fp2-T4	F4-av
P4-O2	F3-A1	F4-Fz	T4-O2	F3-av
Fp1-F3	C4-A2	Fz-F3	Fp1-C3	C4-av
F3-C3	C3-A1	F3-F7	C3-O1	C3-av
C3-P3	P4-A2	T4-C4	Fp1-T3	P4-av
P3-O1	P3-A1	C4-Cz	T3-O1	P3-av
Fp2-F8	O2-A2	Cz-C3	T4-C4	02-av
F8-T4	O1-A1	C3-T3	C4-Cz	01-av
T4-T6	F8-A2	T6-P4	Cz-C3	F8-av
T6-O2	F7-A1	P4-Pz	C3-T3	F7-av
Fp1-F7	T4-A2	Pz-P3		T4-av
F7-T3	T3-A1	P3-T5		T3-av
T3-T5	T6-A2	T6-O2		A2-av
T5-O1	T5-A1	O1-T5		A1-av
				T6-av
				T5-av
				Fz-av
				Cz-av
				Pz-av

NOTE: The neonatal montage is only to be used on heads that are too small to prevent bridging because of short inter-electrode distances.







Outcome goals for Chapter 4-derivation/montage

- Recognize the different montages
- Sequences of montages must be identified
- Use the full 10/20 system including ears which will enable you to see abnormalities in different montages
- When using the bi-polar montage make sure there is no bridging (chapter 5) which can lead to channels cancelling out
- When using ear leads in the referential montage – make sure that they are secured properly in order to minimize artefact
- Neonatal montage only should be used for small head circumferences
- Routine application of ECG

Questions for chapter 4

1 During bipolar recordings, localization of a focus is made by:

a) Highest amplitude of a spike

b) Lowest amplitude of a spike

c) Phase reversal of a spike

d) None of the above

e) All of the above

2. "Monopolar" (referential) recordings:

a) Should be made with the patient asleep

b) Require connection of only one electrode to the amplifier

c) Require inter-connection with the ears

d) Are of no value in localizing brain tumours

e) May use a "common average electrode" system for reference

3. Highest amplitude focus is seen in:

1) Referential montage

2) Bipolar

3) Coronal montage

4) Common average montage

5) Neonatal montage

a) 1 and 4 is correct

b) 2 and 3 is correct

c) 5 is correct

d) 2, 3 and 5 is correct

e) None of the above is correct

4. The common average montage is a:

a) Montage using two by two in tandem leads

b) Montage using the same ear leads

c) Montage using a combination of tandem and ear leads

d) Montage using an average of all electrodes

5. What are the advantages and disadvantages of using different montages in a digital machine:

1) Switch montages when you find an abnormality

2) Bi-polar montage can reduce the voltages sometimes to a vanishing point

3) The signal in a common average montage shows identical waveforms when an isoelectric line occurs

4) Some patterns are best seen on a referential montage

5) Contamination of all electrodes from an active reference

a) 1 and 4 is correct

b) 2 and 3 is correct

c) 5 is correct

d) 2, 3 and 5 is correct

e) All of the above is correct

CHAPTER 5

ARTEFACTS

(PHYSIOLOGICAL/NON-PHYSIOLOGICAL)

Artefacts may resemble cerebral activity and are often very subtle. The recognition of these artefacts is important to avoid an inaccurate interpretation of the EEG. The presence of correctible artefacts is considered to be evidence of poor technical standards.

5.1 Physiological artefacts

(arising from parts of patient's body)

A) Movement artefact

- Most common artefact with children
- All or most channels are affected
- When patients are awake there are more movement artefacts
- During sleep movement artefacts can be minimized

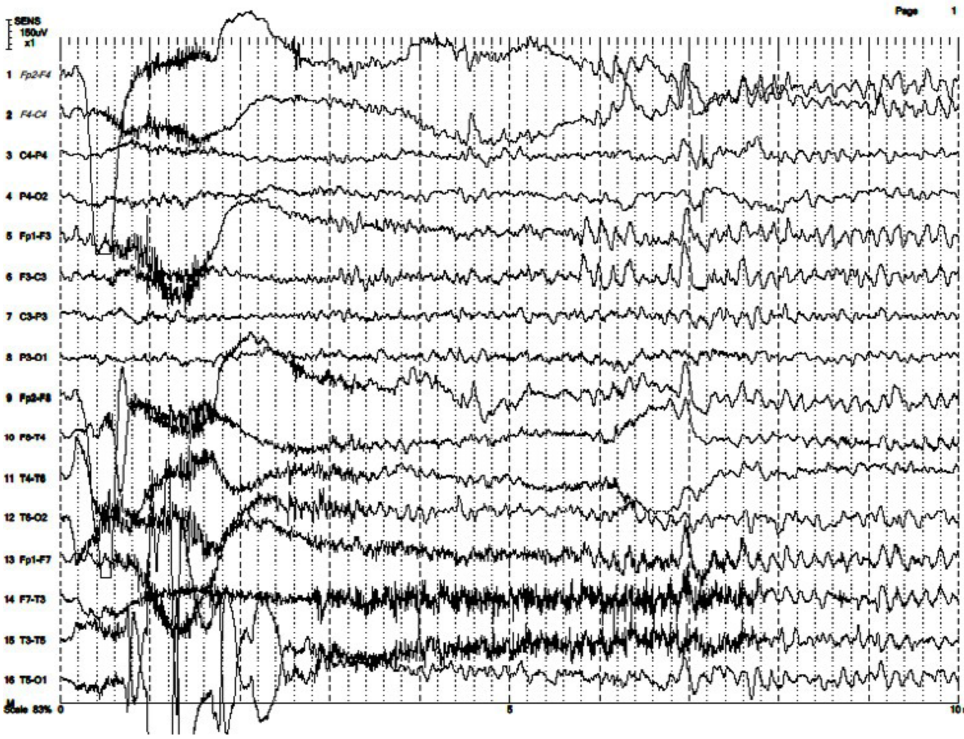


Figure 5.1.1 (Movement Artefact)

Movement artefact in sleep in a 9-year-old - EEG demonstrates that all channels are affected. Note how some drowsy normal EEG activity survives. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

B) Sweat artefact

This is caused by excessive sweating

- The salt in the sweat causes a chemical reaction on the scalp that shows up as a slow wave
- All channels are usually affected
- To eliminate sweat, the room and patient need to be cooled, if that does not work, the electrodes need to be removed, the head cleaned and the electrodes re-applied
- Excess clothing that may cause the babies/children to sweat should be removed. Use air conditioners to cool the room in tropical or humid areas. In the intensive care unit this may be a persistent problem as the heaters in the incubators cannot be turned off. Wrap the head with some gauze to prevent the electrodes from moving and causing bridging

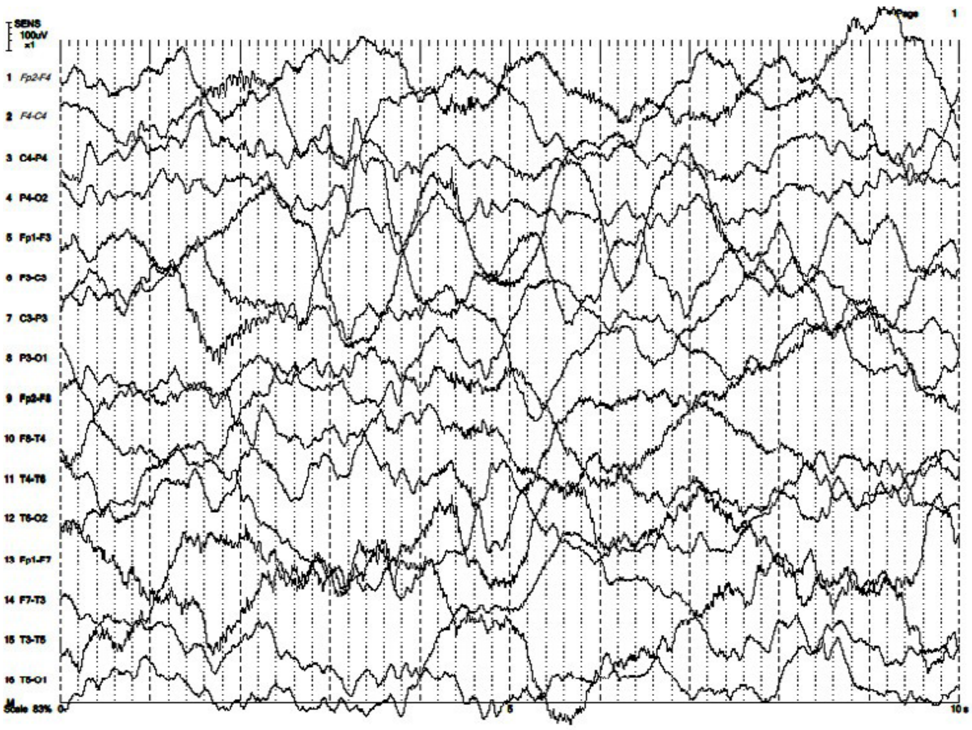


Figure 5.1.2 (Sweat Artefact)

Sweat artefact in sleep in a 1year old - EEG demonstrates the high amplitude delta activity noted with sweat artefact. Sleep spindles peek out from the deluge! Sleep alone would not create this quantity of delta. HF=70Hz, LF=0.3s, sensitivity=10uv/mm

C) Muscle artefact

- Occurs in electrodes over the temporal and pre-frontal regions.
- The artefact occurs when the patient is nervous, clenching their teeth or chewing
- Reassuring the patient and asking them to slightly open their mouths will be reduced or eliminate the muscle artefact. This is not so easy in children
- Babies and young children suckling on the breast/thumb, or a bottle can result in intermittent muscle artefacts
- During sleep muscle artefact is minimized

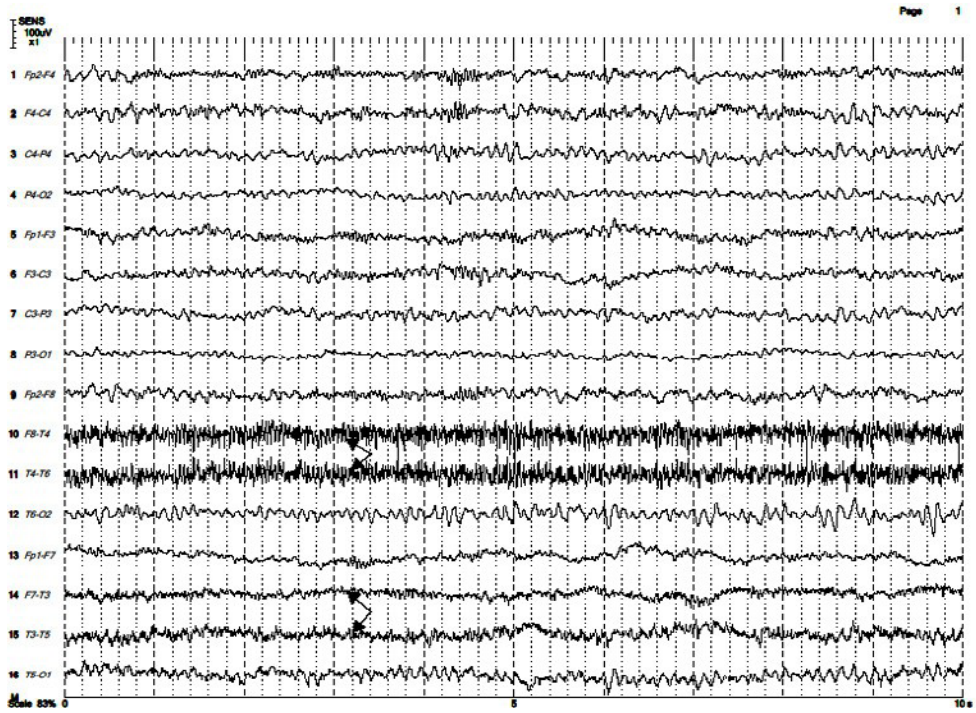


Figure 5.1.3 (Muscle Artefact)

An awake EEG with muscle artefact over the temporal regions in a 9-year-old as shown with arrows and more prominent over the right mid temporal region. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 5.1.4 (Chewing artefact)

Chewing artefact in a 3-year-old – EEG demonstrates all channels are affected with chewing. For an EEG the mouth should not contain chewable objects. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

D) Eye movement artefact

- Occurs commonly over the pre-frontal and frontal regions.
- Much more prominent during awake state than during sleep
- Eye movements in children are difficult to reduce as any effort to get them to close their eyes may result in a child becoming completely unco-operative. Passive eye closure (PEC) is feasible at any age.

  In older children placement of fingers on closed lids may help to reduce eye movements (eye lid flutter)

Figure 5.1.5 (Eye movement artefact)

Eye blinks in a 9-year-old - EEG in the bi-polar montage shows eye movements in the pre-frontal and frontal electrodes. Note the muscle artefact at T3. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

E) Electrocardiograph artefact (ECG)

- Is a very common artefact and is present from the onset of the recording.
- It may be a major problem when using a common referential montage where the A2/A1 is placed too low on the mastoid and the heart rate is picked up. It may also record anterior temporal spikes.
- In paediatrics ECG artefact is less of a problem as the bi-polar montage is frequently used but it could also mimic spikes
- It is also seen in people with short muscular necks
- It is not a severe problem unless it impairs the ability to score sleep stages during a polysomnography with its limited EEG channels

Figure 5.1.6 (ECG artefact)

An example of ECG artefact in a 3-year-old overweight child during sleep in the referential montage. Note the sleep spindles maximally over the fronto-central regions. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

F) Bridging artefact

- The electrolyte in sweat interacts with the electrode paste and can produce a salt bridge
- Occurs between any two adjacent electrodes on the head
- The artefact is caused when there is movement or sweating and the conduction paste is spread to adjacent electrodes
- This may cause a "no signal deflection" (cancelling out) effect in one or many channels

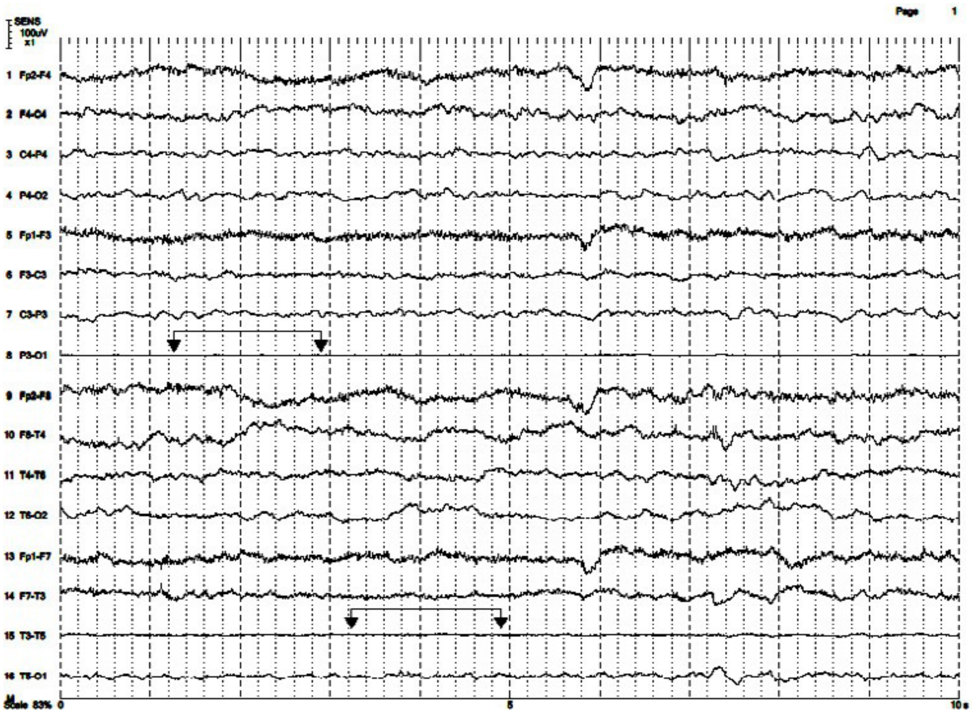


Figure 5.1.7 (Bridging artefact)

Bridging artefact in a 1-month-old. If adjacent electrodes e.g. P3 - 01, T3 - T5 have moved closer or together a cancelling out effect will occur. A salt bridge created by running conduction paste may produce the same effect. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

5.2 Non-physiological artefacts

(arising from other interference outside the patient)

These can be further divided into instrumental and environmental artefacts:

5.2.1 Instrumental

A) Electrode artefact

- Electrode application and electrode movement are the most common problems in EEG recording.
- When an electrode is loosely attached to a patient and there is difference in potentials, the varying resistance will give rise to bursts of 50 hertz artefact. This can also occur when there is too much paste under the electrode
- This can also occur when a lead is not plugged in properly at the head box
- Electrode artefact can also occur if an electrode is broken or faulty. When this occurs, the electrode should be removed and replaced

- The use of clips leads for pad electrodes may produce a “clip artefact” if the contact resistance of the oxidized surfaces of the metals is quite high; a change in the resistance will occur with each patient movement
- Electrode artefact is readily identified in a bi-polar montage as it may appear in two adjacent channels. With referential recordings electrode artefact will occur in one channel or in all.

Figure 5.2.1.1 (Electrode artefact)

An example of an electrode artefact in F3-C3 and C3-P3, where C3 is the common electrode be- tween the two derivations. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

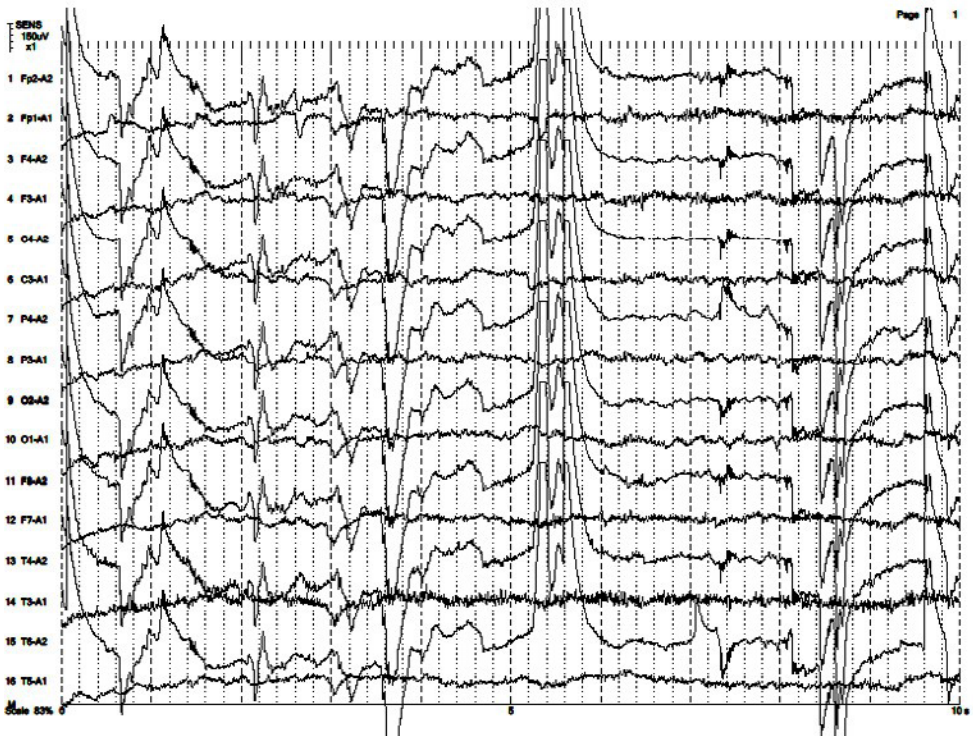


Figure 5.2.1.2 (Electrode artefact)

Electrode artefact in a referential montage in an awake 10-month-old where A2 is artefactual.

B) Machine faults

- Loss of main supply to the machine. Often check to see if the plug is connected to the wall socket and switched on. Alternatively, a fuse might be blown
- Paper machines will not work if ink has run out or solidified or when the switch to a particular channel is accidentally off
- There is interference at the mains or sometimes from other frequencies (dialysis machines, ventilators, lifts etc.)

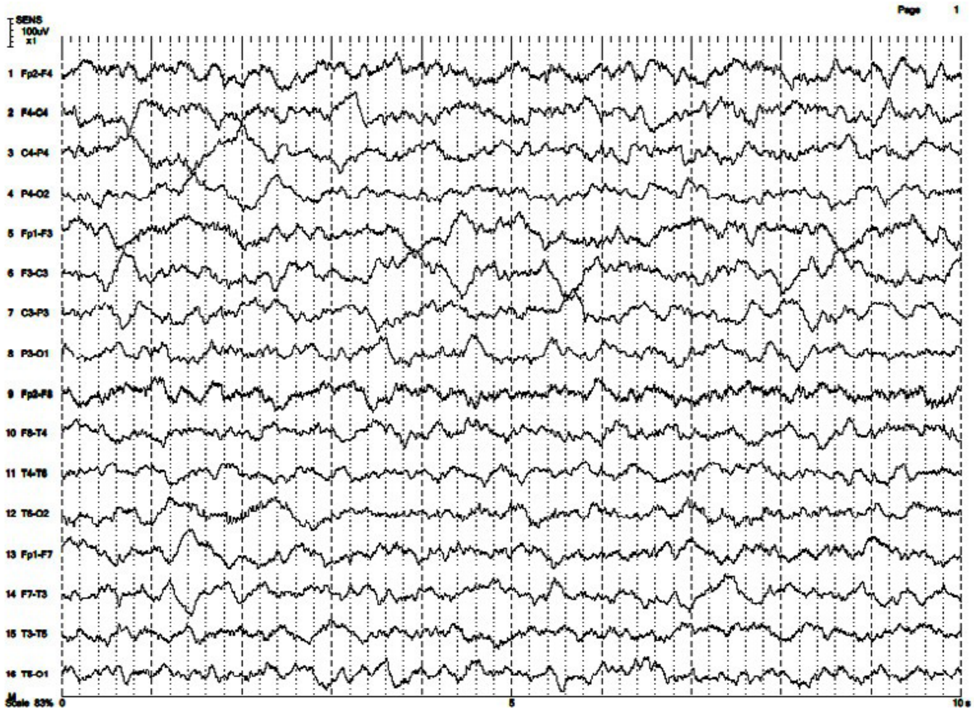


Figure 5.2.1.3 (Open circuit)

An example of no field of any potential (open circuit). HF=70Hz, LF=0.1s, sensitivity=10uv/mm

C) Signal or pen blocking

- Common artefact seen in paper EEG machines
- Occurs when the output sensitivity is expected, then the sensitivity setting on the channel. As a result, the waveform is distorted
- On digital machines this may occur with ECG artefact
- To correct this, change all sensitivities or particular channels where the sensitivity is expected to be high

5.2.2 Environmental

A) Electromagnetic interference (50 Hz activity)

- 50 hertz activity is almost always present in the environment
- The strength of the 50 Hz activity is greatly influenced by other machines e.g.in intensive care units (cardiac, oxygen saturation monitors, brain and apnoea monitors, ventilator, incubator etc.)
- 50 hertz activity can be seen when an electrode is faulty, disconnected from the head box or when the cable between the head box and the machine is disconnected or faulty
- As mentioned above, high impendence can cause 50 hertz artefacts, when an electrode is not properly making contact, or there is a large variety of electrode impedances.
- Correcting 50 hertz artefact:
    a. turn off machines, heated blankets etc. which can be switched off for a limited period whilst recording the EEG without impacting on patient care. Using a bag to ventilate the patient is sometimes necessary

    b. use the 50 hertz filter (*only* if all other methods fail)

    c. tying all electrode lines together can reduce the electromagnetic interference

    d. if all fails remove electrodes, clean skin and reapply. Check that all impedances are low and equal

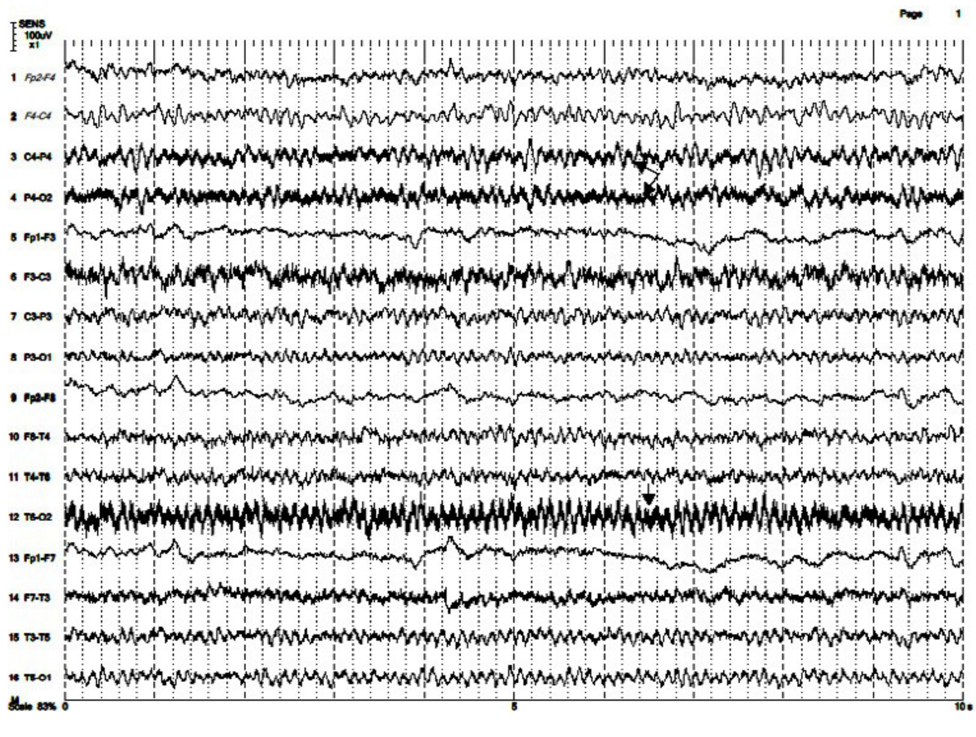


Figure 5.2.2.1 (50 Hz artefact)

50 hertz activity as identified by the arrows. 50 hertz line in itself smooth whereas the muscle artefacts are jagged. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

B) Electrostatic interference

- The body and electrodes are conductors of electrostatic interference
- Electrostatic interference arises from a variety of electrical equipment connected with mains frequency
- Irregular potentials are also picked up from charged objects moving in the vicinity of the patient (e.g. personnel wearing rubber or plastic shoes or dressed in synthetic fabrics)
- In the form of capacitive interference which can be induced by movement of the wires in the input cable. Therefore, all cables should be arranged tidily in a position where they would not be knocked or trodden on. Input cables should be 1.5 meters long or less to avoid capacitive currents. Therefore, extension cords cannot be used.

Figure 5.2.2.2 (Electrostatic artefact)

Electrostatic artefact during a sleep study – It appears in all channels and overshoots the sensitivity. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

C) Radio-frequency interference

- These signals are normally outside the bandwidth of the EEG machine
- Low frequencies such as hospital paging systems, mobile transmitters (used by police and ambulance services) and diathermy equipment
- When selecting a location of the EEG department the possibility of radio frequency interference must be taken into consideration

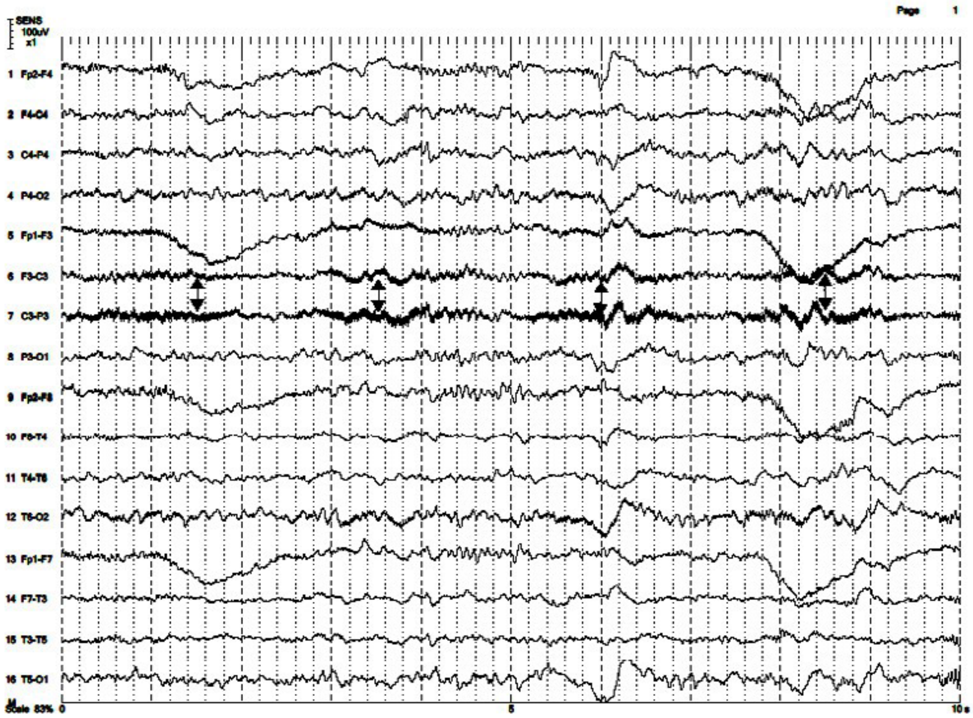


Figure 5.2.2.3 (Radio frequency artefact)

Radio frequency interference during a sleep study in a 13-year-old - intermittent runs of 50Hz artefact as indicated by arrows. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Reduction of external electrical interference

- The new EEG machines with a common mode rejection ratio of 10 000 to 1 or higher are not seriously affected by the levels of interference experienced in wards, laboratories or office environments
- However, some common electrical appliances are easily overlooked which include fluorescent lights and automatic switchgear of all kinds, notably in thermostats (air conditioners, coffee makers, refrigerators etc.)
- Screening the recording area e.g. the use of a Faraday cage, is not only expensive but often unsuccessful

Outcome goals for Chapter 5 - trouble shooting artefacts

- Make sure your machine is plugged in to wall socket before recording
- Before recording assure your headbox is attached to the cable if using a mini box
- Recognize an open circuit recording (an open circuit is an incomplete circuit. This occurs when the head box is disconnected from the main cable connected to the EEG machine)
- Recognize the type of artefact
- Check to see which channels or electrode pairs are affected
- Observe if the artefact is occurring constantly or periodically.

By process of elimination determine the probable or possible cause and then seek the source of the artefact

Questions for chapter 5

1 Electrode impedance imbalance will:

a) Produce an electrode "pop"

b) Increase sharp waves in the EEG

c) Produce 50 Hz interference on the graph

d) Be uncomfortable for the patient

e) All of these

2. With excessive high frequency attenuation muscle artefact can be distorted to look like:

a) Beta activity

b) Lambda activity

c) Alpha activity

d) Theta activity

e) Eye blink artefact

3. If 2 adjacent electrodes become connected by mistake:

a) They will produce scalp negativity

b) They will produce scalp positivity

c) They will produce a 'salt bridge'

d) They will produce none of the above

4. Common artefacts produced by the patient:

1) Movement

2) Sweat

3) Eye blinks

4) Electrostatic

5) 50 hertz

a) 1 and 4 is correct

b) 1, 2 and 3 is correct

c) 2 and 5 is correct

d) 2, 3 and 5 is correct

e) None of the above is correct

5. Artefacts that can be found in ICU:

1) 50 hertz

2) ECG

3) Open circuit

4) Electrode

5) Bridging

a) 1 and 4 is correct

b) 1, 2 and 3 is correct

c) 2 and 5 is correct

d) 2, 3 and 5 is correct

e) All of the above is correct

CHAPTER 6

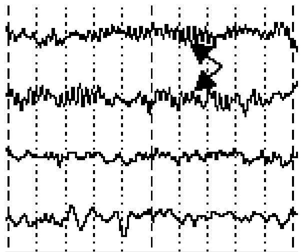
NORMAL WAVEFORMS FROM NEONATAL TO ADOLESCENCE (AWAKE/ASLEEP)

Table 3: Normal waveforms

Age	Approximate value range of posterior waveforms (awake)
< 3 months	No discernible dominant occipital activity
3 months	3-4 hertz
6 months	5-6 hertz
9-18 months	6-7 hertz
2-3 years	7-8 hertz
7 years	9-10 hertz
15 years	10-11 hertz

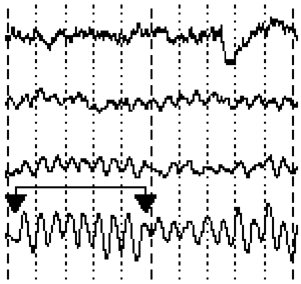
EEG activity can be broken down into four distinct waveforms

- Beta (β) > 13 hertz
- Alpha (α) 8-13 hertz
- Theta (θ) 4-7 hertz



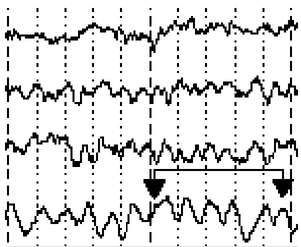
Beta activity

Beta activity is normal activity present when the eyes are open or closed and is seen more often in children owing to sedations. It is seen in the channels over the fronto-central regions. Barbiturates and benzodiazepines are known to increase the amount of beta activity in the EEG



Alpha activity

Alpha is normal activity in awake adults and the prominent rhythm in a child by 3 years of age. It is mainly seen in derivations including O1, O2; P3, P4 and T5, T6 and is fairly symmetrical. It is only seen when the eyes are closed and should disappear or attenuate in amplitude when the eyes are open. Table 3 lists normal frequencies of "background" activity by age. There can be an acceptable difference in alpha amplitude of 50% between hemispheres in adolescence.

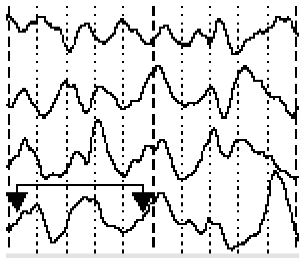


Theta activity

Theta activity can be classed as both a normal and abnormal activity depending on the age and state of the patient. In adult's rhythmic theta is a normal feature of drowsiness. However, it can also indicate brain dysfunction if it is seen in a patient who is alert and awake.

Theta activity is so prevalent among normal children that it cannot help identify cerebral dysfunction (Blume et al 2011). In younger patients from 3 months to 3 years, theta activity may predominate.

Delta activity is only normal in an adult patient if he or she is in a moderate to deep sleep. If seen at any other time it would indicate brain dysfunction. At <3 months of age there is no discernible dominant occipital activity. At 3 months of age there is 3-4 hertz activity as normal background. Normal low voltage delta activity may appear in childhood up to approximately 10 years. Curiously, occipital delta may normally augment with eye *opening*.



Delta activity

The effects of age in childhood and adolescence show progressive EEG changes. As cerebral maturation proceeds faster in some children than in others, such EEG progression may vary markedly among normal children. Diffuse low voltage delta activity with preserved "background activity", progressively diminishing with age, *normally* appears to about age 10-12 years! However, progression through other age-related phenomena may be slowed in patients with developmental delay.

6.1 Normal Phenomena (awake/asleep)

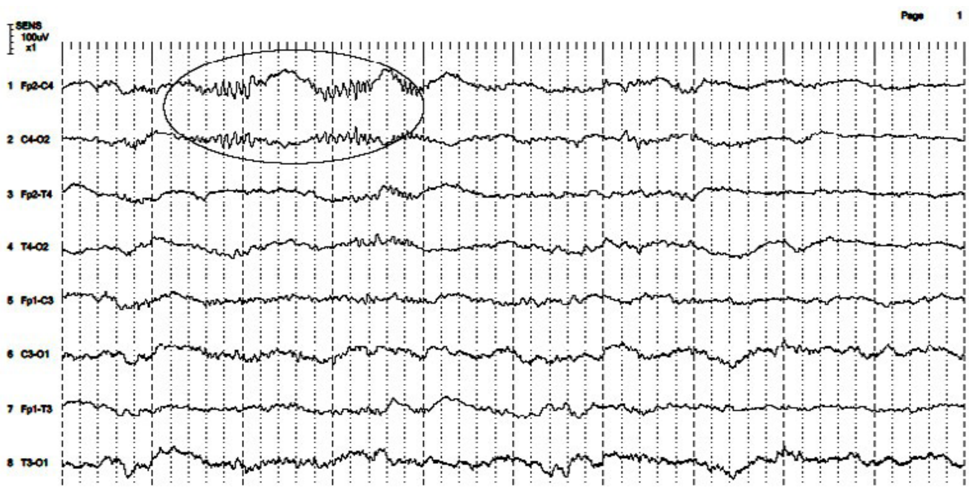


Figure 6.1.1 (45-week-old)

A 45-week premature baby in natural sleep. Delta brushes seen with a neonatal montage. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

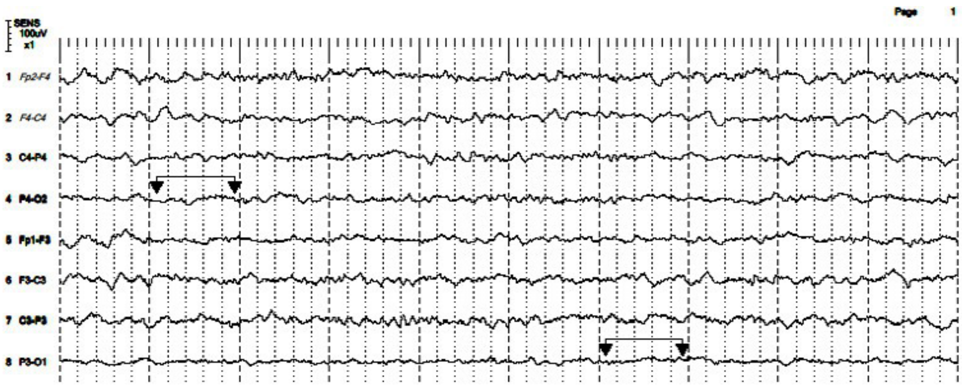


Figure 6.1.2 (18 day old)

Natural sleep EEG in 18 days old neonate. Minimally discernible waveforms seen over the posterior head regions. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

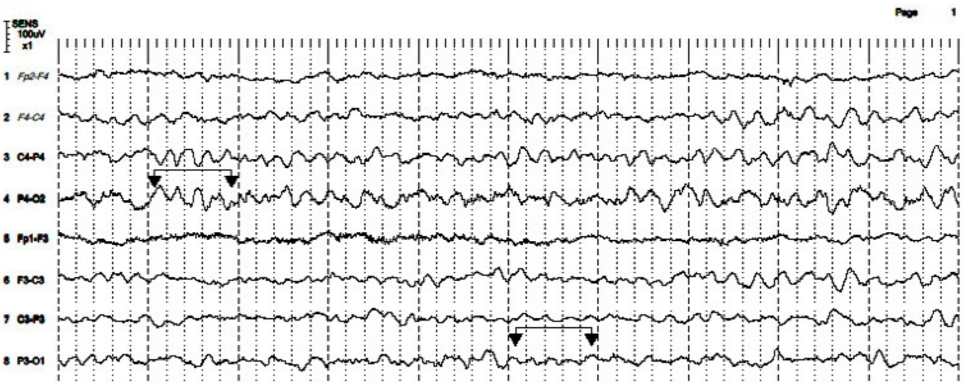


Figure 6.1.3 (1 month old infant)

An example of the appearance of theta activity in an awake 1 month old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

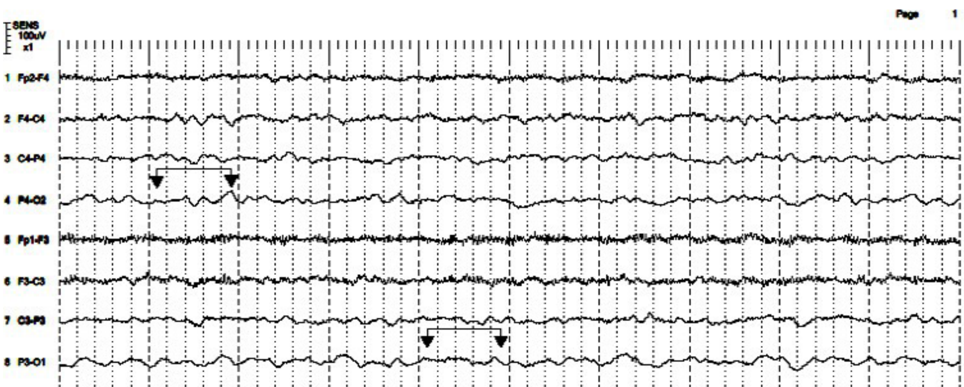


Figure 6.1.4 (2-month-old infant)

Theta activity in an awake 2-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 6.1.5 (3-month-old infant)

3-4 Hz theta activity in an awake 3-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 6.1.6 (4-month-old infant)

5 Hz theta activity in an awake 4-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 6.1.7 (6-month-old infant)

5-6 Hz theta activity in an awake 6-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 6.1.8 (8-month-old infant)

7 Hz theta activity and muscle artefact in an awake 8-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

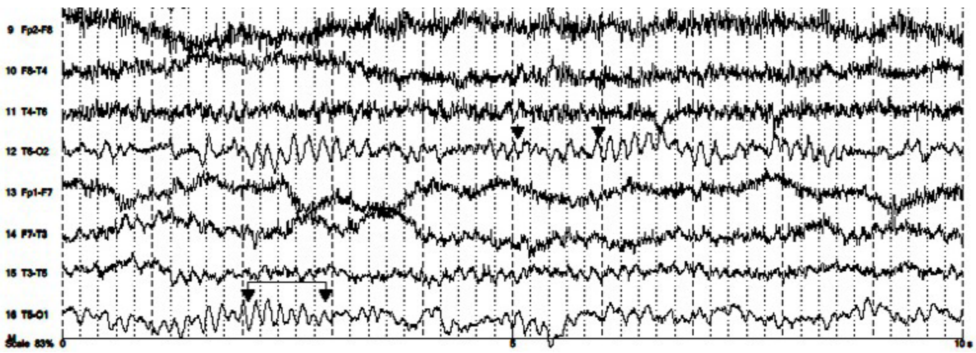


Figure 6.1.9 (10-month-old infant)

6-7 Hz theta activity with muscle and movement artefact in an awake 10-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 6.1.10 (1-year-old child)

An example of an awake 1-year-old child showing 6 Hz theta activity with lots of eye blink and muscle artefact. HF=70Hz, LH=0.1s, sensitivity=10uv/mm

Figure 6.1.11 (2-year-old child)

7 Hz theta activity in an awake 2-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

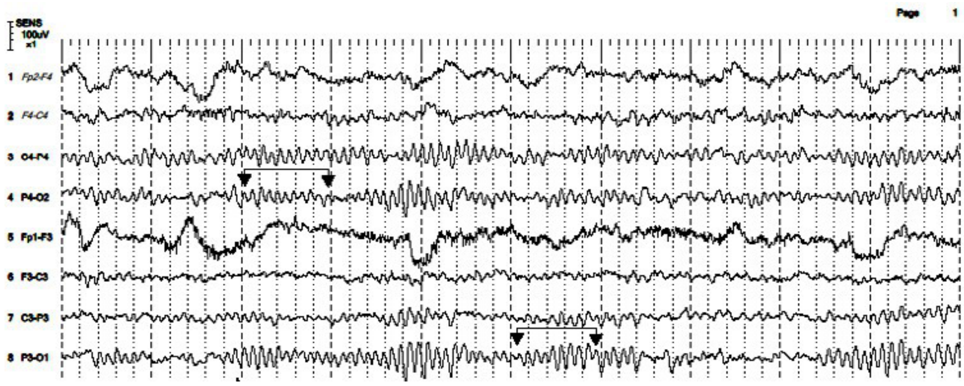


Figure 6.1.12 (11-year-old child)

Well-formed waxing and waning of 9-10 Hz alpha activity in an awake 11-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

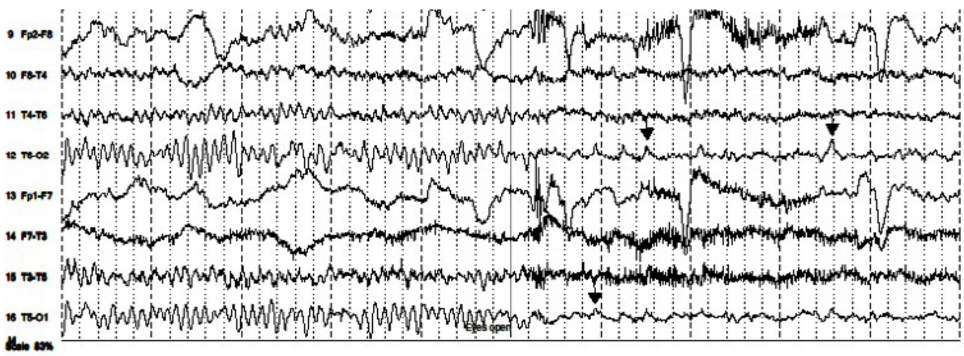


Figure 6.1.13 (attenuation of alpha)

An example of attenuation of alpha on eye opening, replaced by Lambda. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Sleep

(A) "V"- waves

- Occur in light sleep
- May be seen as early as 3-4 months and are well developed by 5 months
  Maximum at 3-4 years
- May be symmetrical or asymmetrical
- May be seen phase reversing over the central and frontal head regions

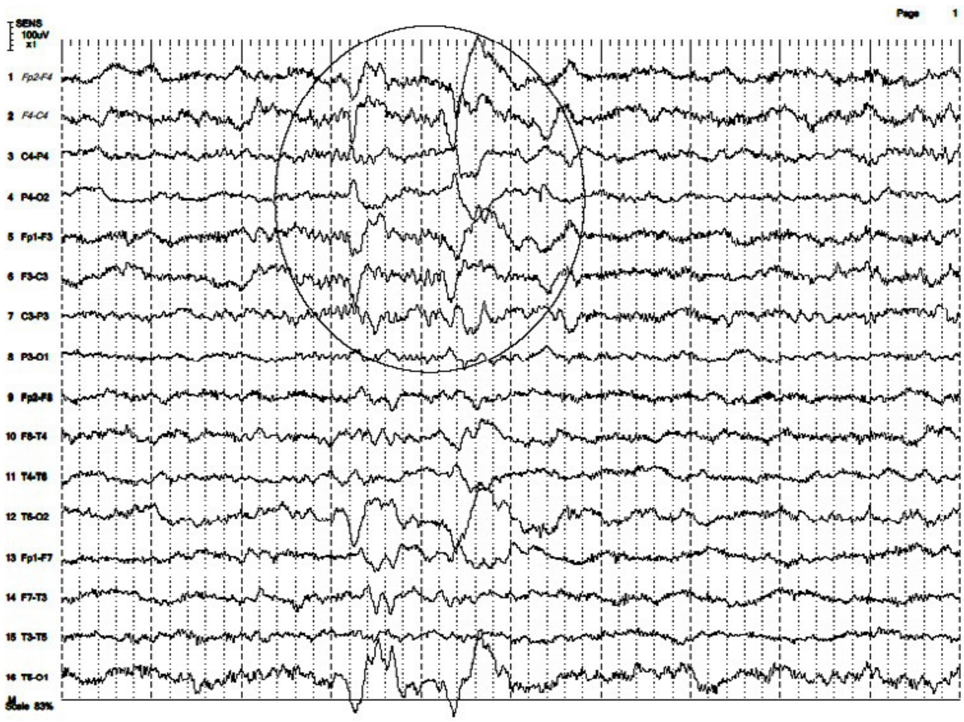


Figure 6.1.14 ("V" waves and sleep spindles)

"V" waves with sleep spindles + overriding beta in 2-year-old infant undergoing sleep EEG with sedation. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

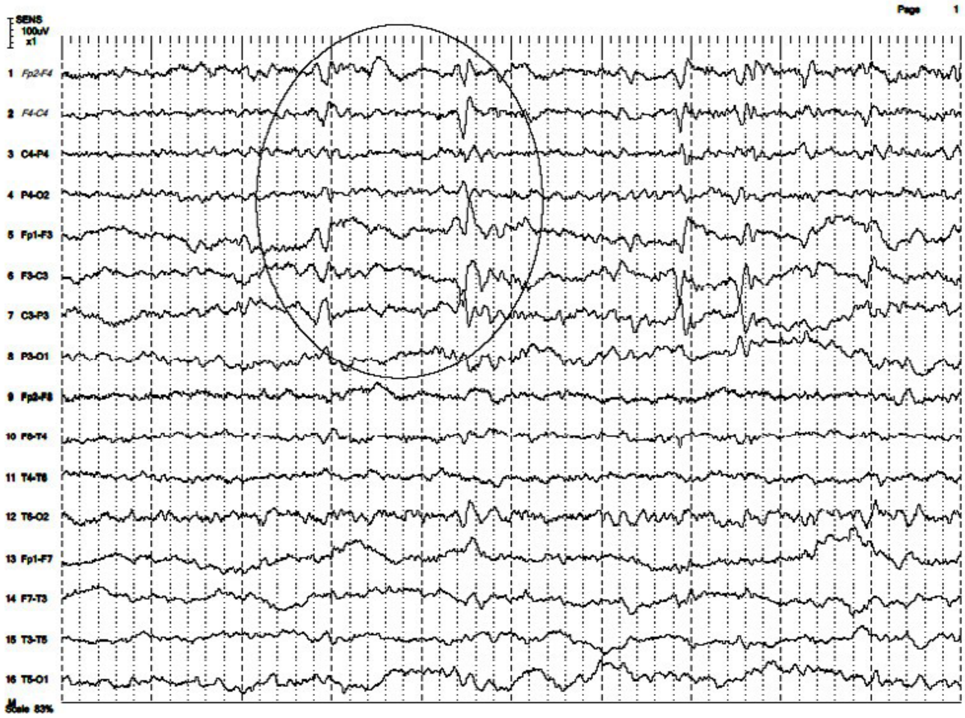


Figure 6.1.15 ("V" waves in a 12-year-old)

An example of "V" waves in 12-year-old child's sleep EEG - for spindles and "K" complexes see normal variants. Note the asymmetry of some normal "V" waves on the right. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

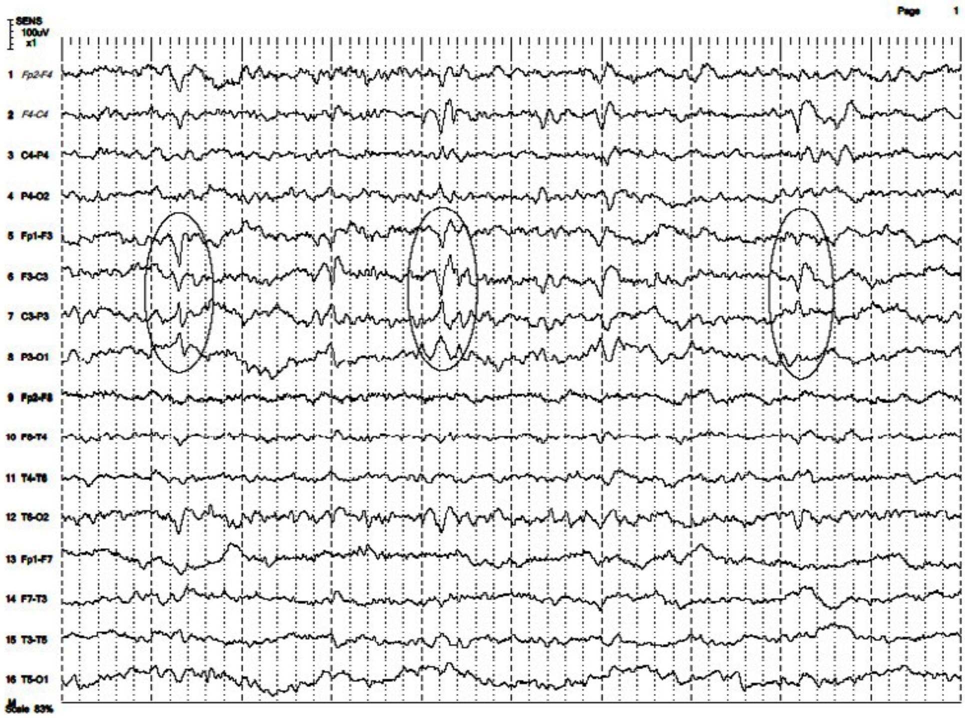


Figure 6.1.16 ("V" waves)

"V" waves in a 12-year-old child during stage 1 sleep. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

(B)

- Appear in light sleep a few days (7-10 days) after full term birth
- More clearly expressed by 3-9 months
- Usually found in the range of 0.5 to 2 seconds
- Prolonged spindles (3 or 4 seconds) are evident in young infants and decrease with maturation (Blume & Kaibara, 1999; Fogel, Smith & Beninger, 2010)
- *Extreme spindles* which appear apiculate and prolonged (>2 sec) and can be associated with learning difficulties (Fogel, Smith & Beninger, 2010; Schabus et al., 2006) High prevalence not- ed in children with mental retardation under the age of 5yrs (Gibbs & Gibbs, 1962)
- Decrease or lack of spindle activity can be an indication of general abnormal maturation process (Schabus et al., 2006)
- Combined with "V" waves are called "K complex"

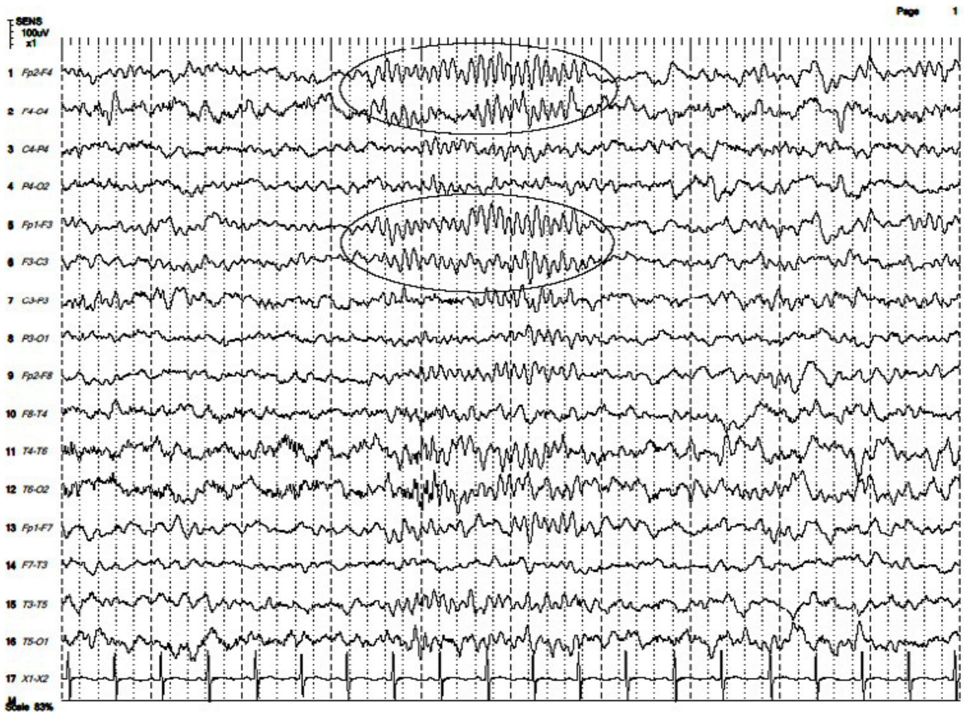


Figure 6.1.17 (normal spindles)

An example of normal sleep spindles in 1 year old infant's sleep EEG. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

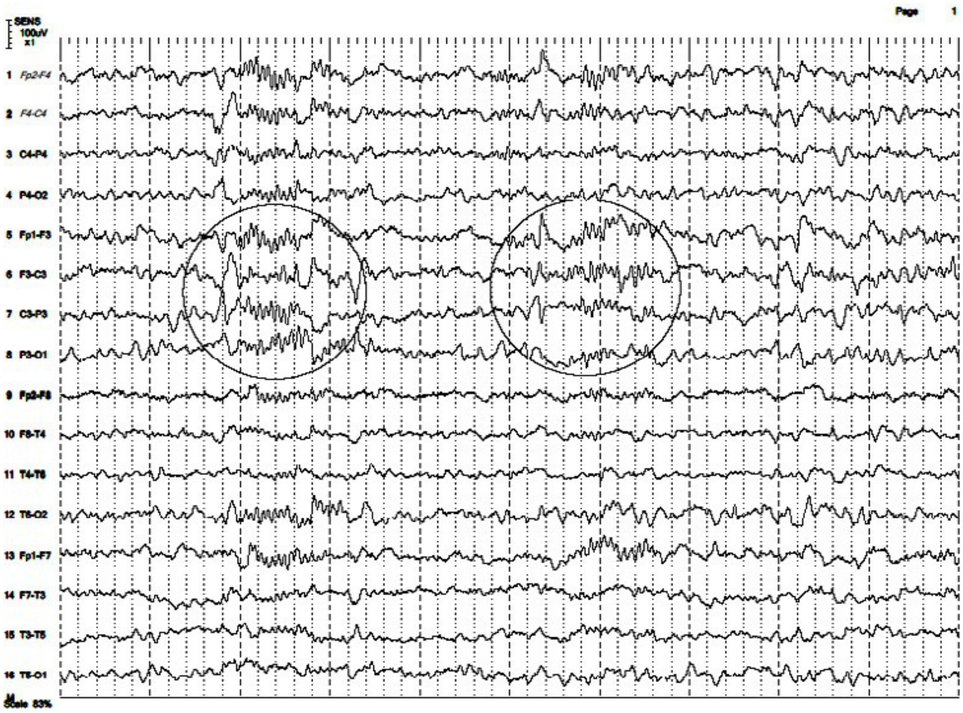


Figure 6.1.18 [“K:” complex (“V” waves + spindles)]

An example of “K” complex (v waves + spindles) in a 12-year-old child’s sleep EEG.HF=70Hz, LF=0.1s, sensitivity=10uv/mm

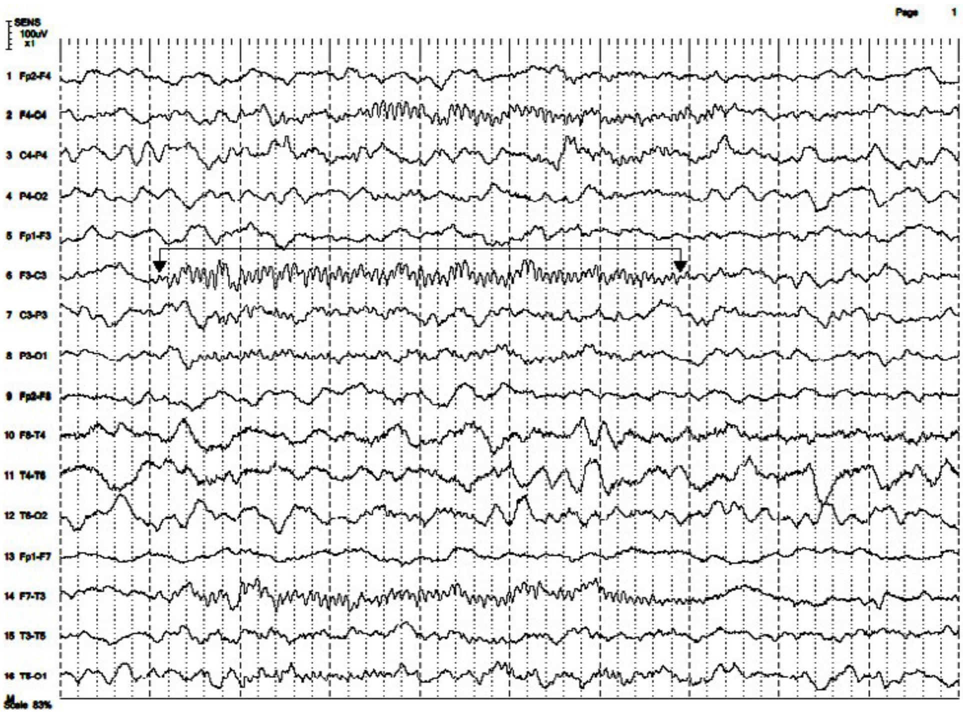


Figure 6.1.19 (Prolonged spindles)

Prolonged spindles in a 4-month-old infant’s sleep EEG. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Outcome goals for Chapter 6- waveforms

- Recognize your 4 types of waveforms (delta/theta/alpha/beta)
- Brain maturation from neonatal to adolescence and how the waveforms change accordingly
- Values in Table 3 above represent value ranges of waveforms for age
- The difference of an awake EEG and asleep EEG – look for features of sleep (the emergence of slow waves, sleep spindles and V waves)
- The difference between background activity with eye closure and eye opening
- Count your background rhythms over the posterior head regions (O2, O1, P4, P3, T6 & T5)

Questions for chapter 6 - waveforms

1 Prolonged and extreme sleep spindles: -

1) Decrease with brain maturation
2) Can reflect learning difficulties
3) Can be seen up to 6 months of age
4) Can continue up to 3 years of age
5) Can be seen in mentally retarded children

a) 1 and 4 is correct
b) 2 and 3 is correct
c) 1, 2, 3 and 5 is correct
d) 5 is correct
e) None of the above is correct

2. The first person to record electrical activity from the human brain in 1958 was:

a) Hans Berger
b) Adrian and
c) Penfield and Jasper
d) Charcot
e) Gibbs and Gibbs

3. "V" waves:

1) Can be seen in the first month of life

2) Can be symmetrical or asymmetrical

3) Can be seen in stage 1 sleep

4) Phase reverses frontally or centrally

5) Can be seen with sleep spindles

a) 2, 3, 4 and 5 is correct

b) 2 and 3 is correct

c) 5 is correct

d) 1 and 4 is correct

e) None of the above is correct

4. A 3-year-old has a background of:

1) 2-3 hertz delta activity

2) 5-6 hertz theta

3) 6-7 hertz theta

4) 7-8 hertz

5) 8 hertz activity

a) 3 and 4 is correct

b) 2 and 3 is correct

c) 4 and 5 is correct

d) 1 is correct

e) None of the above is correct

5. The occurrence of beta activity:

1) Can increase during drowsiness and stage 2 sleep

2) Can be seen occipitally

3) Can be seen over the fronto-central regions

4) Can be seen with barbiturates

5) Can be seen overriding the background rhythms

a) 1 and 3 is correct

b) 3 and 4 is correct

c) 1, 3, 4 and 5 is correct

d) 2 is correct

e) None of the above is correct

6.2 NORMAL VARIANTS

A) Posterior slow waves of youth

- These are slower rhythms that intersperse with trains of alpha rhythm
- Found over the occipital channels where alpha activity is most prominent
- Is quite prominent between the ages of 6-12 years but normal, in diminishing amounts up to age 30 years

Figure 6.2.1 (Posterior slow waves of youth)

An example of posterior slow waves in an awake 6-year-old - intermixed with the normal background rhythms. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

B) Slow posterior rhythm

- Found over the posterior head regions unilaterally or bilaterally
- May occur in brief sequences or in prolonged runs
- May be associated with absence epilepsy if spike waves can be demonstrated, but not exclusively (also seen in normal children)
- Occurs more commonly in younger children

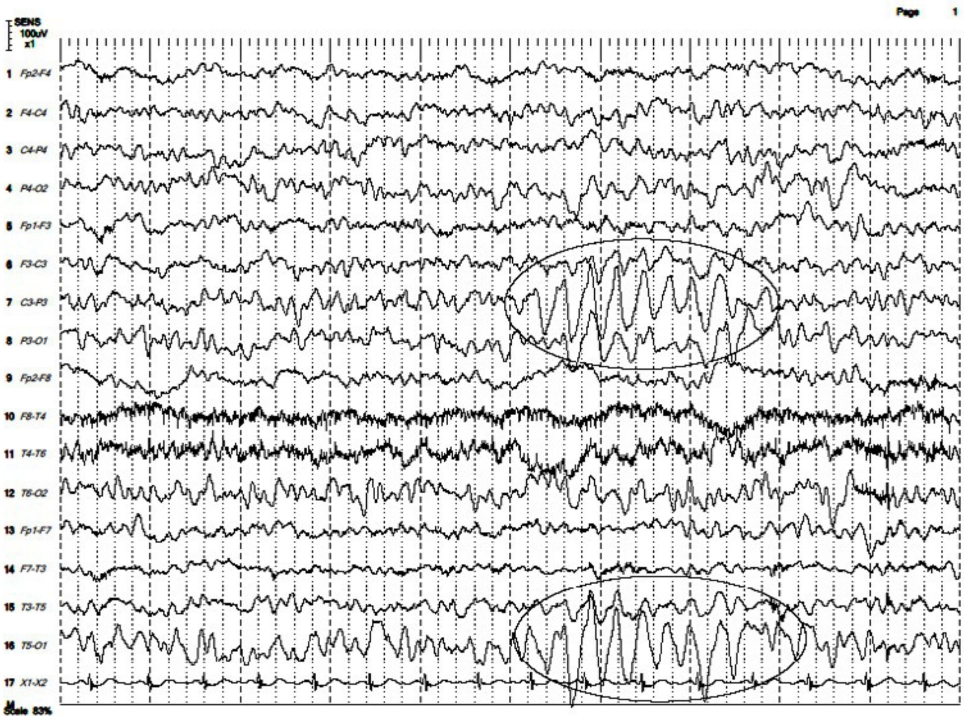


Figure 6.2.2 (Posterior slowing)

An example of unilateral posterior slowing in an awake 10-year-old child. See 3 hertz spike and wave activity chapter 7 for posterior slowing with superimposed spikes. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

C) Slow alpha variant

- Found over the posterior head regions
- Occurs when there is partial fusion or two alpha waves creating a notched waveform at half of the alpha frequency

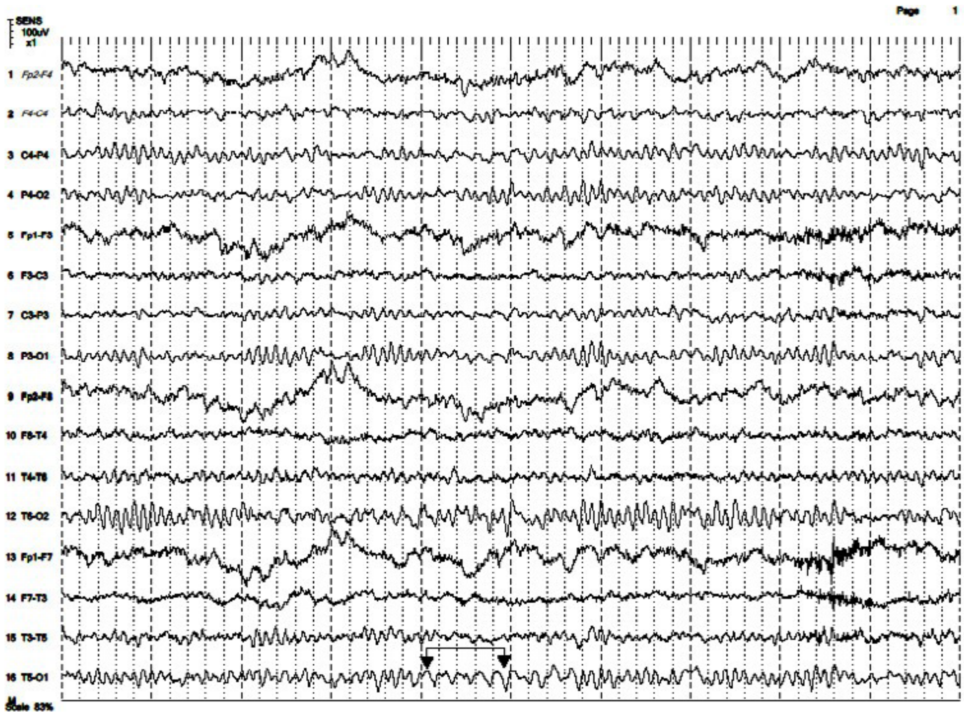


Figure 6.2.3 (Slow alpha variant)

An example of slow alpha variant in an 11-year-old child is showing a notched waveform at half the alpha frequency. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

D) Lambda waves

- Seen in the posterior head region during eye opening. Present at all ages.
- They are sharply contoured occipital transients evoked by saccadic eye movements scanning a well illuminated picture or complex design
- Seen as surface positive deflections

Figure 6.2.4 (Lambda waves)

Typical example of lambda waves over the posterior head regions during eye opening in an 11year old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 6.2.5 (Lambda waves doing a puzzle)

An example of runs of Lambda waves in an 11-year-old child, doing a puzzle. Note the muscle artefact over the temporal regions. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

E) Mu (wicket/arcade/comb or somatosensory)

- Mu occurs over the central head regions during the awake state (over the rolandic area)
- Does not attenuate with eye opening
- Movement of the contra lateral thumb can block/attenuate mu waves

Figure 6.2.6 (Mu activity)

An example of Mu activity over the central head regions during eye opening in an awake 11-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

F) Positive Occipital Sharp Transients of Sleep (POSTS)

- Occurs in deep drowsiness and can persist into light and deep sleep
- Found in the occipital areas 02, 01, T6, T5
- Most commonly seen in adolescents and young and middle-aged adults

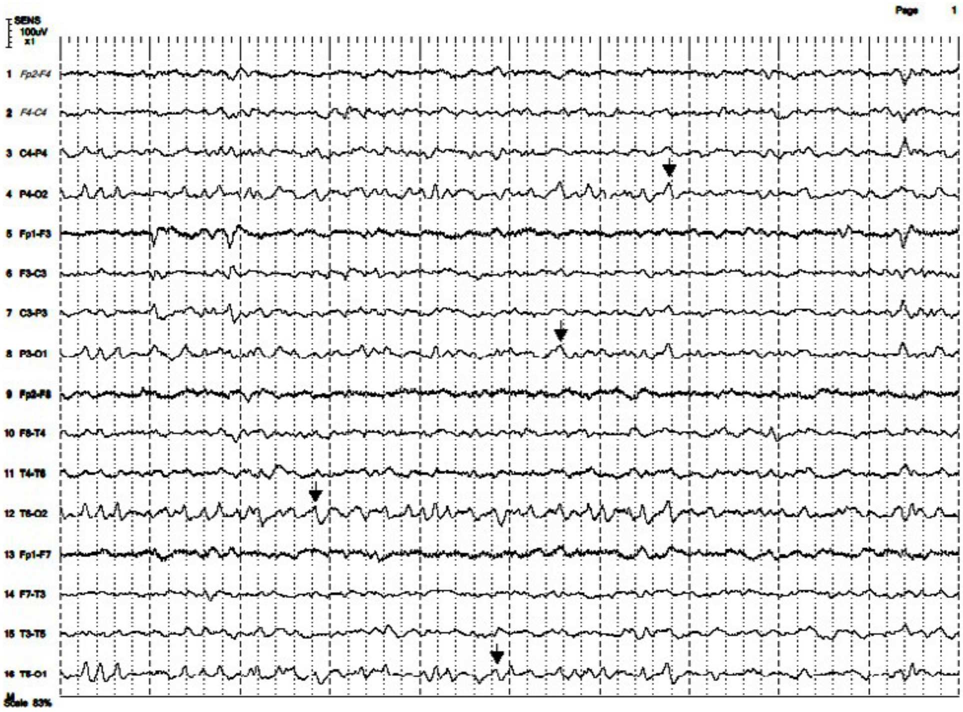


Figure 6.2.7 (Posterior occipital sharp transients of sleep)

An example of POSTS in an 11-year-old child during stage 1 sleep. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

G) Excess Beta

- Seen in children that have been sedated
- Occurs generalized and overrides normal sleep activity
- Enhanced by barbiturates

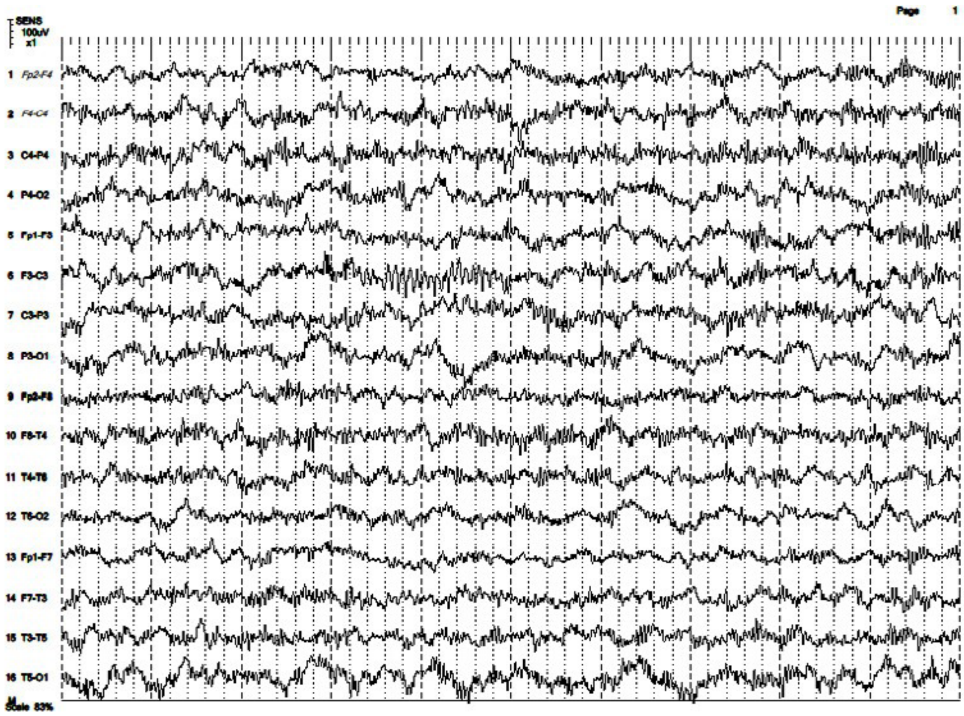


Figure 6.2.8 (Excess beta)

An example of excess beta with sedation in 1 year old infant showing overriding normal sleep rhythms such as spindles. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

H) Low voltage

- 10% of individuals have low voltage mixed frequency activity which is a normal

Figure 6.2.9 (Low voltage)

An example of low voltage mixed frequency activity in an awake 11-year-old child with no prominent occipital waveforms noted. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

I) Breech Rhythm

- high amplitude activity seen over a skull defect

Figure 6.2.10 (Breech rhythm)

Breech rhythm in a 7-year-old child due to a burr hole over the left central head region. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

J) Burst pattern of drowsiness (Hypnagogic hypersynchrony)

- Generalized high amplitude of theta activity (4-6 Hz) seen during drowsiness in childhood
- Commonly is maximum over the mid-frontal region

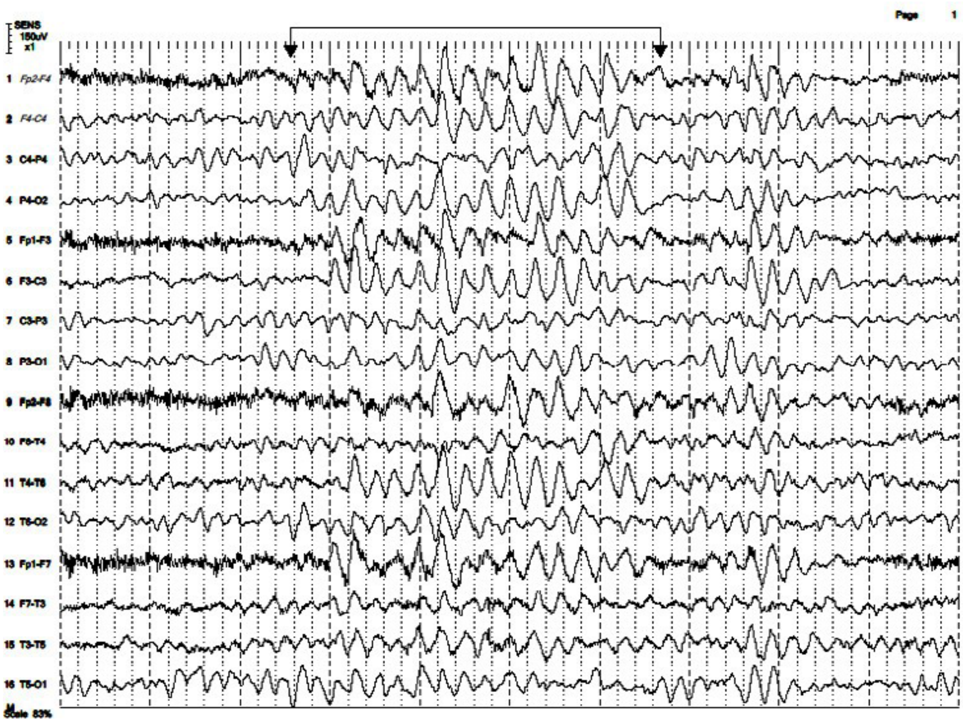


Figure 6.2.11(Hypnagogic hypersynchrony)

Runs of theta activity during drowsiness in a 3-year-old child. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

K) Fourteen and six per second positive spikes

- Occur in drowsiness or light sleep
- Combed shaped at 14 and/or 6 to 7 per second
- Can be seen widespread but more over the posterior temporal regions

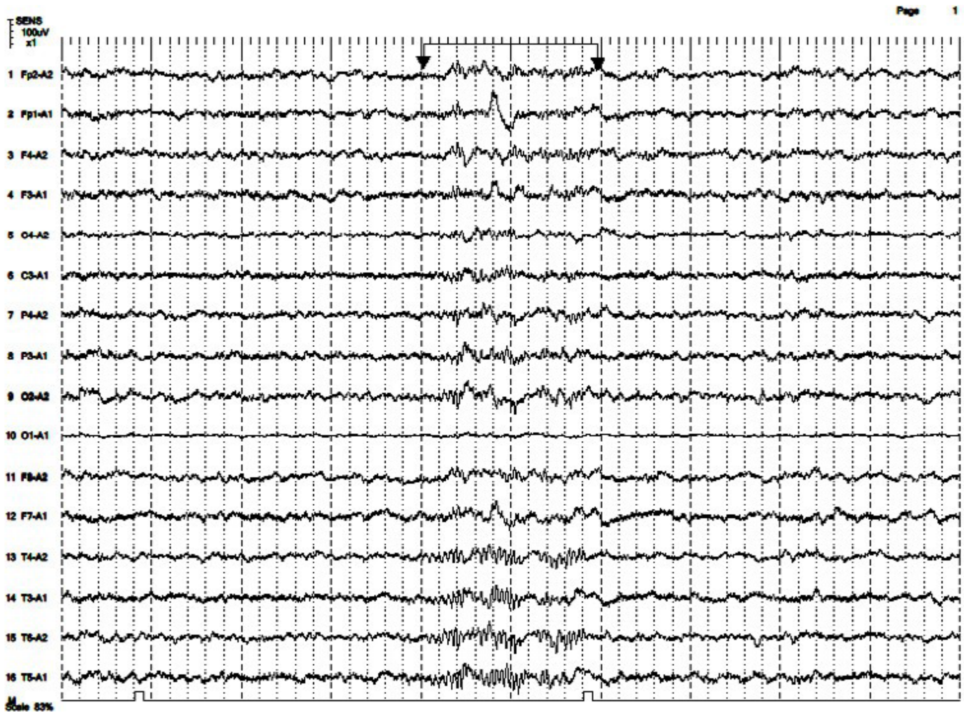


Figure 6.2.12 (14 and 6 positive spikes)

An example of 14 and 6 per second positive spikes in a 10-year-old child during drowsiness. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Outcome goals for Chapter 6 - normal variants

- Recognize normal variants and waveforms for each age range including sleep
- Normal variants are not potentially epileptogenic
- In the case of prolonged spindles repeat EEG after 1 year of age to document brain maturation

Questions for chapter 6 - normal variants

1 Posterior slowing:

1) Are seen over the frontal head regions
2) Are seen posteriorly
3) Can be a normal phenomenon
4) Is often associated with absence seizures
5) Attenuates with eye opening

a) 1 and 3 is correct
b) 3 and 4 is correct
c) 2, 3, and 4 is correct
d) 2 is correct
e) None of the above is correct

2. Lambda waves are:

a) Sharply contoured and surface positive
b) Rounded and surface positive
c) Negative
d) Seen with eye closure
e) Possibly abnormal

3. A 10 hertz central rhythm which fails to block on eye opening is most likely:

a) A rolandic seizure
b) Mu
c) Represented of a parasagittal meningioma
d) Kappa rhythm
e) Psychomotor variant

4. “V” waves:

a) Are of higher voltage in adults than children

b) Are of higher voltage in children than adults

c) May be occipital in early youth

d) May be maximum bi-temporally

e) None of the above statements about “V” waves is correct

5. Bursts of diffuse, high amplitude, sinusoidal, 3-5 hertz waves can be a manifestation of normal drowsiness in the EEG of a subject:

a) Under 1 year of age

b) Between 1 and 8 years of age

c) Between 8 and 21 years of age

d) Between 21 and 65 years of age

e) Over 65 years of age

CHAPTER 7
ACTIVATION PROCEDURES

Hyperventilation, Intermittent photic stimulation and Sleep

Activation methods may be used to enhance pre-existing abnormalities and induce abnormal findings in an otherwise normal EEG.

7.1 Hyperventilation

- the patient is asked to breathe deeply for 3 minutes or to blow on a handheld windmill
- when performed properly there is diffuse slowing maximum posteriorly, which *may* be the result of hypocapnic cerebral vasoconstriction (increase of oxygen and reduction in carbon dioxide)
- post hyperventilation runs for 2 minutes, and the background normalizes during this period
- if the slowing continues, see if the patient is still hyperventilating
- hypoglycaemia also enhances the slowing
- hyperventilation enhances focal slowing and seizure discharges (3 Hz activity seen in absence seizures)

  If frequent spike waves occur on the resting record or with sleep, HV should not be done to avoid provoking absence status epilepticus

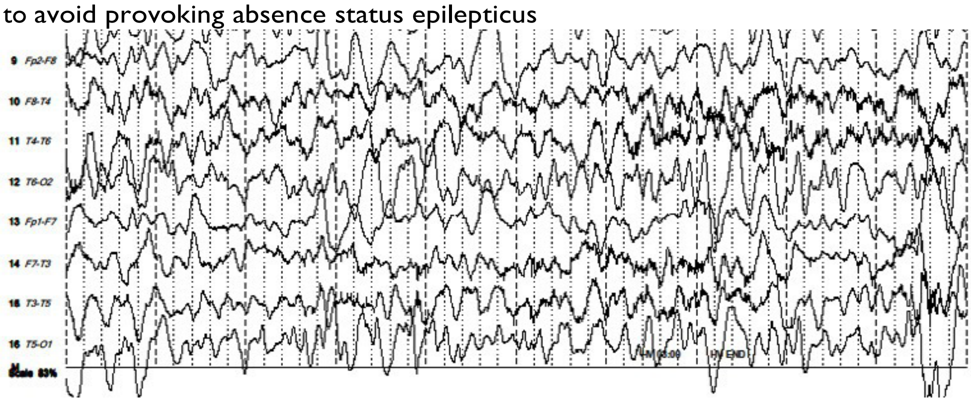


Figure 7.1.1 (Generalised slowing during HV)

An example of generalized slowing during HV in a 5-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

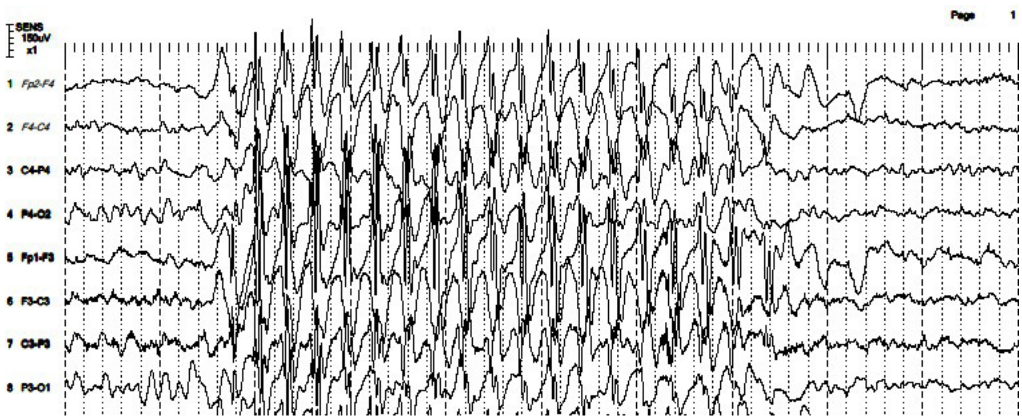


Figure 7.1.2 (3 Hz spike and wave activity during HV)

An example of 3Hz spike and wave activity with HV in a 7-year-old child. The Fp1 slow waves after the spike wave activity is artefactual. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

7.2 Intermittent photic stimulation: 3 phenomena – photomyogenic, photic driving, photoparoxysmal response

Intermittent photic stimulation is the flashing of lights using a strobe light from frequencies of be- tween 1-33 hertz with alternating 5 seconds flash and 4 seconds rest at 1,3,6,9,12,15,18,21,24,27,30,33 hertz. The strobe is placed 30cm from the patient's eyes. There are 3 responses to IPS: -

A) Photo myogenic

- IPS evokes repetitive peri-ocular muscle spikes at the flash rate at FP2, Fp1
- these often gradually increase in amplitude as stimulation continues and it cease promptly when the stimulus is withdrawn
- the response is associated frequently with eyelid flutter and vertical oscillation of the eyelids and eyeballs
- a normal response to IPS

B) Photic driving

- consists of rhythmic activity elicited over the posterior regions of the head by IPS frequencies of about 1-33 hertz, at the flash rate or ½ (sub-harmonic) of the flash rate
- a normal response to IPS

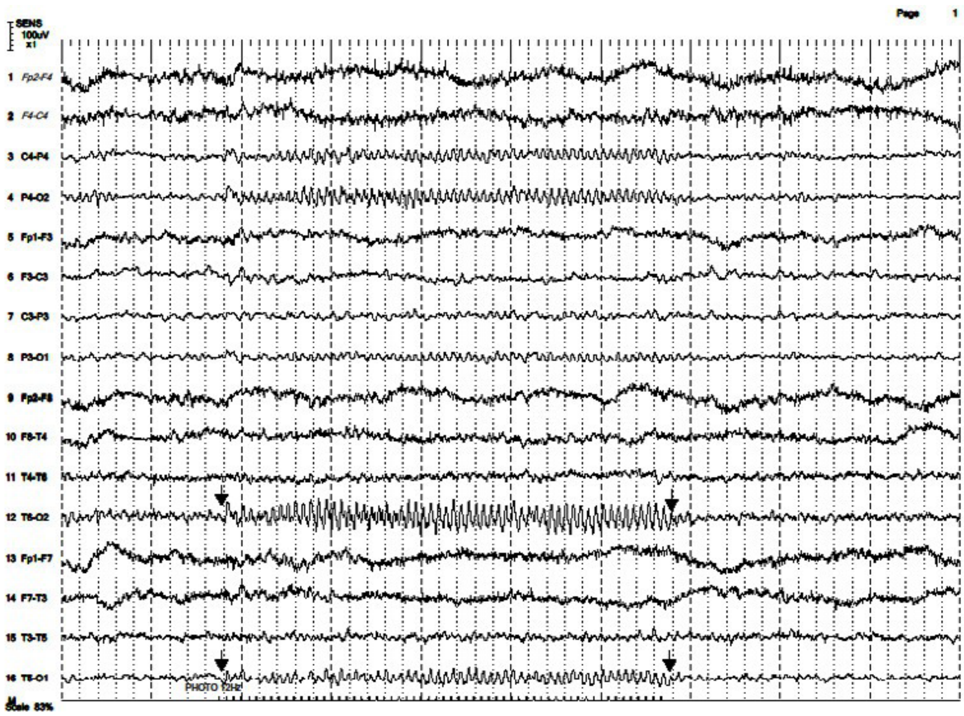


Figure 7.2.1 (Photic driving response)

An example of photic driving response in a 10-year-old child at 12 hertz frequency. Asymmetry of photic driving has no clinical value in most patients. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

C) Photo paroxysmal response

- is a response to IPS characterized by spike and wave and multiple spike and wave complexes that are bilaterally synchronous, symmetrical and generally may outlast the stimulus by a few seconds
- stop stimulus *immediately* as it can evoke a seizure
- seen in Benign myoclonic epilepsy in infancy (BMEI), Epileptic Spasms and Lennox Gastaut syndromes, Childhood absence epilepsy (CAE), Myoclonic astatic epilepsy Juvenile onset absence epilepsy (JAE), Juvenile myoclonic epilepsy (JME), Progressive myoclonic epilepsies (PME), Visual sensitive IGE, Epilepsy with generalized tonic clonic seizures on awaking and Primary reading epilepsies
- 20% of individuals that have photo paroxysmal responses have generalized seizures
- is an abnormal response to IPS

  if an ambiguous photic response occurs, clarification may be elicited by the following: use of adjacent flash frequencies, eye closure, forceful eye closure

Figure 7.2.2 (Photo paroxysmal response)

Photic paroxysmal response in a 12-year-old child at 18 hertz frequency (IPS should have been stopped immediately when spike-waves occurred). HF=70Hz, LF=0.1s,

7.3 Sleep studies (natural/induced)

Sleep studies can be performed in natural sleep with or without sleep deprivation and with sedation.

- abnormalities are noted as early on in drowsiness and stage 2 sleep as seen in EEG (a)
- enhances spike and wave activity (focal/generalized) as seen in EEG (b) and slowing (focal/generalized)
- can confirm diagnoses such as electrical status epilepticus during sleep (characterized by continuous spike and wave activity during non-REM sleep)
- anterior temporal spikes are markedly enhanced with sleep in older children.

Figure 7.3.1 (Temporal spikes during an arousal)

(a) An example of left mid temporal spikes noted during an arousal in a 10-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 7.3.2 (Temporal spikes in sleep)

(b) Same patient runs of left mid temporal spikes in sleep. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Outcome goals for Chapter 7 – activation procedures

- What inter-ictal or ictal activity can be evoked by HV
- What effect does hypoglycaemia have on an EEG during HV
- Normal and abnormal responses in IPS
- Stop stimulation if a photo paroxysmal response occurs during IPS
- When sleep should be encouraged or not during an EEG
- Use your activation procedures to enhance any abnormalities noted during an EEG

Questions for chapter 7

1 Which of the following is most likely to activate focal anterior temporal waves in the EEG of a patient with temporal lobe seizures?

a) Hyperventilation

b) Sleep

c) Photic stimulation

d) Metrazol

e) Megimide

2. High amplitude diffuse 1-3 hertz waves in bursts in response to hyperventilation in a child:

a) Indicates that intracranial pressure is elevated

b) Indicates that a seizure disorder is likely

c) Is a normal finding

d) Is a sign of diffuse encephalopathy

e) Is a characteristic of “minimal brain

3. In response to 20 hertz rhythmic photic stimulation, a 20 hertz rhythm arising from occipital regions should probably be considered suggestive of

a) Organic cerebral disorder

b) Epilepsy

c) Personality disorder

d) Cerebral immaturity

e) None of the above, it is a normal response

4. The vast majority of epileptics who have bursts of spike-wave complexes in response to rhythmic photic stimulation have

a) Genetic epilepsy

b) Uraemia

c) Acquired epilepsy

d) Temporal lobe

e) Focal motor epilepsy

5. 3 hertz spike and wave activity seen during HV:

1) Lasting less than 20 seconds

2) Inter-ictal spikes

3) Normal inter-ictal background activity

4) Staring with eye blinks and mouthing movements

5) Slowing post-ictally

a) 1, 3 and 4 are compatible with typical absence seizures

b) 2 and 5 are compatible with typical absence seizures

c) 1 and 4 are compatible with typical absence seizures

d) Only 2 is compatible with typical absence seizures

e) None of the above is compatible with typical absence seizures

CHAPTER 8

EPILEPTIFORM &

NON-EPILEPTIFORM ACTIVITY

8.1 Epileptiform (focal)

Sharply contoured cerebral electrical activity can be recognized as *epileptiform* if the "background" rhythms, when superimposed, could *not* have produced a similar morphology. Such sharply contoured waves, known as *spikes,* therefore stand out from the background rhythms.

A waveform of 20-70ms, sharply countered and usually followed by a slow wave is referred to as a **spike**. A spike can occur alone or with a slow wave; it is then referred to as a spike and slow wave complex, or in runs (spike and slow wave activity). Spikes that have multiple phases can be referred to as **polyspikes**.

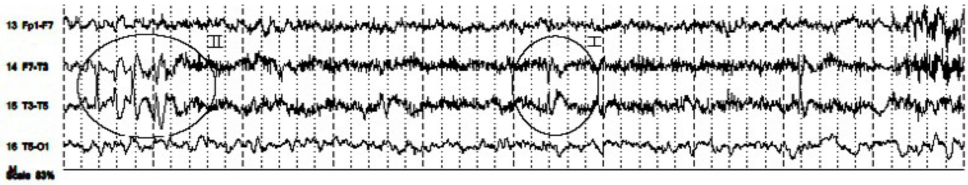


Figure 8.1.1 (Spike and wave)

EEG shows 1= spike and slow wave complex and 2= runs of spike-wave activity. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

A Spike can be considered *focal* on a bipolar montage when its principal phase reverses over an area. There can be many focal spikes occurring independently in a recording.

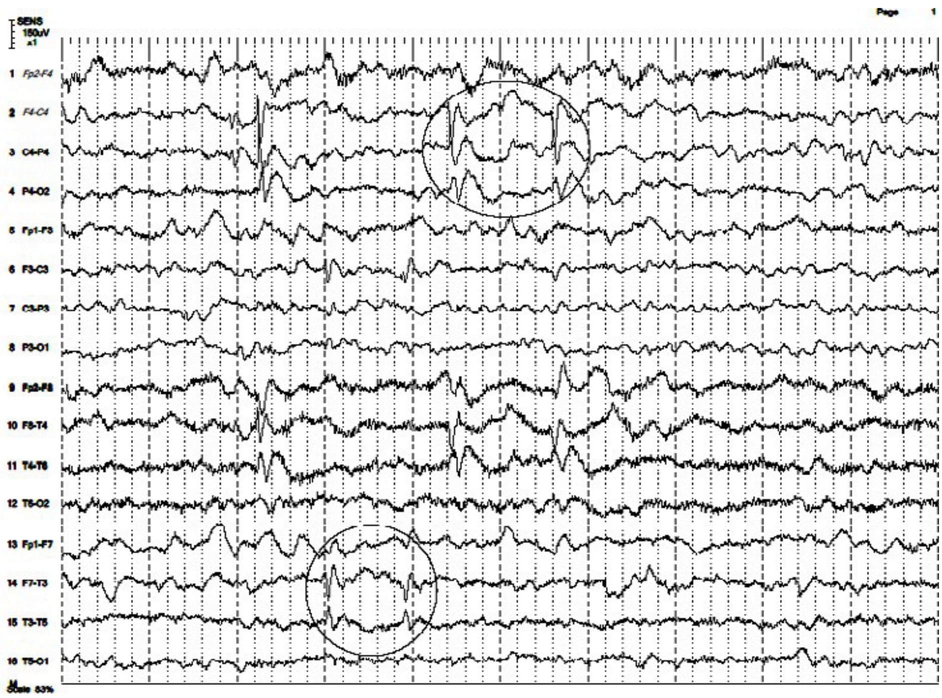


Figure 8.1.2 (Independent spikes)

Independent right centro-temporal and left mid temporal spikes respectively in a 3-year-old child with slight spread to adjacent regions. HF=70Hz, LF=0.1s, sensitivity=15uv/mm.

A **sharp wave** is between 70-200ms and can also occur singly or with a slow wave. Sharp waves are differentiated from spikes by their similar negative characteristics but longer duration.

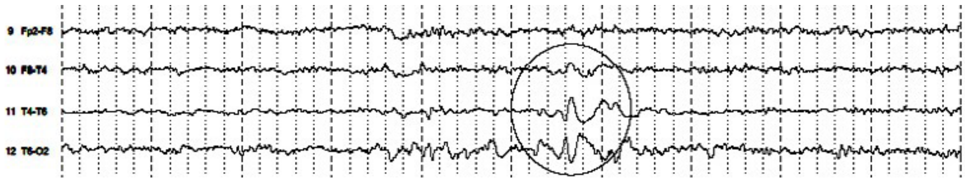


Figure 8.1.3 (Sharp wave)

An example of sharp and slow wave complex during sleep. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

8.2 Epileptiform (generalised)

In contrast a *spike-wave* can usually be distinguished from a *spike* by 1) a prominent second phase, the *trough*, 2) a more prominent wave, and 3) a wider, often bisynchronous, field distribution.

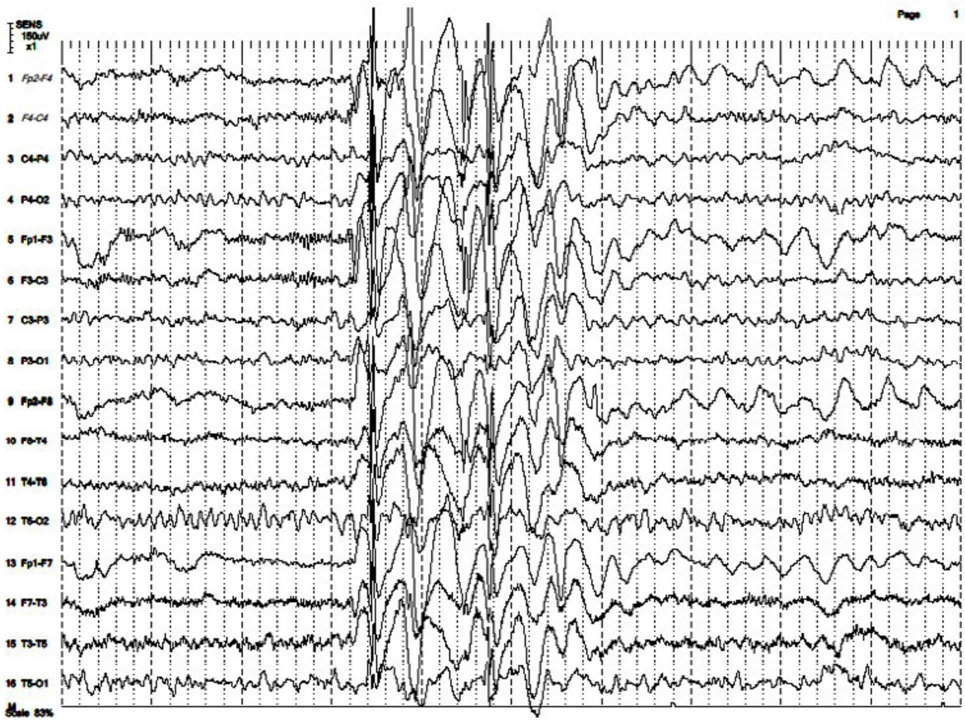
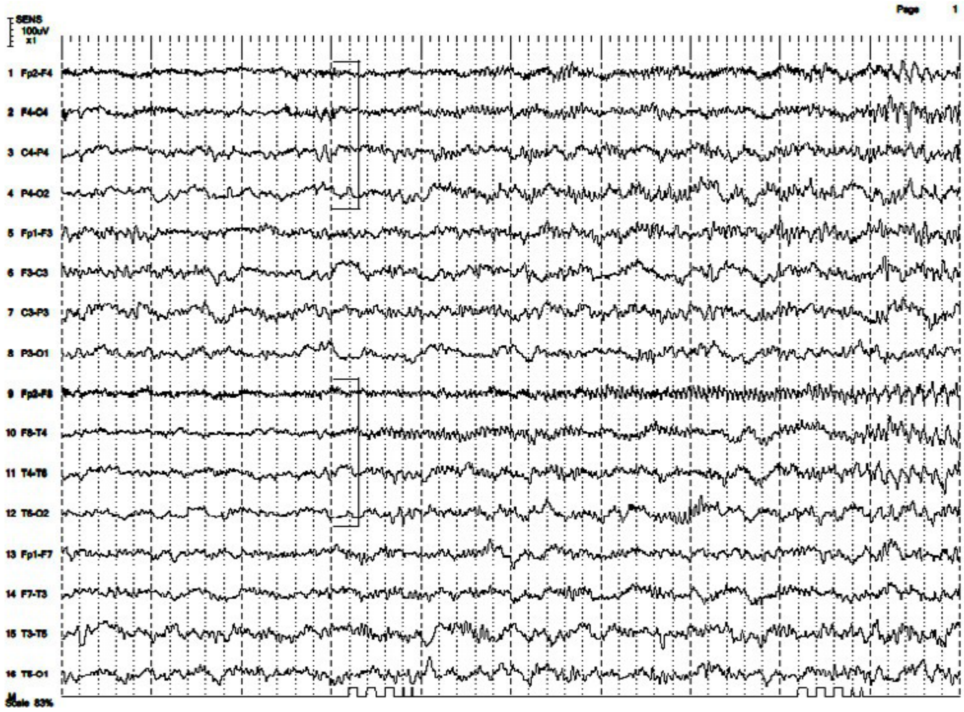


Figure 8.2.1 (Generalised spike and wave activity)

An example of generalized spike-wave discharge in an awake 6-year-old child. It's wide field spread distribution exceeds that of many spike-wave discharges that could be limited to the anterior (F4/3) or posterior (P4/3) regions. The slow waves over FP2/1 after the spike waves are eye movements. HF=70Hz, LF=0.1s, sensitivity=5uv/mm

Seizure pattern consists of a new and sustained focal or diffuse phenomenon that does not necessary represent a change in alertness and is with or without clinical manifestations. This is manifested by rhythmic waves or sequential spikes with a gradual evolution of morphology and/or frequency as the seizure progresses.

This is termed a “**sub-clinical seizure**” when no clinical manifestations are apparent.



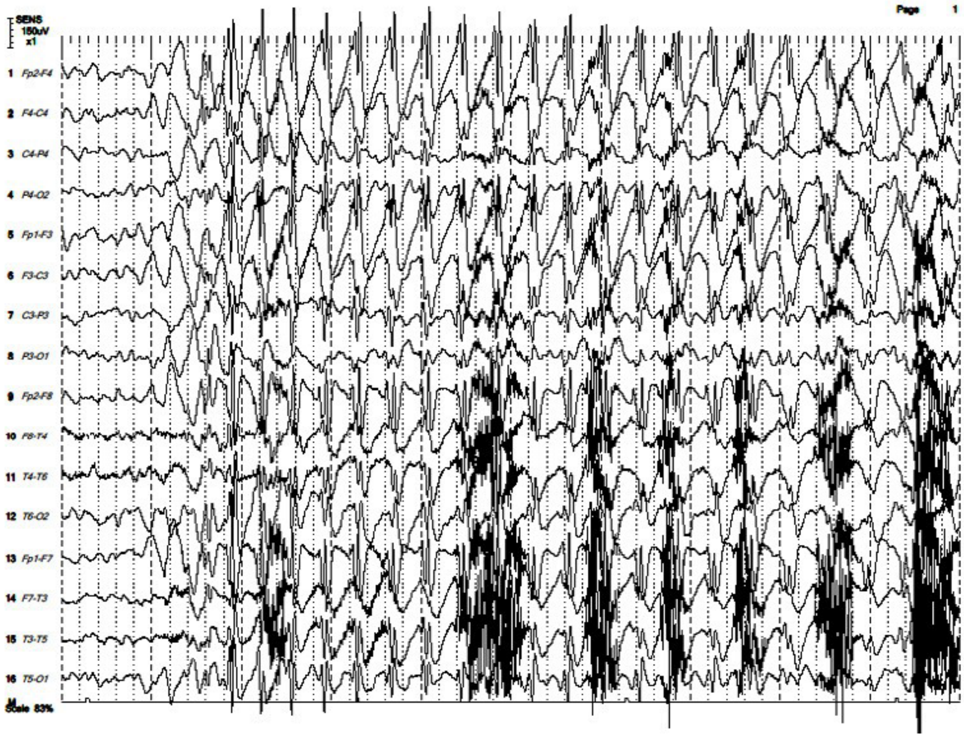
(I)

(II)

Figure 8.2.2 (Sub-clinical seizure)

An example of a right hemisphere sub-clinical seizure in a 5-year-old child during sleep. Seizure originates over the right anterior hemisphere. Note the regional post-ictal delta and attenuation. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Three hertz spike and slow wave complex is a paroxysm seen in absence seizures. It is bilateral at onset and termination, generalised and with maximum amplitude over the frontal areas, the waveform is usually between 3-3.5Hz. Onset and termination are usually discrete and well defined.



(I)

(II)

Figure 8.2.3 (3 Hz spikes and wave activity with eye blinks and mouthing movements)

An example of 3 hertz spike-wave activity in a 9-year-old child during hyperventilation, associated with eye blinks and mouthing movements. Some slowing is noted pre-and post-seizure in this example. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

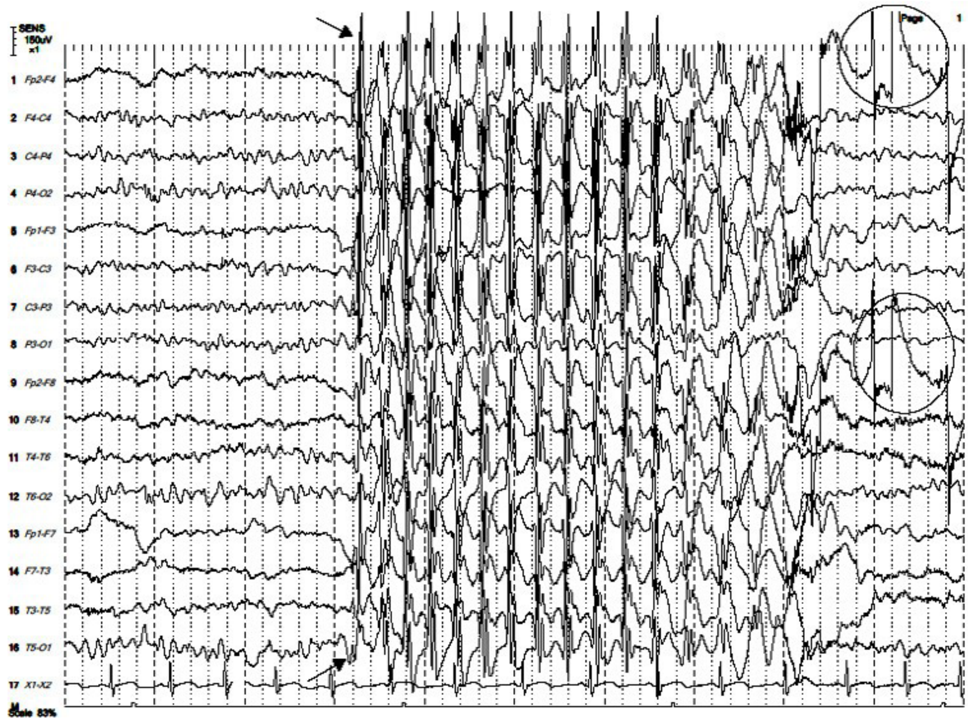


Figure 8.2.4 (3 Hz spike and wave activity – abrupt onset and termination)

An example of 3 hertz spike-wave activity in a 6-year-old child during HV, showing an abrupt onset and termination lasting approximately 4 seconds. Note FP2 artefact after seizure. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

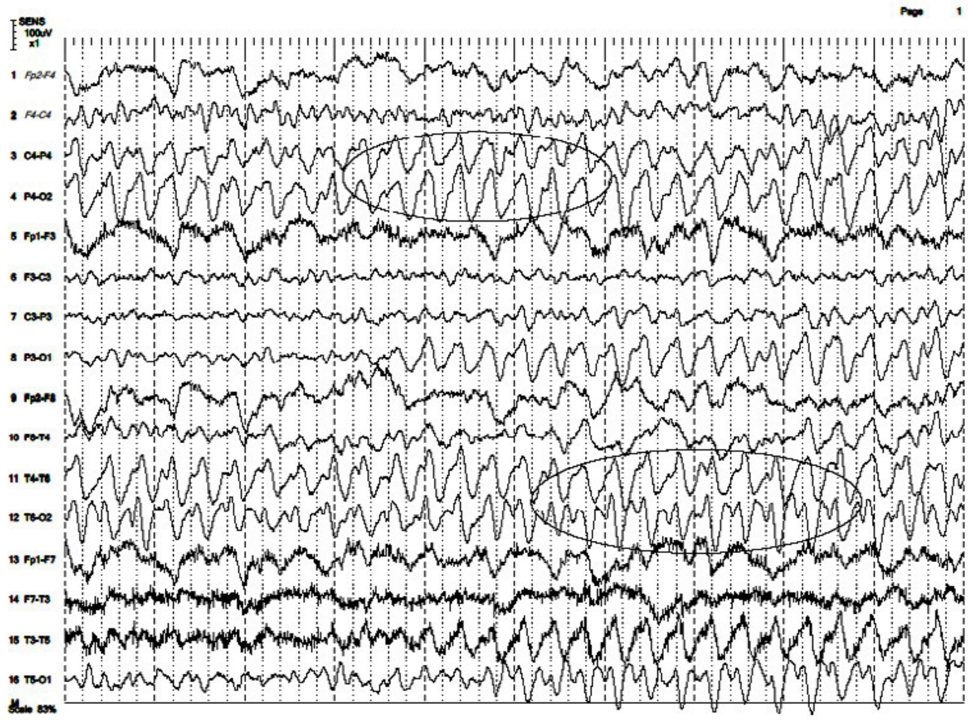


Figure 8.2.5 (Posterior slowing with superimposed spikes)

An example of runs of slow posterior rhythm in a 4-year-old child with superimposed spikes often seen in patients with absence seizures. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Atypical spike and slow wave complex is a 3 Hz paroxysm seen in absence seizures but with unilateral take-off or unilateral slowing afterwards. In addition, frequent inter-ictal activity can also be noted throughout the recording in comparison to a typical absence record.

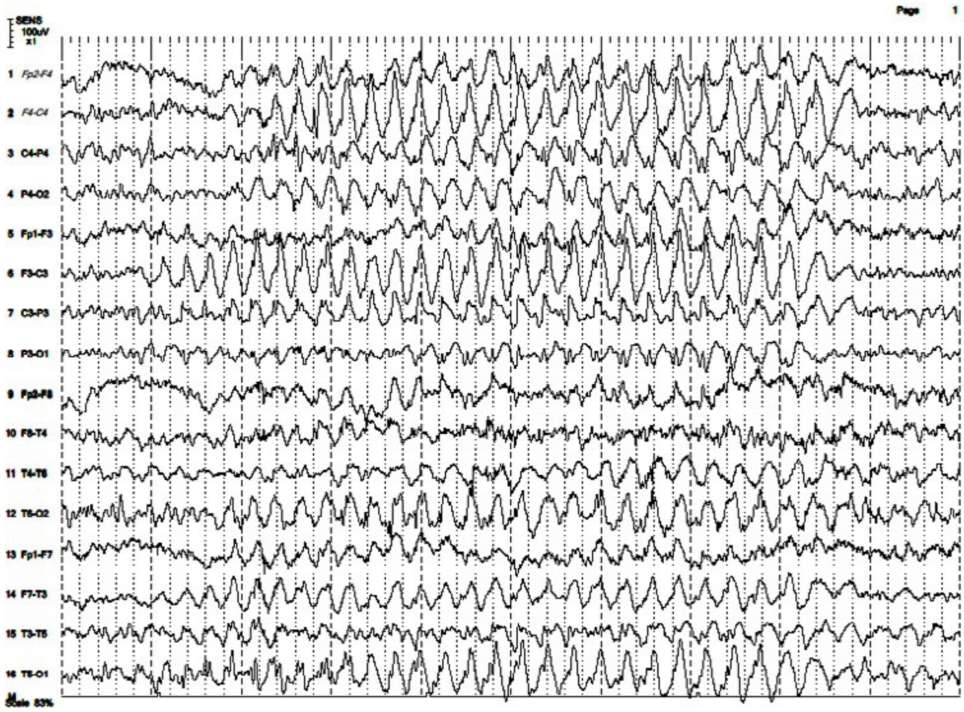


Figure 8.2.6 (Atypical 3 Hz spike and wave activity)

An example of atypical 3 hertz spike-wave activity in an 11-year-old child. A left hemisphere take- off is also noted. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Multifocal spike and slow wave complex is a sequence of multiple spike and slow wave complexes occurring at the same time.

Figure 8.2.7 (Multifocal spikes)

An example of multifocal spikes in sleep in an 11-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

8.3 Non-epileptiform (focal/generalised)

Non-epileptiform activity consists of generalized or focal excess delta or theta for age and state. Although this activity is not specific enough to be called epileptic, the abnormality may appear over an epileptogenic region. Fully reversible conditions such as a post-ictal state, metabolic or endocrinological abnormalities or mild trauma may also produce such waveforms.

Deep non-REM sleep may also be accompanied by diffuse delta activity. Distinction of this normal state from an encephalopathy can be attained by: - 1) reactivity to stimuli, 2) presence of sleep patterns (spindles, V waves)

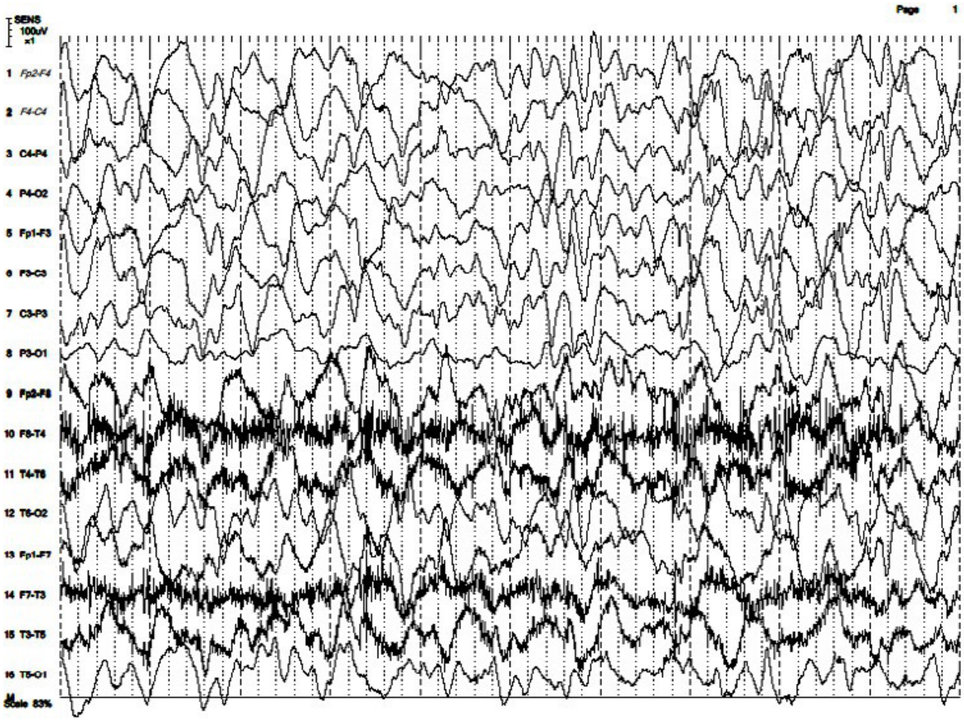


Figure 8.3.1 (Generalised slowing)

An example of a moderate encephalopathy in a 4-year-old child. Note muscle artefact occurs over the temporal regions. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

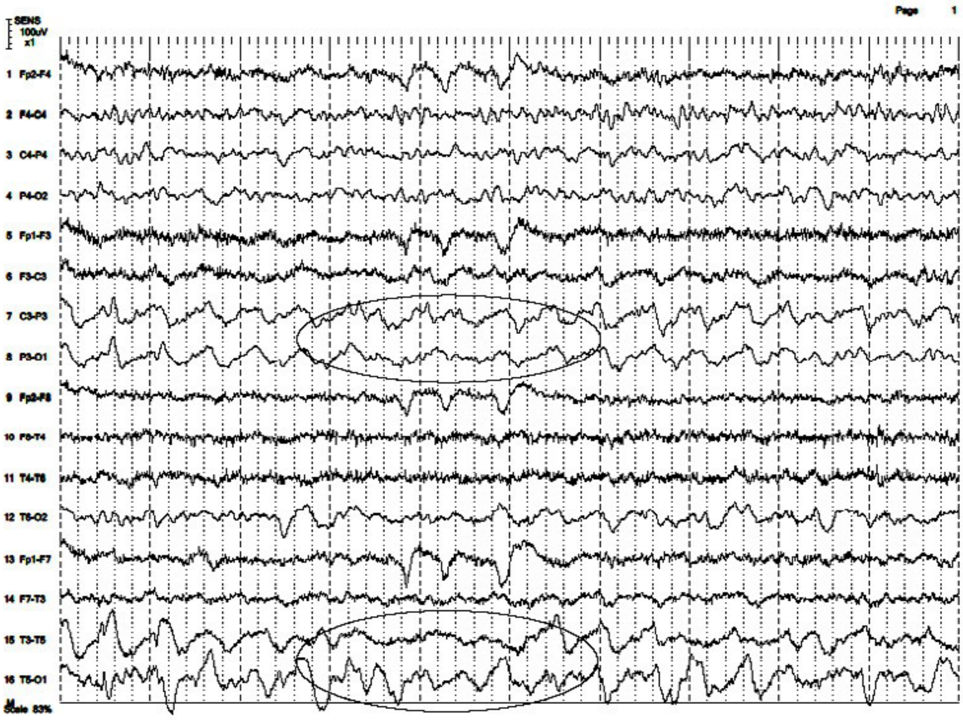


Figure 8.3.2 (Focal slowing)

An example of focal slowing in the left posterior region in an 8-year-old child; this represent an epileptogenic area; further recording seeking spikes may be of value. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Outcome goals for Chapter 8 - epileptiform & non-epileptiform activity

- Distinction between a spike and a sharp wave
- Recognition of a seizure pattern
- Differentiate between ictal and inter-ictal activity
- Know the difference between an encephalopathy compared to sleep activity
- Use your activation methods or sleep to enhance epileptogenic abnormalities during a recording

Questions for chapter 8

1 According to the Committee on Terminology of the International Federation, the duration of a sharp wave is:

a) Less than 200msec

b) 70-200msec

c) 20-70msec

d) 20-200msec

e) None of the above

2. Which of the following is most definitely abnormal?

a) Lambdoid waves

b) Psychomotor variant

c) Small sharp spikes

d) 14 and 6 positive spikes

e) Rolandic spikes

3. Generalised slowing in an EEG recording is a non-epileptic finding:

1) Can result from post-ictal slowing after a generalised seizure

2) Can represent stage 4 sleep

3) Can represent an encephalopathy of many causes

4) Can result from an open circuit

a) 1, 2 and 3 are correct

b) Only 4 is correct

c) 1 and 3 are correct

d) 2 and 3 are correct

e) All are correct

4. Which of the following clinical and EEG features represent typical absence seizures:

1) 3 hertz spike-wave activity
2) Duration less than 20 seconds
3) Inter-ictal spikes/polyspikes are evident
4) Automatism of eye blinks and mouthing movements

a) Only 4 is correct
b) 1, 2 and 4 are correct
c) 1 and 4 are correct
d) 2 and 3 are correct
e) All are correct

5. A patient referred for temporal lobe epilepsy will most likely show abnormalities:

1) During an awake 20-minute recording
2) During a sleep study
3) During Hyperventilation
4) During Intermittent photic stimulation

a) 1, 2 and 3 are correct
b) Only 4 is correct
c) 1 and 3 are correct
d) 2 and 3 are correct
e) All are correct

CHAPTER 9
REPORTING OF ELECTROENCEPHALOGRAMS

Every laboratory has different styles of reporting. However, if you can follow basic steps with a systematic approach, then generating your own report is possible. A reader should review the entire recording and take note of the following steps before interpreting an EEG.

Step 1- background rhythm/normal variants

- The reader should be unbiased i.e. should have no clinical data on the patient when interpreting the EEG.
- What is the prominent background activity over the posterior head region of the child? Is the patient awake/asleep/drowsy/has decreased level of consciousness or comatose? Note if it is normal /abnormal for age?
- Is the background activity reactive to eye opening and to passive eye closure?
- Does the background activity show generalized or focal attenuation.
- Does the background activity show generalized or focal slowing for age?
- Ask if the patient has had a seizure prior to recording and if so when?
- Has the patient been given any drugs prior to recording which will affect the background activity e.g. excess beta or generalized slowing
- Are there any normal variants to comment about e.g. "V" waves/spindles during sleep etc?
- Are there any correctable artefacts?
- Perform mental alerting if drowsiness is suspected.

Step 2- activation procedures

- Hyperventilation – normal HV phenomenon or whether abnormalities are elicited or enhanced
- Intermittent photic stimulation – normal or abnormal responses elicited
- Activation procedures not performed owing to poor patient co-operation
- HV and IPS not performed during sleep study

Step 3- abnormalities

- Waveforms that stand out of the background: - sharp/spike or slow waves. Is there any behaviour correlation e.g. eye blinks, mouthing movements, jerks, unresponsive etc.?
- Is the abnormality focal or generalized (post ictal or encephalopathic)?
- Are the abnormalities symmetrical or asymmetrical?
- Is the abnormality frequent/persistent/infrequent etc.?
- Has the abnormality many phases and many foci e.g. polyspike activity or multifocal? Whilst recording did the patient have sub clinical or clinical seizures
- Were the abnormalities enhanced by activation procedures or sleep?

Step 4 – final interpretation (conclusion)

- Is the study normal or abnormal?
- Summarize the abnormalities found in the study (in order of importance)

- In a setting where a specialist is unavailable, the patient should be referred to a specialized clinic e.g. neurology where the patient would benefit from specialized care or telephonic discussions with a Neurologist for additional information on treatment of patient
- Compare present study to previous records e.g. follow up for status epilepticus, infantile spasms after a course of ACTH etc.

Outcome goals for Chapter 9 - reporting of electroencephalograms

- Distinguish the background rhythms/normal variants
- Differentiate between abnormalities and artefacts
- To know if any of the activating procedures/sleep produce any abnormalities
- Distinguish between clinical or sub-clinical seizure activity
- Recognize clinical manifestations
- Look for waveforms and abnormalities that stand out of the background activity
- Give a concise summary of the findings
- Alert the appropriate people concerned in the case of neurological emergencies in available settings (status epilepticus/hypsarrhythmia and sub-clinical seizures)
- An EEG review in 1-2 years is usually helpful when patient is seizure free

EXAMPLES OF HOW TO COMPLETE AN EEG REPORT

Table 4: Document the following aspects in every report

REFERRING PROBLEM	**MENTAL STATE**	**BACKGROUND BASELINE ACTIVITY** Select from the following	**EPILEPTIC ACTIVITY** Focal activity	**INTERPRETATION** (Summarize description)
Epilepsy Seizures, focal, generalised Status epilepticus Syncope Sub-clinical Sz's "Convulsions" **are examples** Document the key medical concern which has generated the referral for EEG and the question asked	Awake Natural sleep Sedated sleep Decrease level of consciousness Drowsiness Note: A patient can have more than 1 mental state e.g. awake/ natural sleep	The record consists of symmetrical ...... activity, reactive to eye opening alpha theta delta beta	Spike or sharp wave activity is noted phase reversing over the R or L ....temporal anterior mid posterior	The awake or asleep EEG is normal
		OR The record consists of symmetrical mixed frequency activity with "V" waves and sleep spindles	**OR** Spike or sharp wave activity is noted phase reversing over the R or L...... frontal central parietal parasagittal region	**OR** The awake or asleep EEG is normal. Posterior slowing is a normal variant and not necessarily indicative of absence seizures
		OR The record consists of an admixture of theta and delta activity or transients	**OR** Spike and wave activity phase reversing over the .....region with secondary generalisation temporal or parasagittal	**OR** Within normal limits
		OR The record consists of generalised beta or delta activity	**Generalised activity:**	**OR** Within normal limits. Occasional or intermittent slow transients are noted focally or generalised

REFERRING PROBLEM	MENTAL STATE	BACKGROUND BASELINE ACTIVITY Select from the following	EPILEPTIC ACTIVITY Focal activity	INTERPRETATION (Summarize description)
		OR The record consists of mixed frequency activity with overriding beta activity	Rhythmic 3 hertz spike and wave complexes lasting ... seconds with maximal amplitude frontally	**OR** Abnormal showing a focus over the right or left .....head region anterior or parasagittal
		OR The right hemisphere consists of....alpha or theta or delta activity and the left hemisphere .....alpha or theta or delta activity e.g. in an EEG with focal slowing	**OR** Generalised spike and wave or slow spike-wave activity is noted with a left or right hemisphere preponderance	**OR** Abnormal showing multifocal foci
		OR Drowsiness produces drop out of alpha activity and the emergence of theta transients	**OR** Sub-clinical or clinical seizure noted (describe seizure pattern seen on EEG)	**OR** Abnormal showing generalised slowing found in association with a mild/moderate/ severe encephalopathy of many causes including a post-ictal state or drug toxicity
		ACTIVATION PROCEDURES	**OR** Continuous spike and wave activity (status)	**OR** Abnormal showing generalised suppression
		Hyperventilation and intermittent photic stimulation adds nil further of note	**OR** Almost continuous spike and wave activity (intermittent status)	**OR** Abnormal showing background slowing for age
		OR Hyperventilation produces mild generalised slowing – a normal HV phenomenon	**OR** Poly spike and wave activity noted with periods of bursts suppression	**OR** Abnormal showing focal slowing over the right or left temporal region; right or left hemisphere

REFERRING PROBLEM	MENTAL STATE	BACKGROUND BASELINE ACTIVITY Select from the following	EPILEPTIC ACTIVITY Focal activity	INTERPRETATION (Summarize description)
		OR HV was not performed owing to unco-operation of patient	**OR** Runs of fast frequency activity – nil clinical correlation	**OR** Abnormal showing generalised 3 hertz spike and wave activity found in association with absence seizures
		OR Intermittent photic stimulation produces a photic driving response at certain flash frequencies	**OR** Myoclonic jerks noted with bursts of generalised spike and wave complexes	**OR** Abnormal showing atypical 3 hertz spike and wave activity
		Artefacts:	**With Hyperven-tilation:**	**OR** Abnormal showing burst suppression with poly spike and wave activity
		Movement and muscle artefact disrupts the baseline from time to time.	3 hertz spike and wave activity is enhanced by HV, associated with eye blinks or mouthing movements	**OR** Abnormal showing recorded sub clinical seizure originating over the .....area
		OR Movement and muscle artefact disrupts the baseline from time to time.	**With Intermittent photic stimulation:**	**OR** Abnormal showing recorded clinical seizure **OR**
		Normal variants:	Photo paroxysmal response noted during IPS	**Comparison:**
		Mu or lambda waves are noted during eye opening. **OR** POSTS are noted during sleep	**With Sleep:**	The record has slightly/ moderately/ markedly improved since the previous study done on the ..... (date)

REFERRING PROBLEM	MENTAL STATE	BACKGROUND BASELINE ACTIVITY Select from the following	EPILEPTIC ACTIVITY Focal activity	INTERPRETATION (Summarize description)
		Mental alerting for drowsiness: To confirm encephalopathy versus drowsiness	Sleep enhances spiking	**OR** In comparison to the previous record the study has slightly/ moderately/ markedly improved
		Mental alerting fails to abolish all slow rhythms	**OR** Sleep accentuates spikes	**OR** The study has worsened since the previous study done on the .... (date)
		OR Mental alerting abolishes all slow rhythms and produces .... Hertz activity. Depends on age of patient		**Suggestions:**
		Pseudo-events:		Suggest referral to neurology
		Nil EEG correlation with myoclonic jerks or seizure or fisting of hand		**OR** Suggest imaging to exclude pathology
		OR During the seizure no paroxysmal activity is seen		**OR** If clinically indicated a sleep study might elicit more specific abnormalities
		NON-SPECIFIC ABNORMALITIES		**OR** If symptoms persist a sleep study is suggested
		Occasional slow transients noted throughout the study		

REFERRING PROBLEM	MENTAL STATE	BACKGROUND BASELINE ACTIVITY Select from the following	EPILEPTIC ACTIVITY Focal activity	INTERPRETATION (Summarize description)
		OR A single slow transient noted over the R or L temporal or parasagittal region		
		OR Runs of posterior slow waves are evident		

NOTE: Keep language simple and easy for the reader to appreciate. Retain objectivity (report on the most important abnormalities) and aim at simple communication. Electroencephalograms should not be used in isolation to diagnose or exclude epilepsy.

Outcome goals for examples of how to complete an EEG report

- Generate a clear, concise and to the point report that should be understandable by any health care practitioner
- Repeat EEG if awake EEG was marred with artefact with a sleep study
- Repeat for a sleep study if the awake EEG was normal and history was highly suggestive of epilepsy
- Encourage sleep to enhance abnormalities
- Additional discussion with specialists if available will recommend referral into neurological service for complex conditions
- Referral for imaging if available when a focal abnormality is suspected

GLOSSARY FOR EEG REPORTING

A

Abnormalities
Abolish
Absences
Accentuate
Accompanied
Activation
Admixture
Alerting
Alpha
Amplitude
Anterior
Anterior temporal
Area
Arousal
Artefact
Atypical
Associated

B

Background
Baseline
Benign
Beta
Bilateral
Bouts

C

Central
Cerebral
Certain
Characterized
Clinical
Clinically
Consist
Compared
Comparison
Compatible
Component
Continuous
Correlates

D

Decreased level of consciousness
Definition
Deflection
Delta
Diagnosis
Diffuse
Discharges
Disrupts
Disruption
Distribution
Disorder
Dominance
Dominant
Drop out
Drowsiness
Drowsy
Duration

E

Elicit
Emergence
Encephalopathy
Enhanced
Enhances
Epilepsy
Epileptogenic
Episodes
Events
Evident
Exclude
Expression
Extreme
Eye blink
Eye closure

F

Fails
Fast frequency activity
Feature
Flash
Focal
Foci
Focus
Frequencies
Frequency
Frequent
Frontal
Fronto-central

G

Generalised
Gradual

H

Hemisphere
Hemispherical
Hertz
High
Hypsarrhythmia
Hypnagogic

I

Imaging
Improved
Indicated
Indicative
In keeping
Inter-ictal
Intermittent
Intermittent status

J

Jerks
Juvenile

K

"K" complexes

L

Lambda
Low voltage

M

Manifestation
Marred
Markedly
Maximal
Mental alerting
Merits
Mild
Mid-temporal
Mixed frequency
Moderate
Modified
Movement
Mouthing movements
Mu
Multifocal
Muscle
Mvoclonic

N

Natural
Negative
Neurology
Non-specific
Notched

O

Occasional
Origin
Originate
Overriding

P

Parasaggital
Parietal
Paroxysmal discharges (IPS)
Partially
Pathology
Persist
Persistent
Phase
Phenomenon

Polyspike and wave activity / complexes

Posterior

Posterior occipital sharp transients of sleep (POSTS)

Posterior parietal

Posterior temporal

Post-ictal

Positive

Potentially

Precedes

Preceding

Preponderance

Presence

Previous

Procedure

Prolonged

Pronounced

Progressive

Pseudo

Q

Quiet sleep

R

Range

Reactive

Record

Recorded

Referral

Region

Regular

Respectively

Response

Responsive

Reversing

Rhythmic

Rhythmical

Rhythms

S

Sedated

Seizure

Severe

Sinusoidal

Sleep

Sleep spindles

Slight

Slow

Sharp

Showing

Somnolence

Specific

Spike and wave activity/ complexes

Spikes

Spiking

Spindles

Spontaneous

Status epilepticus

Stimuli

Stimulus

Stretching

Sub Clinical

Suckling

Suggest

Superimposed

Suppression

Symmetrical

Symptom

Synchronous

T

Take off

Technically

Telemetry

Theta

Toxicity

Transients

U

Unconscious

Unco-operation

Un-reactive

Unresponsive

Unsatisfactory

V

Variants

Variation

Vertex ”V” waves

W

Wake

Waxing and waning

Within normal limits

Y

Yawning

CHAPTER

EPILEPTIC DISORDERS

“Adapted from “Epileptic syndromes in infancy, childhood and adolescence: 3rd Edition; editors Roger.J, Bureau.M, Dravet.Ch,Genton.P,Tassinari.CA,Wolf.John Libbey 2002, United Kingdom”

Some epileptogenic disorders/syndromes have a specific electrographic profile. It is important to recognize these profiles which may directly assist with correct diagnosis and appropriate management thereby potentially improving neurological outcome.

A. Early Myoclonic Epilepsy

- Myoclonic seizures can be seen in the neonatal period or early infancy
- May be associated with inborn errors of metabolism but can also be noted with cerebral mal- formations which is uncommon
- Myoclonus or tonic spasms have variable clinical foci and may continue in sleep

EEG

- Characterized by a burst suppression pattern with complex bursts of spikes occurring both during the awake and sleep record
- Bursts can be bilateral or independent in both the hemispheres often associated with a myoclonic jerk
- Photo paroxysmal response may be first manifestation of myoclonic epilepsy of childhood; therefore, photo stimulation is indicated in any child with bilateral motor seizures, even febrile

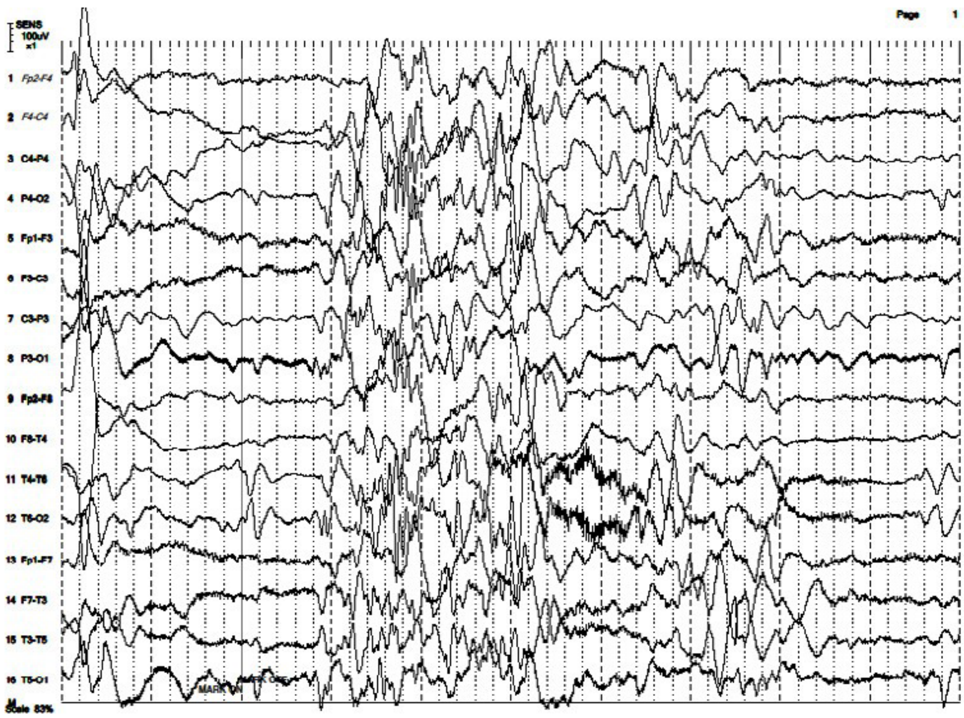


Figure 10.1 (Myoclonic jerk in EME)

An example of a myoclonic jerk in EME in a 3-month-old infant as noted with mark on/off. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

B. Early infantile epileptic encephalopathy with burst - suppression (Ohthara syndrome)

- Onset in the neonatal period / infantile period
- Frequent tonic spasms and often in clusters
- Is usually associated with cerebral malformations
- Prognosis is poor with a 50% mortality rate or severe developmental delay
- This EEG pattern can also be seen in patients with hypoxic ischemic encephalopathy (HIE)
- Generally, evolves into infantile spasms or other severe epilepsy syndromes

EEG

- Characterized by burst - suppression pattern both in awake and asleep
- Bursts consists of high amplitude slow waves mixed with spikes
- Suppression lasts between 3-4 seconds and may be asymmetrical, asynchronous and even unilateral

Figure 10.2 (Periods of suppression in EIEE)

An example of periods of suppression in an infant at 7 months of age in sleep with interspersed spikes. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

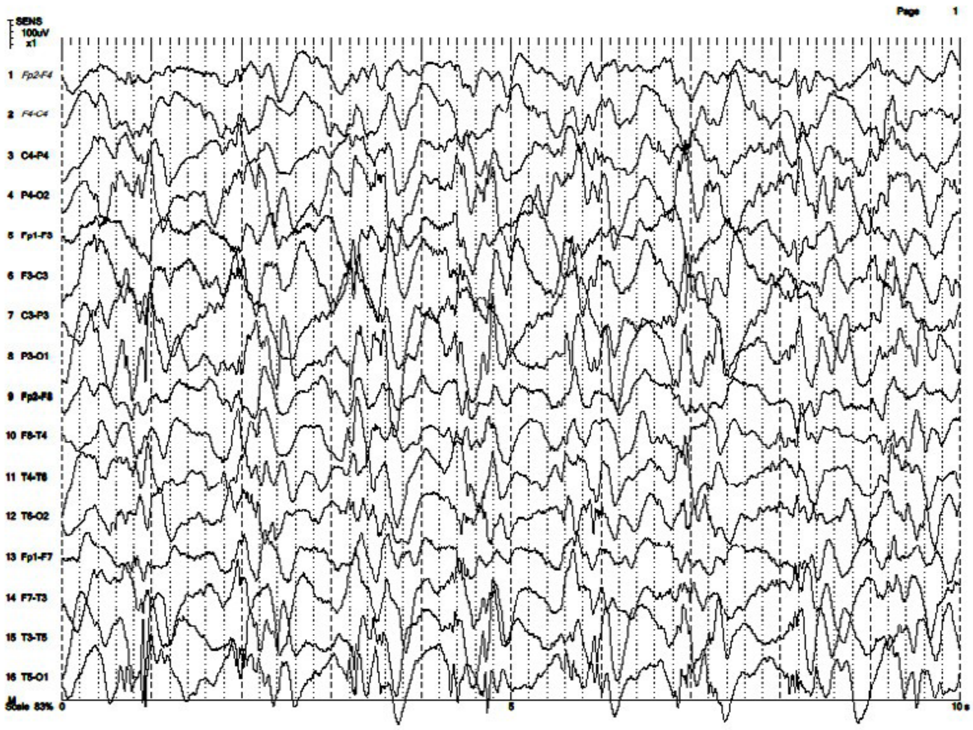


Figure 10.3 (EIEE at 1 year old)

The same patient at 1 year of age during sleep. Periods of burst suppression is not obvious at 1 year of age, but spikes are still noted overriding the slow rhythms. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

C. Epileptic

- Peak onset is between 4 and 7 months and always before 12 months of age. It is the most common epilepsy disease to occur in the infantile period.
- Infants and children with hypsarrhythmia (very chaotic and disorganized brain electrical activity with no recognizable pattern) and modified hypsarrhythmia (focal or asymmetric discharges, episodes of voltage attenuation, and some interhemispheric synchronization)
- Often show an arrest of development of perceptual and motor skills as well as reduced visual attention
- The combination of epileptic spasms, mental retardation and hypsarrhythmia is referred to as West Syndrome. Clinical events typically occur in states of drowsiness and recent awakening; the infant suffers a series of flexion or extension spasms which occur in flurries, particularly in arousal. The infant is often distressed and cries.
- 70% of children with epileptic spasms will demonstrate typical hypsarrhythmia
- The long-term prognosis is poor in cases of hypsarrhythmia with epileptic spasms where there is a known etiology as only 5% of such patients develop normally or with only mild impairments.
- Pyridoxine dependency or deficiency should be sought by the clinician
- The finding of hypsarrhythmia is a medical emergency requiring urgent admission for initiation of medical treatment (usually ACTH or prednisone or vigabatrin)

EEG

- A pattern consisting largely of a chaotic admixture of spikes, sharp waves and slow waves
- The classical pattern of hypsarrhythmia differs from other patterns of multi-focal epileptiform discharges in that the locations of the focal spikes and sharp waves are not constant but shift from moment to moment
- In addition, the spikes and sharp waves are often greatest in amplitude over the posterior head region (helps distinguish hypsarrhythmia from the early onset of Lennox-Gastaut Syndrome)
- Hypsarrhythmia is more pronounced during wakefulness and is often greatly attenuated during sleep
- The clinical seizures consist mainly of infantile spasms (95%) and tonic seizures
- Electro decremental pattern (where there is a sudden generalized attenuation of activity across all channels) can accompany epileptic spasms and also can be seen inter-ictally
- Bi-temporal spikes are often seen with evolving hypsarrhythmia

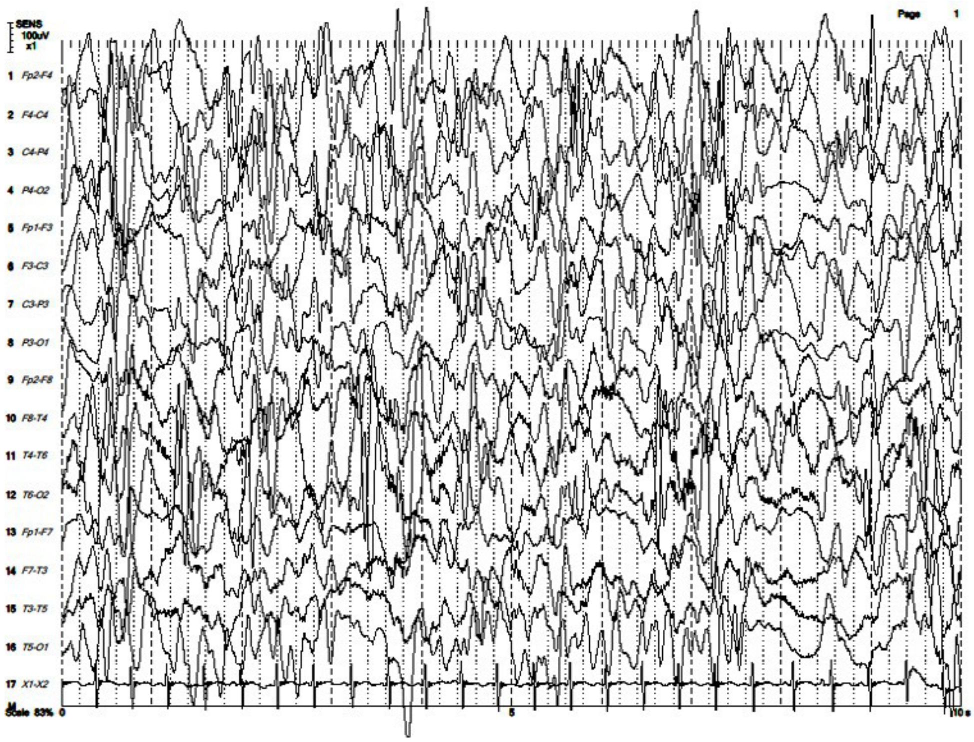


Figure 10.4 (Hypsarrhythmia)

An example of high amplitude chaotic spike and wave activity as seen in Hypsarrhythmia in an awake 8-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

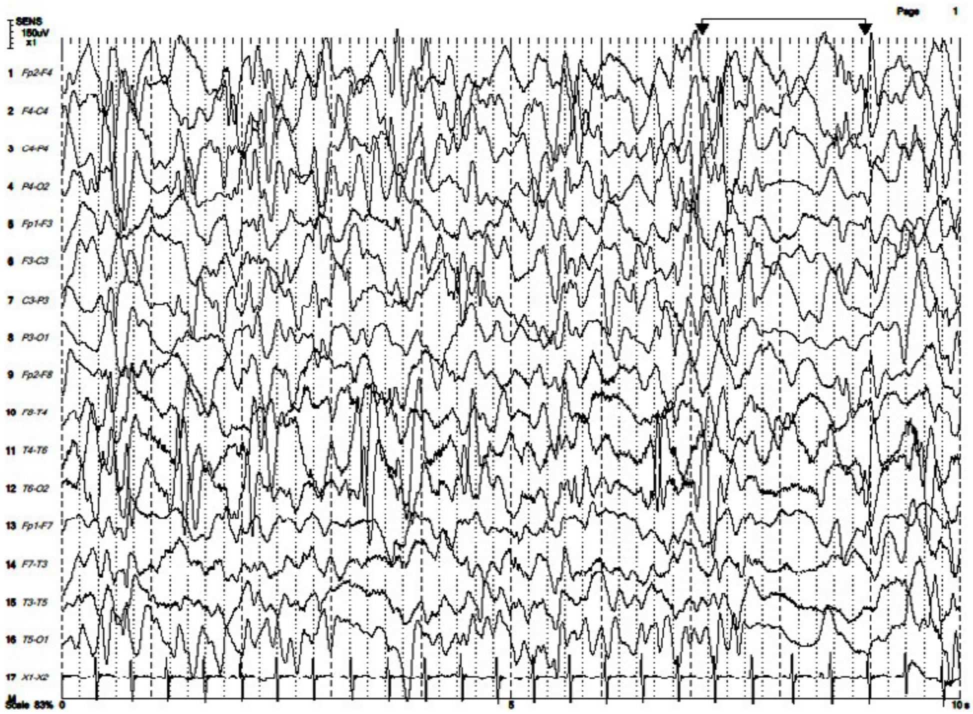


Figure 10.5 (Reduced sensitivity showing burst suppression)

Same patient as above with reduced sensitivity and showing some burst suppression.
HF=70Hz, LF=0.1s, sensitivity=15uv/mm

D. Modified Hypsarrhythmia

- A term used to describe a commonly occurring variation of classical hypsarrhythmia EEG pattern and carries an even worse prognosis.
- Pre-dominantly high voltage, generalized, asynchronous, slow wave activity
- Unilateral or asymmetrical hypsarrhythmia
  A discontinuous pattern with frequent epochs of widespread or localized attenuation similar in appearance to the burst - suppression pattern
- The burst - suppression variant in particular carries a guarded prognosis with high mortality and little likelihood of normal development
- The unilateral or asymmetric pattern is more likely to be non-idiopathic and to be associated with underlying localized structural or functional abnormalities

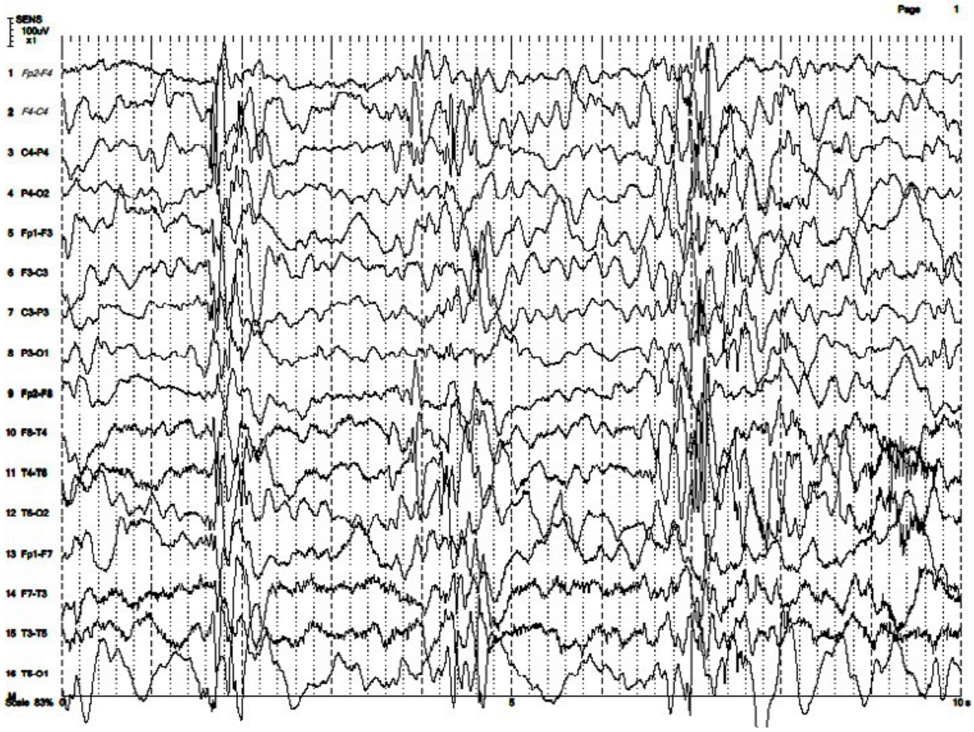


Figure 10.6 (Modified hypsarrhythmia)

Modified hypsarrhythmia - EEG demonstrates less of a chaotic pattern with periods of suppression in an awake 4-month-old infant. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

E. Landau- Kleffner

- Onset starts between 1 to 8 years, typically around 3 years
- Landau Kleffner syndrome or acquired epileptic aphasia is a rare disorder that usually occurs in children and is characterized by focal motor, absences, generalized tonic clonic and dyscognitive seizures and a progressive disturbance of language function
- The language disturbance may initially be limited to difficulty with comprehension and then progress to include speech
- Onset of the language regression can be sudden (over a few days) and is often accompanied by behavioral problems
- The seizures may precede or follow the onset of the language disturbance
- Seizures may be very intermittent but the neurocognitive and behavioral effects are typically persistent

EEG

- Inter-ictal epileptiform activity typically consists of moderate to high amplitude spike and
- wave complexes that are localized to the temporal-parietal regions.
  The discharges may be strictly unilateral or appear in a bilateral independent fashion
- They often become more abundant with the onset of sleep

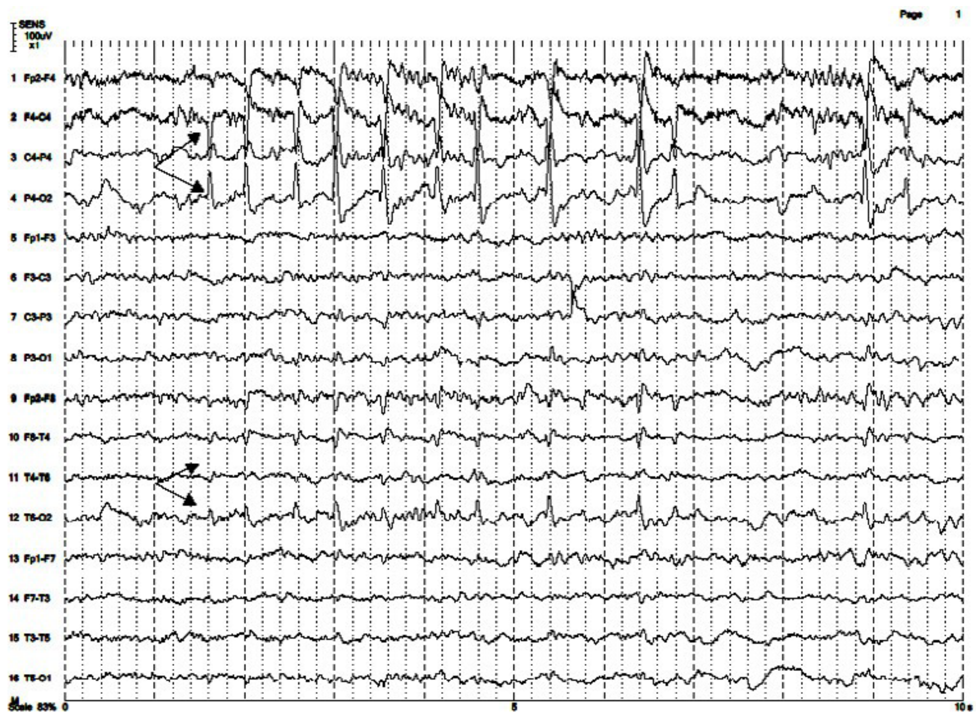


Figure 10.7 (Landau kleffner)

In stage 2 sleep in a 7-year-old child. EEG demonstrates right central-parietal spikes with field spread to the temporal region. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 10.8 (Landau kleffner in sleep)

Same patient. EEG demonstrates the enhancement of spikes in sleep and the left hemisphere is now more prominent. This is the same patient as above but now in deeper sleep. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

F. Lennox- Gastaut Syndrome

- This syndrome is defined as the occurrence of multiple generalized seizure types [tonic, atypical absence, myoclonus and occasional tonic- clonic seizures (GTCS)], and typical EEG changes
- Typically, poor treatment response with accompanying intellectual disability and frequently demonstrable neurological deficits
- A multitude of aetiologias may result in this condition, but in most cases, the cause remains unknown
- This condition usually starts between the ages 1 and 3 years, onset in the 2nd decade of life is much less common
- Onset at the age of 6 to 12 months has been observed and requires solid EEG documentation for differentiation from hypsarrhythmia (epileptic spasms)
- About 10 to 20% of the cases have previously suffered from epileptic spasms (hypsarrhythmia) before evolution into the Lennox Gastaut syndrome becomes evident

EEG

- The outstanding feature is the bisynchronous slow spike - wave complex ranging from 1 - 2.5Hz in sleep
- It is generally an inter- ictal rather than an ictal discharge and is most often of a generalized bisynchronous character. Lateralization is also fairly common; but focal slow spike wave activity is quite rare
- The spikes are maximal over the frontal or parietal regions
- This discharge is enhanced in non-REM sleep and may become almost continuous
- Must be carefully distinguished from the condition known as electrical status during sleep in children
- The slow spike and wave discharge may be present in early infancy between the ages 6 to 12 months
- Equally requisite for the diagnosis is the presence of bilateral fast rhythmic waves ("epileptic recruiting rhythm" that appears principally in non-Rem sleep). Therefore, sleep recordings are usually essential in evaluating such patients

Figure 10.9 (Lennox Gastaut)

An example of 2 hertz spike and wave activity (slow spike and wave activity) in a 14-year-old child. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

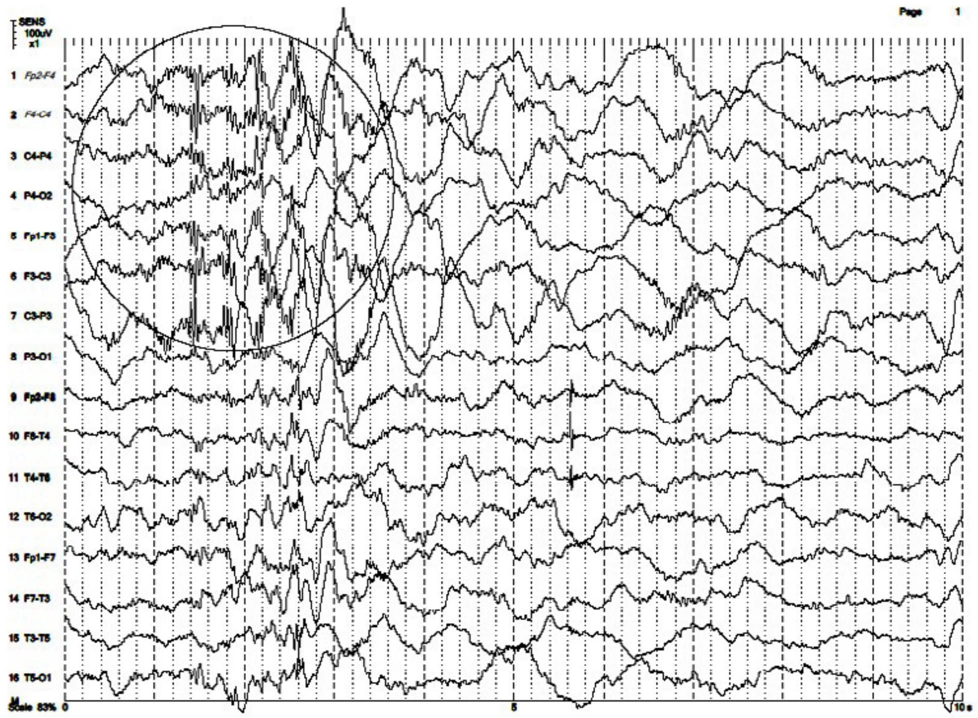


Figure 10.10 (Fast rhythmic activity)

An example of 10 hertz activity (fast rhythmic waves= epileptic recruiting rhythm) in sleep in a 4-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Figure 10.11 (Myoclonic jerk in a patient with LGS)

An example of a myoclonic jerk in a 4-year-old patient with LGS accompanied with a generalized burst of spike and wave activity. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

G. Benign Rolandic Epilepsy (BFEC)

- A benign and controllable type of epileptic seizure disorder with focal motor and/or generalized tonic clonic seizures
- Occurs between the ages 3 to 12 years and boys are more often affected. Majority seen be- tween the ages of 6-10 years
- The seizures can disappear during adolescence or even prior to puberty
- The seizures regardless of focal or generalized character tend to occur during nocturnal sleep
- (80%), mostly during the first 2 hours or the last hour of sleep
- About 10% of seizures take place shortly after awakening. Nocturnal seizures may awaken the child
- Focal seizures often involve the face; the child may be aware of the event with normal receptive language but be unable to talk (expressive dysphasia) during the seizure event. In most cases parents can be reassured that this form of epilepsy is benign. A sensory component may only be apparent to the child
- Not all require medication, those that are treated usually respond well to carbamazepine
- Benign rolandic epilepsy is based on dysfunction rather than structural pathology. Similar spikes (see below) can be seen in patients with evidence of cerebral palsy
- Behaviour disorders are very common in children with rolandic spikes

EEG

- Spiking occurs over the central region and/or adjacent mid-temporal and parietal areas. The spikes themselves are large and may be either spikes or sharp waves
- Spiking is usually enhanced in light sleep

Figure 10.12 (Central spikes in BFEC)

Awake EEG demonstrates central spikes (BFEC) more marked over the right hemisphere in a 5-year-old child. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

H. Childhood Epilepsy with Occipital Paroxysms

- Is a syndrome of idiopathic epilepsy in which seizures begin in childhood and usually cease by adulthood
- The seizures begin with unformed visual symptoms (e.g. light flashes, transient loss of vision like a "shutter coming down"; vomiting and may be followed by a post-ictal migraine head- ache)
- Onset between ages 2 and 8 years and predominantly nocturnal; seizures with deviation of the eyes and vomiting
- Several factors combine to make this syndrome less well defined than the more common
  a. The prognosis is more variable
  b. A similar EEG pattern may be seen in individuals with underlying structural abnormalities
  c. Headaches may precede or follow a variety of seizure types and
  d. There may be some overlap with rolandic epilepsy since it has been reported that some children with rolandic spikes may initially have epileptiform activity localized to the occipital head regions

EEG

- The inter-ictal EEG shows prominent occipital spikes or sharp waves that may occur in a semi-rhythmic pattern at 1-3 hertz
- The discharges attenuate or disappear with eye opening and are not activated by photic stimulation
- Spikes can occur with fixation off sensitivity
- EEG background activity is usually normal. Lack of alpha activity unilaterally would suggest a structural lesion

Figure 10.13 (Occipital spikes in BEOP)

An example of bilateral occipital spikes (BEOP) in a 12-year-old child in sleep. HF=70Hz, LF=0.1s, sensitivity=10uv/mm.

I. Childhood Absence Epilepsy (CAE)

- Age of onset is between 3-5 years and affects girls more frequently
- There may be a strong familial pattern
- Absences can be frequent, occurring many times a day
- 80% of patients become seizure free on medication (sodium valproate or ethosuximide)
- If seizures reoccur during adolescence, they may develop into generalized tonic clonic seizures

EEG

- Classical symmetrical 3 Hz spike and wave activity with normal inter-ictal background rhythms lasting less than 20 seconds
- Staring, blinking and occasional mouthing movements may be noted with seizure

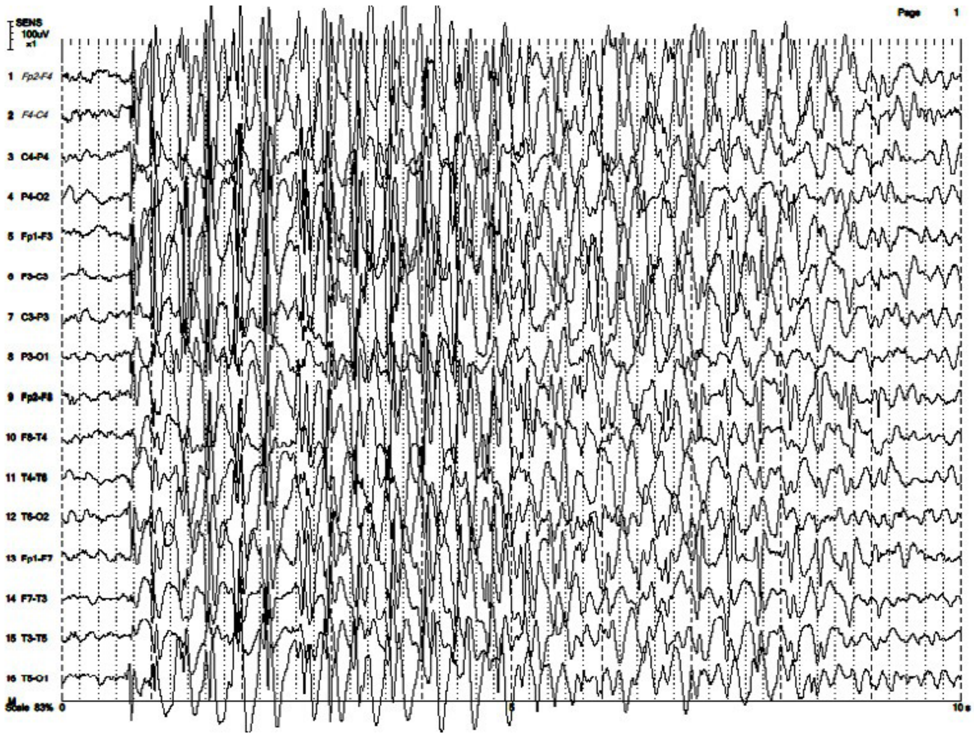


Figure 10.14 (3 Hz in CAE)

An example of CAE in a 4-year-old child in sleep. HF=70Hz, LF=0.1s, sensitivity=15uv/mm

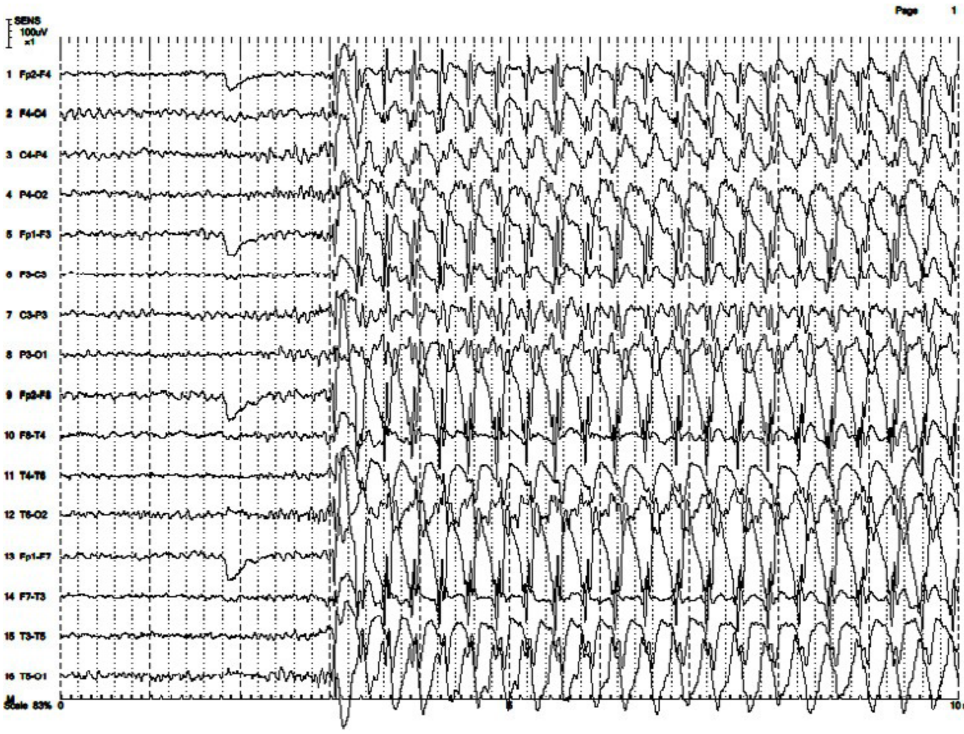
J. Juvenile Myoclonic Epilepsy (JME)

- Characterized by bilateral jerks which may cause the patient to fall and the classic history is dropping things during breakfast time
- The seizure intensity can be mild to moderate involving the neck, shoulder and arms
- Onset usually occurs in the mid - teens but can occur earlier with occasional absences and later followed by tonic - clonic seizures
- The jerks tend to occur most frequently soon after waking from sleep or in the evening

EEG

- EEG correlation is generalized 3-4 Hz spike waves or multiple spike and slow wave complexes noted with myoclonic jerks

- Abnormalities are enhanced by sleep, hyperventilation, at times with eye closure and in 30- 50% by intermittent photic stimulation



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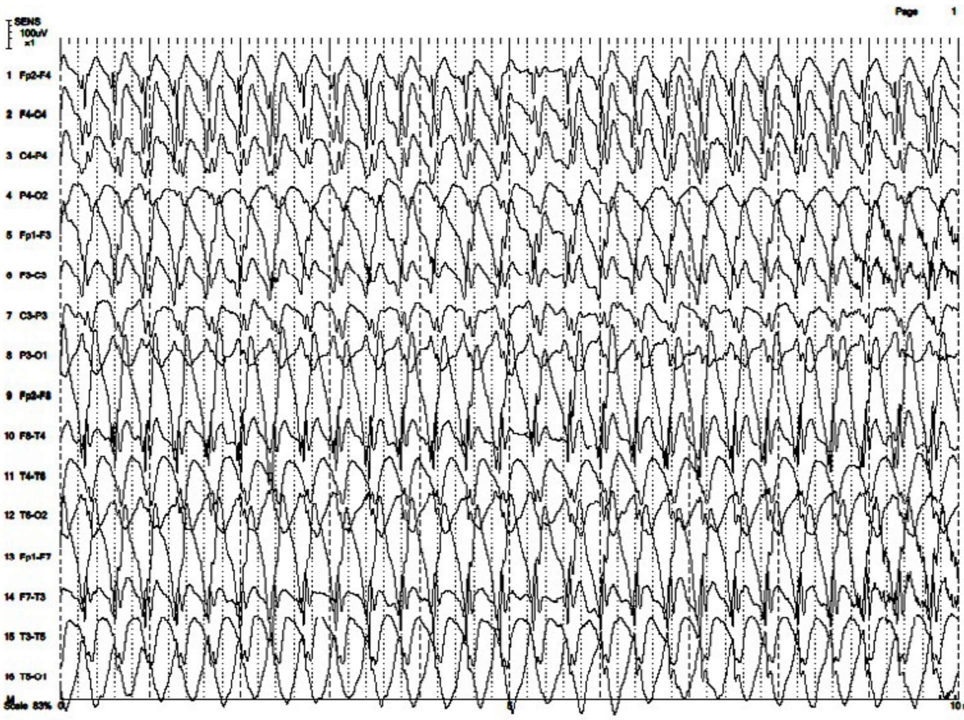

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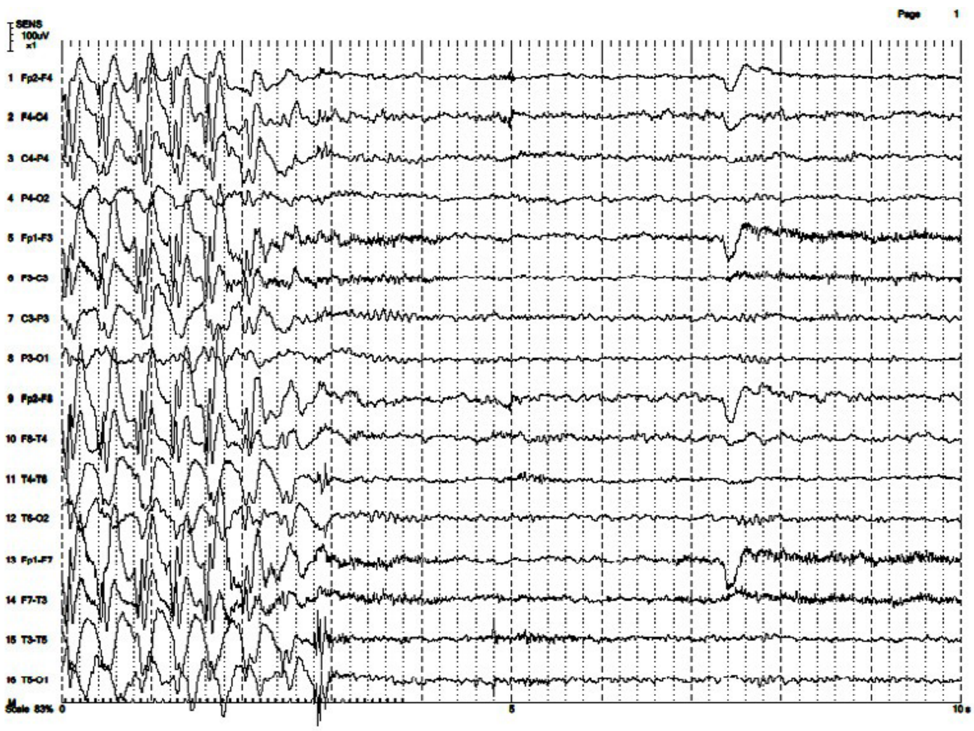

(3)

Figure 10.15 (Absence in JME)

An example of an absence seizure in a 13-year-old child with JME lasting approximately 23 seconds during IPS and with some bi-lateral temporal slowing post seizure. HF=70Hz, LF=0.1s, sensitivity=10uv/mm

Outcome goals for Chapter 10- epileptogenic disorders

- Recognize classic epileptic patterns
- Differentiate which epileptic disorders need immediate intervention
- Know if the EEG pattern answers the referring problem
- Know which disorders would need specialized care
- Make a proper diagnosis in combination with EEG as it would affect appropriate management and neurological outcome in patients

Questions for chapter 10

1 A 12-year-old boy has seizures consisting of seeing stars and coloured lights in bizarre shapes. The most likely origin for his attacks is:

1) Angular gyrus of the parietal lobe
2) Supramarginal gyrus of the parietal lobe
3) Posterior temporal lobe
4) Anterior temporal lobe
5) None of the above

a) 1 and 2 are correct
b) 2 and 3 are correct
c) 5 is correct
d) 3 and 4 is correct
e) 1 and 3 is correct

2. Sporadically occurring sharp waves are noted in the recording of a newborn. The clinical interpretation should indicate:

a) That this finding may occur in normal newborns
b) The presence of a focal lesion (s) at the site (s) of the sharp wave is likely
c) The presence of a focal lesion(s) immediately posterior to the sharp wave is likely
d) A diffuse encephalopathy with potentially epileptogenic features is present
e) Such transients are most likely of artefactual origin

3. **A four-year-old child is described as having episodes of daydreaming associated with staring, blinking and occasional mouthing movements. The most likely diagnosis is:**

a) Juvenile absence seizures

b) Temporal lobe seizures

c) Frontal lobe seizures

d) Absence seizures

e) All are likely

4. **Which of the following statements best describes the seizure picture associated with central-mid-temporal (Rolandic) spike foci in children:**

a) Rapidly spreading Jacksonian march leading to status epilepticus

b) Illusions of fear and strangeness

c) Somatosensory involvement of the tongue and inner cheeks

d) Visual hallucinatory phenomena

e) Adversive phenomena

5. **All of the following EEG patterns occur in Hysarrhythmia EXCEPT:**

a) Chaotic admixture of waveforms

b) Multifocal epileptiform discharges

c) Spikes seen greatest over the posterior head regions

d) Spikes more pronounced during REM sleep than non-REM

e) High amplitude waveforms

CLINICAL PRESENTATIONS AND RECOMMENDATIONS

V Kander (Mtech) / Jo Wilmshurst (MD)

Table 5

AGE	CLINICAL PRESENTATION	EEG CHARACTERISTICS	EPILEPSY SYNDROMES	RECOMMENDATIONS
Neonatal	Occurs in neonatal period with clusters of tonic spasms. Developmental regression	Burst suppression with high amplitude polyspike and wave activity	Ohtahara (EIEE)	Urgent referral to neurology
1 week-7 months	Almost continuous seizures which appear to flit from type and location (focal motor, autonomic, etc). Profound neuroregression	Diffuse slowing, loss of normal background activity, each seizure starts with rhythmic theta activity in one region, migrates to adjacent regions	Migrating partial seizures of infancy	Urgent referral to neurology
3-9 months	Flexor or extensor sustained contractions. Delayed development	High amplitude mixture of spike and wave activity in a chaotic pattern	Infantile (epileptic) spasms/ hypsarrhythmia	Urgent referral to neurology/needs scan/start treatment
Under 1 year	Prolonged and recurrent seizures “triggered” by fever	May be normal at onset. Occasional slowing and generalised spike waves	Severe myoclonic epilepsy in infancy (Dravet syndrome)	Referral to neurology
18-60 months	Often history of febrile convulsions, Recurrent runs of brief myoclonic jerks and drops, slumping to the ground	4-7 Hz diffuse theta activity, maximal over the centro-parietal regions. 2-3 Hz generalised polyspike / wave complexes isolated or repeated at 2-4 Hz for 2-6 seconds.	Myoclonic astatic epilepsy (Doose syndrome)	Referral to neurology
2-8 years	Isolated speech regression-send for sleep EEG. Behavioural problems	Continuous spike waves in sleep(CSWS)	Landau-Kleffner (LKS)	Referral to neurology

AGE	CLINICAL PRESENTATION	EEG CHARACTERISTICS	EPILEPSY SYNDROMES	RECOMMENDATIONS
3-5 years	Tonic seizures, atonic seizures and atypical absences. Multiple seizure types. Often some learning difficulties and some with preceding infantile spasms.	Bursts of diffuse slow spike-waves during awake state. Bursts of fast rhythmic waves and slow polyspikes. Generalised fast rhythms 10Hz in sleep.	Lennox-Gastaut syndrome	Referral to neurology
3-6 years	Blank spells lasting 5-10 seconds.	3 hertz spike and wave activity	Absences	Start treatment with valproate or ethosuximde
5-7 years	Morning seizures before arousal. Can't talk during the event but understands spoken word. May have unilateral sensory-motor seizures	Spikes over the central regions	BFEC	Needs neuroimaging to exclude focal abnormality
3-6 years	Intermittent but prolonged nocturnal seizures starting abrupt loss of vision "like a shutter", headache and vomiting.	Occipital paroxysms or spikes with fixation of sensitivity.	Benign epilepsy with occipital paroxysms	Start treatment with carbamazepine if events recurrent. Consider neuroimaging.
8-12 years	Occurs in childhood. Often associated with myoclonic jerks	3 hertz spike and wave activity and 1/3 of patients are photic sensitive	JME	Referral to neurology
Any age	Focal seizures with or without alteration of consciousness. Behaviour manifestations	Focal spikes with 2nd generalization	CPS-now known as focal seizures with loss of consciousness/ focal epilepsy	Needs neuroimaging/start treatment with carbamazepine

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Answers to self-assessment questions are available on ICNApedia VLE http://icnapedia.org/vle