VENTRICULOPERITONEAL SHUNT FAILURES AT RED CROSS WAR MEMORIAL CHILDREN'S HOSPITAL

MASTERS OF MEDICINE (MMED) IN NEUROSURGERY

UNIVERSITY OF CAPE TOWN

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DECLARATION

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Format

This MMED has been written in a publication ready format, with the future goal of submitting to the accredited journal, 'World Neurosurgery,' as an original research article.

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CSF – Cerebrospinal fluid

VP shunt – Ventriculoperitoneal shunt

RCWMCH – Red Cross War Memorial Children's Hospital

EVD – External ventricular drain

ETV – Endoscopic third ventriculostomy

AIS – Antibiotic impregnated shunt

OSV II – Orbis Sigma valve II

IVH – Intraventricular haemorrhage

MMC – Myelomeningocele

Chapter 1 Introduction

1.1 Context

Hydrocephalus is a common condition faced by paediatric neurosurgeons worldwide and if not treated timeously can lead to severe morbidity and mortality. [1,2] Cerebrospinal fluid diverting procedures are the mainstay of treatment, with the ventriculoperitoneal shunt being the most commonly used.[3] Despite all the advances made since the first permanent shunt was placed, the failure rate of shunt procedures remains high, with Drake, *et al*, reporting a 30% failure rate in the first year.[4] The most common causes of shunt failure are blockage, infection and shunt disconnection and previous studies have tried to investigate shunt failure and potential risk factors. [5,6,7] The purpose of this study was to record our own shunt insertion and failure rates at our institution. The idea was to provide us with information related to shunt failures in our patient population, which varies from the literature published around the rest of Africa and in the developed world. [8,9] This will hopefully provide information to implement change and reduce shunt failure in the future and improve patient outcomes.

1.2 Ethical Consideration

The research protocol was presented to the Surgical Department Research Committee for approval (Project 2020/134). It was then sent to the University of Cape Town's Human Research Ethics Committee for approval (HREC REF 522/2021). All patient records were de-identified to maintain anonymity when analysing data. Patient management was not affected by the study in any way. Care was taken to not publish any personal or identifiable characteristics of the patients

1.3 Author guidelines to the Journal

Chosen Journal: World Neurosurgery

The journal's mission is to: ‘To provide a first-class international forum and a 2-way conduit for dialogue that is relevant to neurosurgeons and providers who care for neurosurgery patients. The categories of the exchanged information include clinical and basic science, as well as global information that provide social, political, educational, economic, cultural, or societal insights and knowledge that are of significance and relevance to worldwide neurosurgery patient care. To act as a primary intellectual catalyst

for the stimulation of creativity, the creation of new knowledge, and the enhancement of quality neurosurgical care worldwide. To provide a forum for communication that enriches the lives of all neurosurgeons and their colleagues; and, in so doing, enriches the lives of their patients.'

Electronic links: https://www.elsevier.com/journals/world-neurosurgery/1878-8750/guide-for-authors

1.4 References

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CHAPTER 2 PUBLICATION READY MANUSCRIPT

ABSTRACT

Ventriculoperitoneal shunt failures at Red Cross War Memorial Childrens Hospital
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Introduction
Ventriculoperitoneal shunt (VP shunt) insertion is one of the mainstays of treatment of hydrocephalus and although very effective, a high rate of shunt failure persists globally. The purpose of the study was to quantify the ventriculoperitoneal shunt failure rate at Red Cross War Memorial Children's Hospital (RCWMCH) and assess potential factors contributing to shunt failures.

Methods
A retrospective review of VP shunts done at RCWMCH between August 2015 through December 2019 was performed. Operative notes, discharge summaries and patient folders were reviewed to collect information about patient age, aetiology of hydrocephalus, index vs revision shunt, shunt system and other noticeable variables. Overall shunt failure was recorded.
Univariate and multivariate models were used to determine causal relationship.

Results
Four hundred and ninety-four VP shunt operations were performed on 340 patients with 48.8% being index shunts and 51.2% revision shunts. Average patient age was 3.4months. The total VP shunt failure rate over the study period was 31.2%, with a 7.3% infection rate, 13.6% blockage and 3.6% disconnection rate. The most common aetiologies were Post infectious hydrocephalus 29.4%, Myelomeningocele 19.7% and Premature Intraventricular haemorrhage 14.1%. Orbis-sigma II(OSVII), Distal slit valves and Antibiotic impregnated catheters were used most frequently. Failure rates were highest in the revision group, 34.7% compared to 27.3% in index shunts.

Conclusion
VP shunt failure occurs most commonly in revision surgery, and care should be taken at the index operation to reduce failure risk. Surgeon level, duration of surgery, aetiology of hydrocephalus and shunt system used did not influence overall failure rates.

INTRODUCTION

Hydrocephalus is a common paediatric condition faced by neurosurgeons.[1] A wide variety of aetiologies and theories behind its pathophysiology are postulated. If left untreated, hydrocephalus results in severe morbidity and mortality.[2]

Since the first documented permanent ventricular shunt, placed by Mikulicz in 1893, cerebrospinal fluid (CSF) shunting has evolved, and has since become the mainstay of treatment for hydrocephalus.[3] Shunt insertion is mentioned as one of only two neurosurgical procedures listed on the 44 essential surgeries published by the World Bank group. [4,5]
Sadly, CSF shunt complication rates are still high, reported as between 8.6% and 50% in developing countries.[3] Up to 30% of shunts will fail within 1 year of insertion.[6] Shunt failure is described as the need for any surgical procedure for definitive CSF diversion in a previously shunted patient.[7] The most common reasons being blockage, infection and shunt disconnection.
Various authors [8,9,10] have tried to identify risk factors for shunt failure and many [11, 12,13,14] have studied factors linked to shunt survival. The aetiology of hydrocephalus, shunt type, surgeon experience and previous revisions have all been linked to shunt failure and poor outcomes.

There is an increased risk of shunt sepsis and failure every time a revision is needed; shunt failure is shown to even impact cognitive development in children.[15]

Given the wide range of complication rates reported, and the variation in hydrocephalus aetiology and patient demographics in different regions, it is important that each institution documents its own complication rates and shunt outcomes. This is also the basis for understanding how interventions or protocol changes influence shunt outcomes. With this study, we aimed to record our shunt insertion and failure rates for the first time at our institution. It will attempt to highlight certain risk factors that are specific to the population subgroup that contribute to shunt failure and the information to implement change. This may ultimately lead to a reduction in shunt failure rates and improve patient outcome.

Methods

Following institutional review approval, a retrospective folder review of all patients undergoing a ventriculoperitoneal shunt insertion between August 2015 and December 2019 was conducted. This period was selected as departmental data collection protocols were amended prior to this. Patients under the age of 13 are treated at Red Cross War Memorial Children's Hospital (RCWMCH), although not uncommonly, slightly older patients do present for emergency surgery.
We excluded, in isolation, ventriculopleural shunts, ventriculoatrial shunts, ventriculosubgaleal shunts, external ventricular drains (EVDs), and endoscopic third ventriculostomy (ETV).

Information was obtained from operative notes, discharge summaries and electronic radiological archiving systems. Outcome data was analysed from patient folders retrospectively. Data collected included patient age, sex, aetiology of hydrocephalus, time of shunt insertion and surgeon seniority. Each shunt insertion was designated as index shunt (first shunt placed in patient) or a revision shunt (all subsequent shunts inserted), and the type

of shunt was recorded. Additional factors, such as use of endoscope and number of surgeons involved in the case, were also collected.
The aetiology of hydrocephalus was categorised as postinfectious/TB meningitis, myelomeningocele, posterior fossa/brainstem tumour, prematurity-related intraventricular haemorrhage, optic pathway glioma/hypothalamic glioma/ventricular tumours, aqueduct stenosis/pineal region tumour, cysts, cortical malformations, encephalocele, post-traumatic hydrocephalus, and in cases when no discernible cause was found, "other". Head circumference was recorded as per the South African 'Road to Health Chart', using the Z-score classification. This chart is validated for the South African population.

The timing of surgery was classed as: during working hours, 07:00 to 17:00; after hours, 17:01 to 00:00; and after midnight, 00:00 to 06:59. The experience of the surgeon was classified as junior registrar (trainee, 2 or less years in the department), senior registrar (2 to 5 years in the department), and consultant.

Shunt failure was defined as 'any reason for shunt to be revised/removed.' Cause (Type) of shunt failure was as determined by the operating surgeon at the time of shunt insertion, revision, or removal. In the minority of cases a cause was not clear and labelled "not specified". Reasons for shunt failure were classified as Infection; Blockage (proximal and distal obstruction grouped together); Shunt disconnection; Catheter malposition; Shunt erosion through skin; Shunt fracture; Migration of proximal or distal catheter; CSF overdrainage and Intraventricular haemorrhage. Due to low numbers in certain failure groups, subgroup clusters were made when analysing data.

Outcome data 2 years post-insertion of last shunt was recorded, taking note of the patient's last visit to RCWMCH. This was a convenience decision and allowed comparison to similar international studies. Shunt survival or subsequent revisions and the number of revisions were recorded.

Statistical analysis

Measures of central tendency included median and interquartile or minimum-maximum range, given the non-parametric distribution of data. Frequency data are reported as number and percent, the association between shunt failure and potential risk factors was analysed using Chi-square, Mann-Whitney's U or Kruskall Wallis tests using SPSS Statistical program (IBM)®. A p-value of <0.05 was set as significant. Given the small sample size multiple testing was not controlled for.

Results

Table 1: Patient demographics and aetiology of hydrocephalus

(Data are displayed as patient number (%))

Variable	Patients n=340 (%)
Age	
Min	1 day
Median	1y 3m
Max	16.6 yrs
Sex	
Female	154 (45.3)
Male	186 (54.7)
Head circumference (at presentation)	
3 z score	93 (27.4)
2 z score	10 (2.9)
1 z score	2 (0.6)
0	30 (8.8)
-1 z score	2 (0.6)
-2 z score	4 (1.2)
-3 z score	4 (1.2)
Not recorded	195 (57.3)
Aetiology of hydrocephalus	
Post-infectious/TB Meningitis	100 (29.4)
Myelomeningocele	67 (19.7)
Posterior fossa/brainstem tumour	15 (4.4)
Premature Intraventricular haemorrhage	48 (14.1)
Optic pathway glioma/Hypothalamic Tumour/Intraventricular tumour/Craniopharyngioma	18 (5.3)
Aqueduct stenosis/Pineal region Tumours/Tectal tumours	15 (4.4)
Cysts	18 (5.3)
Cortical malformations	8 (2.4)
Encephalocele	4 (1.2)
Congenital	34 (10)
Other (Suspected X-linked hydrocephalus/Mucopolysaccharidosis/Down syndrome with CCJ instability/Crouzons syndrome/Migrational disorder)	7 (2.1)
Post traumatic	6 (1.8)

The demographic data of this study is summarised in **Table 1**. A total of 340 patients underwent 494 ventriculoperitoneal shunt surgeries during the study period. Head circumference (HC) was not routinely recorded in older patients (>5 years old) and data was only available in 143 patients (42.7). For the available data, the most common HC of patients was a +3 z-score, with a 65% prevalence, as compared to the next highest of a 0 z score of 20.9%.

Post-infectious hydrocephalus, including TB meningitis(13.5%), was the most common aetiology of hydrocephalus at 29.4%, followed by Spinal dysraphism (19.7%.), most commonly myelomeningocele, and Premature Intraventricular Haemorrhage (14.1%). The remaining aetiologies are shown in **Table 1**.

Number of shunts placed per patient

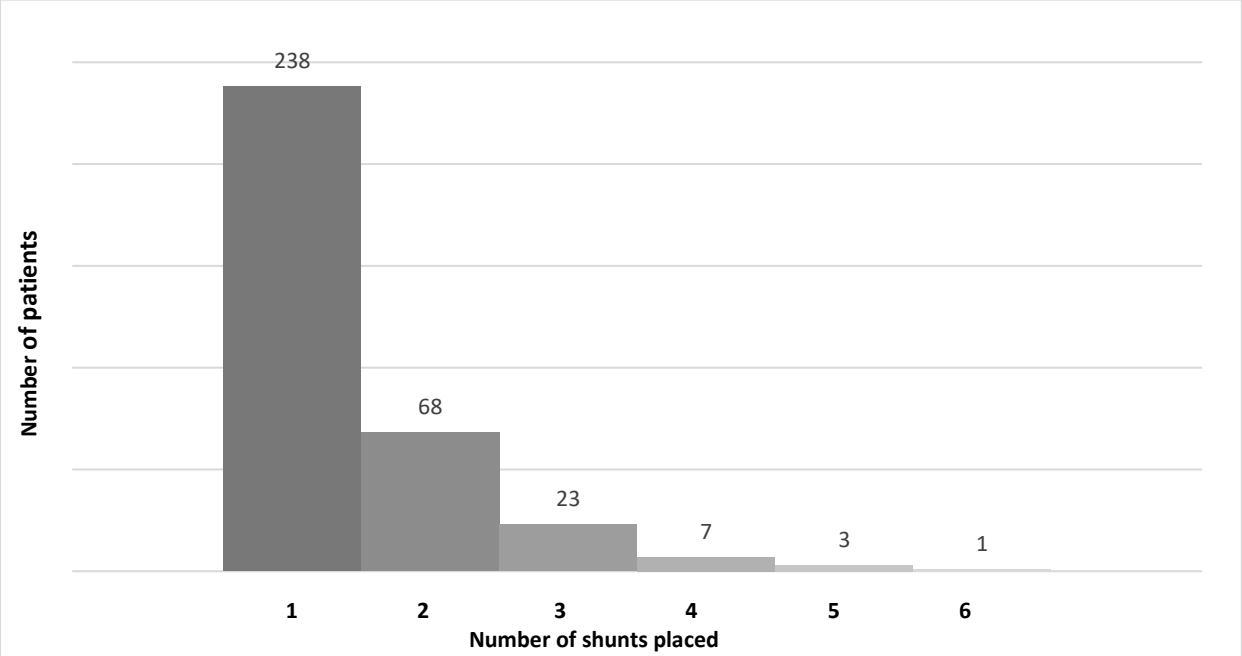

Figure 1: Total number of shunts placed per patient during study period.

Figure 1 shows the number of shunts placed per patient during the study period. 1 patient had a total of 6 shunts placed.

The overall failure rate for shunts inserted over the study period was 31.2%. The failure rate was higher in the revision group (34.75%) compared to the index group (27.3%) (*p=0.047*).

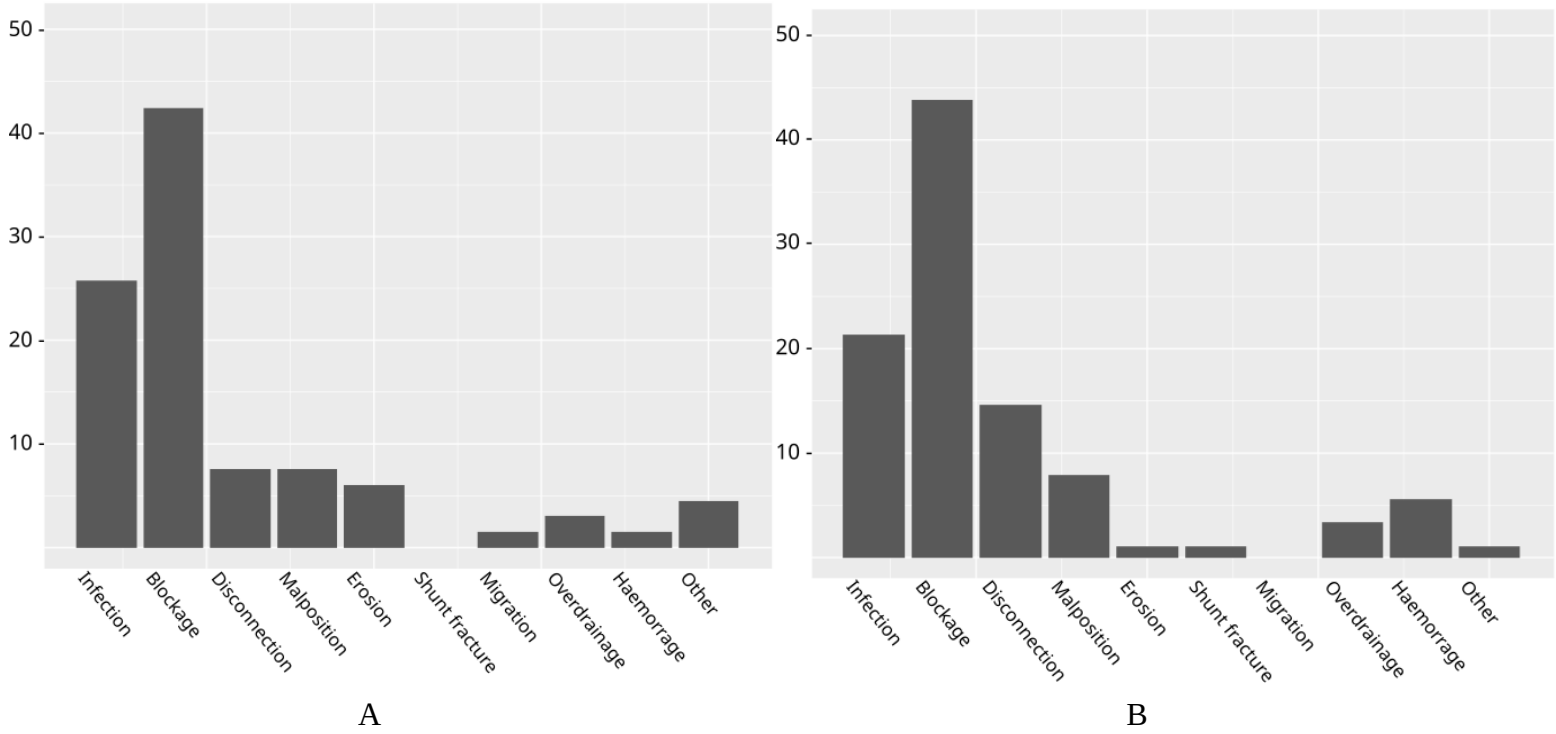

Figure 2: Bar graph illustrating types of shunt failures in Index (A) and Revision (B) groups as a percentage of total failures.

Figure 2 summarizes the aetiologies of shunt failures. Shunt blockage (proximal and distal obstruction) was the most common cause of shunt failure. Overall infection rates for the study (both index and revision) was 7.3%. The shunt disconnection rate was 3.6%, making this the third most common cause of failure. There was no increased risk of disconnection based on shunt type or level of surgeon. Shunt fracture was noted in 0.4%.

The time to failure was recorded as early (<1week post insertion), intermediate (1 week to 1 year) and late (>1 year). No shunt infections occurred within a week of insertion, 91.7% occurred within the 1st year, and 8.3% occurred thereafter. No shunt disconnections occurred in the first week; 27.8% occurred after 1 year, with the remainder occurring in the intermediate period. Of note, malpositioned shunts failed during the first week in 41.7% and 50% failed in the intermediate range.

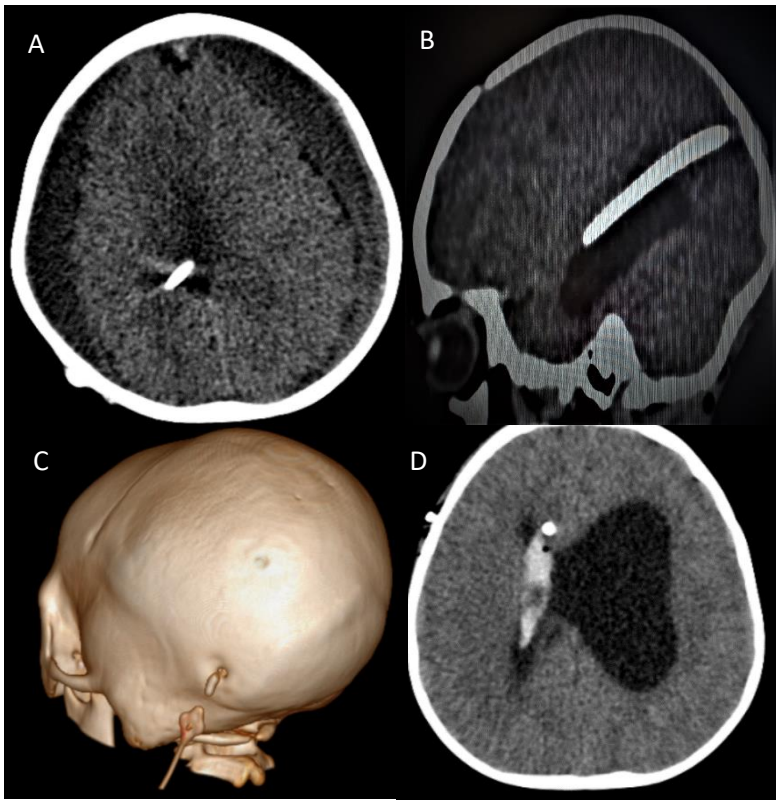

Figure 3: Figure showing various shunt complications encountered.

Figure A shows a patient with shunt overdrainage, that developed bilateral chronic subdural haematomas. B, Malpositioned ventricular catheter, sagittal view, with catheter in the right temporal horn of lateral ventricle. C, Shunt disconnection with distal catheter shown disconnected from valve. D, Intraventricular haemorrhage noted in right lateral ventricular following catheter placement.

Table 2: Factors contributing to shunt failure

		Index/Revision									
		Index Shunt failure					Revision Shunt failure				
		No		Yes		P value	No		Yes		P value
		No.	%	No.	%		No.	%	No.	%	
Age	<6months	94	39.0%	42	17.4%	0.504	26	10.3%	15	5.9%	0.651
	6m to 1year	26	10.8%	6	2.5%		18	7.1%	6	2.4%	
	1year to 5years	26	10.8%	9	3.7%		46	18.2%	29	11.5%	
	>5years	29	12.0%	9	3.7%		75	29.6%	38	15.0%	
Aetiology	Post-infectious/TB Meningitis	53	22.0%	11	4.6%	0.129	46	18.2%	34	13.4%	0.359
	MMC	36	14.9%	15	6.2%		32	12.6%	14	5.5%	
	Prem IVH	19	7.9%	12	5.0%		29	11.5%	12	4.7%	
	Other	67	27.8%	28	11.6%		58	22.9%	28	11.1%	
Level of Surgeon	Junior Registrar	105	43.6%	38	15.8%	0.886	93	36.8%	48	19.0%	0.956
	Senior Registrar	50	20.7%	19	7.9%		46	18.2%	26	10.3%	
	Consultants	20	8.3%	9	3.7%		26	10.3%	14	5.5%	
Surgical Time	<50min	83	35.2%	22	9.3%	0.056	53	21.5%	29	11.7%	0.899
	>50min	89	37.7%	42	17.8%*		108	43.7%	57	23.1%	
Time of day	07:00-17:00	147	61.0%	58	24.1%	0.590	106	41.9%	58	22.9%	0.815
	17:01-00:00	21	8.7%	7	2.9%		41	16.2%	19	7.5%	
	00:01-07:00	7	2.9%	1	0.4%		18	7.1%	11	4.3%	
Shunt Used	Orbis-sigma II (OSVII)	56	23.2%	32	13.3%	0.095	82	32.4%	52	20.6%	0.200
	Distal Slit	74	30.7%	23	9.5%		31	12.3%	12	4.7%	
	Antibiotic impregnated shunt(AIS/ (Bactiseal®)	30	12.4%	6	2.5%		34	13.4%	20	7.9%	
	Other	15	6.2%	5	2.1%		18	7.1%	4	1.6%	
Endoscope used	Yes	19	7.9%	5	2.1%	0.448	17	6.7%	8	3.2%	0.758
	No	156	64.7%	61	25.3%		148	58.5%	80	31.6%	
CSF Protein (g/L)	<1	115	47.7%	40	16.6%	0.517	109	43.1%	49	19.4%	0.262
	>1	51	21.2%	20	8.3%		37	14.6%	25	9.9%	
	No result	8	3.3%	6	2.5%		19	7.5%	14	5.5%	
CSF Poly count (/uL)	<5	150	62.2%	56	23.2%	0.416	136	53.8%	71	28.1%	0.482
	5 or more	16	6.6%	4	1.7%		17	6.7%	7	2.8%	
	No result	9	3.7%	6	2.5%		12	4.7%	10	4.0%	
CSF RBC count (/uL)	<100	87	36.1%	32	13.3%	0.113	94	37.2%	47	18.6%	0.528
	100-1000	41	17.0%	8	3.3%		35	13.8%	15	5.9%	
	>1001	39	16.2%	20	8.3%		24	9.5%	16	6.3%	
	Not recorded	8	3.3%	6	2.5%		12	4.7%	10	4.0%	

None of the factors listed in **Table 2** showed any significant correlation to shunt failures.

Surgery duration and time of day

Mean surgical time was 59min, with revision shunts taking longer (68min) than index shunts (56min). The shortest surgical time was 23min and the longest 180min. Multiple surgeons resulted in faster surgical times (*p=0.002*) compared to single surgeon operations. Index shunt failure was seen more frequently if surgical duration was longer than 50min, with a *p*-value approaching significance (*p=0.056*).

The time-of-day that the surgery was performed was not significant, neither for index nor revision shunts (*p=0.590* and *p=0.815* respectively).

Level of surgeon

Level of surgeon showed no significance with regards to overall shunt failure (*p=0.091*). Junior registrars placed 284 shunts, senior registrars 141, and consultants 69. Consultants had a slightly higher percentage of revision shunts placed (57.9%), as opposed to Senior and Junior Registrars (51% and 49.6% respectively), but this was not statistically significant.

Table 3: Shunt systems used at RCWMCH.

Shunt system	Index	Revision	Total	%
OSV II	88	134	222	44.9
Distal slit valve	97	43	140	28.3
AIS (Bactiseal®)	36	54	90	18.2
Other (Miethke® gravitational valve/ Integra® Essential® valve, Atlas valve, Non-specified shunt systems)	20	22	42	8.5
Total	**241**	**253**	**494**	

Shunt system

OSV II, Distal slit valves and AIS catheters were the most frequently used shunt systems at RCWMCH. **Table 3** illustrates the frequency of shunts used in the index and revision group.

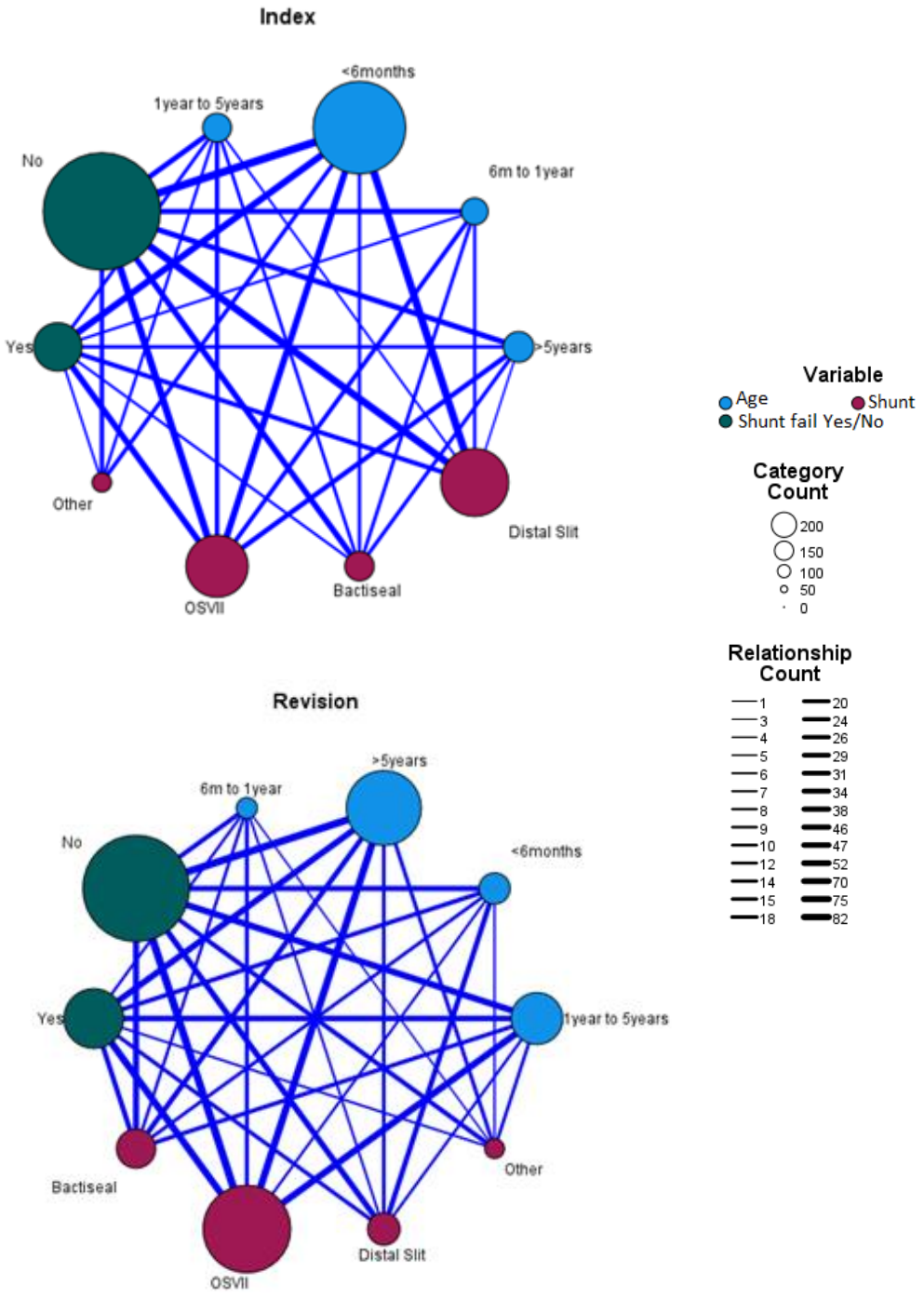

Figure 4: Relationship Map illustrating the relationship between shunt systems used, the ages groups and the number of failures for each subgroup. Both index and revision groups are indicated. Circle size and line thickness dictates the number of each variable in the connection. The key for the relationship map is indicated on the side.

Figure 4 above illustrates that Distal slit valves were used more frequently in both index and revisions groups (33.6% and 9.5%) in patients <6months of age compared to the OSV II (14.1% & 2%) and AIS (3.3% and 3.6%) catheters. Over 6months of age, OSV II catheters were used most frequently in both study groups. When comparing failure rates of Distal slit valves to OSV II shunts, in patients under 6 months, there was no significance regarding shunt failure in both the index and revision groups. (*p=0.100* and *p=0.100* respectively)

There was no overall significance regarding type of shunt used and risk of failure (*p=0.095* and *p=0.200*) for index and revision shunts respectively.

Shunt infections

Of the 90 Antibiotic-impregnated catheters placed, 36 were in the index group and 54 in the revision group. There were no infections recorded in the index group. Distal slit shunts had a higher rate of infection as compared to OSV II in the index group, 25% vs 16.7%. OSV II shunts in the revision group had an infection rate of 22.2% compared to distal slit and AIS catheters (13.9% & 11.1%), although significance was not reached when comparing AIS catheters to the other shunt systems for shunt infection, both index and revision groups (*p=0.130* and *p=0.867*).

Regarding patient age and type of failure: In the revision group, patients under the age of 6months had a higher rate of shunt infection (p=<0.001). Significance was not achieved in the index group (p=0.316)

Follow up
Patient folders were retrospectively analysed for 2 year follow up data. Of the 340 patients included in the study group, 199 (58.5%) had follow up data. 76 (22.4%) did not follow up and a further 11 (3.2%) died before a 2 year follow up. Fifty four (15.9%) of the folders could not be located. After a 2 year follow up outside the study period, 31 (9.1%) of the patients experienced shunt failure, with 26 (7.6%) requiring 1 revision and 5 (1.5%) requiring 2 shunt revisions.

Discussion

Of the 494 shunts placed in 340 patients, the overall failure rate was 31.2%. Revision shunts failed statistically more than index shunts. The majority of failures occurred due to blockage, both proximal and distal obstruction grouped together and our shunt infection rate of both index and revision was shunts was 7.3%. Failure rates of the various shunt systems used was insignificant, as well the influence of surgeon seniority or duration of surgery.

Age and sex
Children younger than 2 years old have a higher shunt failure rate [11,12,16]. The median age of patients in this study was 15months. We did not find a correlation between age and shunt failure. However, younger children who had revision shunts had a higher infection rate. This is replicated in other studies [16-18]. Reasons for this are not completely understood and Kulkarni, *et al*. described a less developed immune system in these young children as a possible contributing factor. [19]

Head circumference (OFC)
Children who had a large head circumference (above 3rd Z-score) on first presentation had a higher rate of shunt dysfunction – especially if larger than 60cm. This was also found by Gathura, *et al.* [20]. Most patients presenting to our unit charts above the 3rd z-score, reflecting late presentation, often *in extremis* and requiring urgent CSF shunt surgery. The larger heads tend to increase the chance of scalp pressure sores and potential for infection, although we did not specifically look at this. There was a high number where head circumference was not documented in the patient folders. This is – at least in part - due to the head circumference charts used, only recording up to 5 years of age.

Aetiology

Aetiology of hydrocephalus varies across the world. In low- and middle-income countries, for example, postinfectious hydrocephalus and myelomeningocele-related are more common than in high-income countries. Warf and colleagues have documented that up to 60% of hydrocephalus cases in Africa is caused by infection. [21, 22] This is in stark contrast to the developed world, where premature IVH is the most common aetiology. [11, 23] In our study post infectious hydrocephalus, including TB meningitis (29.4%), followed by myelomeningocele (19.7%) and premature intraventricular haemorrhage (IVH)(14.1%), was most common.

Several studies have investigated aetiology of hydrocephalus and risk for shunt failure. Berry, *et al*. identified spinal dysraphism as a predictor for multiple shunt failures [24], and several reports have noted a lower shunt survival in children with premature IVH.[25-28]

There was no significance found in this study regarding shunt failure and aetiology. This is consistent with reports of Piatt and Carlson[12].

Shunt failure

Shunt failure has been extensively researched [29-31]. Our failure rate of 31.2%, compared to an analysis of hospital databases in Thailand by Limwattananon, *et al.* [32], which showed failure rates of shunts inserted at 3, 6, 12 and 24 months being 11,5%, 19%, 25.2% and 31,3% respectively. Rossi, *et al.*[33] reported higher failure rates at 3 and 6 months of 24,1% and 29.9%. Drake, *et al.* reported that first time shunts placed in children failed 30% of the time in the first year.[6]

The longer the follow up period for shunted patients, the more it becomes clear that most will develop shunt failure at some point: longer follow up periods up to 15 years have been described with only 15.5% of patients not requiring a shunt revision.[34]

We demonstrated that revision shunts have an increased risk of shunt failure compared to index shunts. Several studies have identified a similar trend, with increasing failure rates with increasing number of shunt revisions [11, 35].

Blockage, followed by infection and disconnection were the three most common causes of shunt failure in the study for both index and revision groups. Blockage is the most widely reported cause of shunt failure worldwide, with rates ranging from 53.8% to 66.7%.[11, 17].

The disconnection rate of 2.1% in index shunts and 5.1% in revision shunts is similar to a 10 year follow up studying by Erol, *et al.* of 2.6% [36] and lower than findings reported by Sainte-Rose, *et al*. of 13.5% [37].

Misplacement of a shunt requires special mention: only 8.3% of malpositioned shunts functioned for longer than 1year in this study. The high early and intermediate failure rate does warrant further investigation and consideration of early revision if misplacement is noted on follow up imaging. Every safe measure should be taken to ensure accurate ventricular catheter placement in all patients.

Shunt infection

Shunt infection rates have been widely studied with many instituting protocols to reduce infection rates.[10, 14, 38-40]. There are certain protocols that are adhered to in the unit, such as cleaning with both alcohol based solution and iodine solution, limiting manual manipulation, and frequent changing of surgical gloves, previously described by Faillace, *et al.*[41], while placing and securing the shunt, although this was not analysed during this

study. The department introduced disposable tunnellers in April 2016 and a change to the antibiotic protocol of Ceftriaxone and Cloxacillin from 3 days to 24 hours of Cefazolin post operatively for shunt procedures, was instituted. Limited theatre thoroughfare is enforced while shunt surgery is ongoing. As this was a retrospective review, we were not able to analyse the adherence to the protocol as it is not documented whether it is followed in the patient notes.

The overall shunt infection rate in this study was 7.3%. This compares well to figures reported by units around Sub-Saharan Africa of 9.1% and 9.7%, as well as units around in the United States of America and the rest of the world, where reported figures range from 2% to 19%. [17, 20, 25, 35]

The recently published BASICS trial from Mallucci, *et al*. in 2019, as well as a papers from Sciubba, *et al*. and a meta-analysis from Klimo, *et al*., demonstrated a significant benefit of using antibiotic impregnated shunts (AIS) to reduce the incidence of shunt infection.[42-44] This study did not show significance regarding the use of AIS shunts and a reduction in shunt infection, although there were lower rates of infection in the AIS group compared to the Distal slit valve and OSVII group. As noted, there were a greater number of AIS catheters placed in the revision group and when comparing the different shunts in this group there was still no significance in the rate of shunt infection. It is important to note that AIS were not placed randomly, therefore the group may be biased. We prefer to place AIS catheters in patients in whom there is a concern of future shunt infection or in patients who had presented with shunt infection, but this subgroup was not investigated in this study but would be of interest to note in future studies.

Surgeon influence

A 1979 paper by George, *et al.* reported lower rates of infection in cases done by more experienced surgeons. Similarly, Choux and Hale reported similar findings regarding surgeon experience.[40, 45, 46] A Cochrane review in 2003 demonstrated a slightly higher failure risk for lower volume surgeons compared to their higher volume colleagues .[47] The findings in this study did not show a significant difference in shunt failure when comparing surgeons at different levels in their training, which mirrors the findings in, The Shunt Design Trial by Kestle, *et al*.[13] However, shunt complexity and risk was not controlled for, and there are likely reasons for why an operation required more experienced surgeons, which likely biases the groups. Not all of these reasons are recorded here. As previously mentioned, there is a higher failure rate in patients undergoing revision shunts and consultants are more frequently involved in the more complex revision cases in the unit. These cases tend to have higher failure rates and this may be contributing to the lack of significance found between the groups of surgeons.

Surgery duration and time of day

As a general principle, based on the paper by Choux, *et al*, attempts are made to keep operative time below 50min in the unit. [40] There was a trend toward significance of increased rates of failure in the index group with surgeries lasting more than 50min. Reasons could be longer exposure of shunt system to the atmosphere or increased ‘fiddle factor’ and handling of shunt system, both with the theoretical increased risk for infection. Longer procedures may also imply more complicated operations, such as for difficult peritoneal access in patients with previous abdominal scarring.

Revision surgeries tended to take longer, a trend commonly seen with any revision surgery.

The elective or emergency nature of cases theoretically may influence shunt outcomes. There was no association between the time of day that the shunt was inserted, although we did not control for bias: more complicated shunt surgeries are generally done during the daytime and consultant involvement preferred.

Endoscope

The use of an endoscope to assist with shunt insertion has been described to increase the risk of shunt infection and subsequent failure. [8, 46] Complex hydrocephalus may necessitate an endoscope. Use of the endoscope for ETVs and Intraventricular biopsies was also included if the patient had to have a ventriculoperitoneal shunt inserted during their admission. There was no associated increase in shunt infection or failure noted in this study group, although the sample size was small. Given the relative low number of endoscopic-assisted shunts placed in the study period, it may be helpful in future studies to include a large sample size. It may also be important to note that these procedures will be done by a consultant. This may affect the outcome.

CSF protein and red cell concentration

There was no association found with CSF protein or red blood cell level and the rate of shunt failure, as described in other studies.[48, 49] Protein and cell count may have influenced surgeons' choice of shunt, though, which may influence the outcome. In the past surgeons in the unit would have opted for a distal slit valve shunt in these cases. This was not examined in this study but could be a future subject to investigate.

Follow up

A major limitation of every retrospective review, especially in a folder-based system such as ours, is the loss of data. At the time of this study 15.9% of the folders could not be retrieved. Furthermore, loss to follow up is common in a mobile population - several of the patients in our system fall outside of our main referral region. This study was limited to our unit, and a national database does not exist, hence no conclusions can be drawn from the 22.4% of patients that who did not follow up, regarding shunt failure. These patients could have potentially returned to their home province and required further shunt surgery, demised in the community, or may be living without any shunt issues. This is unfortunately a high rate of attrition common in environments such as ours.

Limitations of study

This study is a retrospective study and results are subject to bias, some of which have already been described. Multiple factors may have contributed to the differences found between the two groups analysed, not all of which are documented. Conversely, identification of certain risk factors may have required a larger sample size. The data collected were based on available clinical data and as mentioned, the cause of shunt failure was left open to interpretation by the operating surgeon. As certain patients required multiple revision surgeries, it is possible that this patient subgroup may skew the overall failure rates but is important in the overall picture of shunt failure. Various factors potentially associated with outcomes are skewed by bias in different groups: for example, experience of surgeon, timing of surgery, choice of shunt type, etc. Prospective data collection, or better yet, randomisation

where possible, might yield better results. Finally, missing data may influence the results and the true 2-year failure rate could be different than the quoted figure.

Conclusion

VP shunt failure is commonly encountered by neurosurgeons around the world. Our universal desire to improve shunt survival and investigate potential causes of shunt failure is clear. This study documents the institution's overall shunt failure rate based on existing data, and as such forms the foundation for quality improvement initiatives. The overall failure rate was 31.2% and the shunt infection rate was 7.3%. Revision cases have higher failure rates. As this was a retrospective study, a future prospective study will be of great value and only by remaining critical of one's own shunt outcomes can we endeavour to improve the lot of these desperate children.

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Appendix 1: Department of Surgery Research Committee Approval

UNIVERSITY OF CAPE TOWN

Department of Surgery
Departmental Research Committee
Dr Timothy Pennel
D24 Office, Groote Schuur Hospital
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South Africa
Tel (021) 404 3430
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5 Oct 2020

Dr J Lazarus

Department of Surgery
University of Cape Town

Dear Dr Lazarus

RE: Project 2020/134

PROJECT TITLE: Shant Failures At Red Cross War Memorial Children's Hospital. A Retrospective Review.

The above protocol has been reviewed by the Department of Surgery Research Committee. I am pleased to inform you that the committee approved the scientific merit of the study, and endorse the protocol for submission to the relevant ethics committee.

Although this letter serves as confirmation that the above protocol has successfully passed through the surgical DRC, respective ethics committees still require DRC chair signature before submission.

Please use the above project number in all future correspondence.

Signed by candidate

DR TIMOTHY PENNEL
CHAIR: SURGICAL DRC

Signed by candidate

DR MARITZ LAUBSCHER
CHAIR: PROTOCOL REVIEW COMMITTEE

Appendix 2: University of Cape Town's Human Research Ethics Committee approval

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

Room G50- Old Main Building
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Telephone [021] 406 6492
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Website: www.health.uct.ac.za/fhs/research/humanethics/forms

19 August 2021

HREC REF: 522/2021

Dr N Enslin
Division of Neurosurgery
Email: johannes.enslin@uct.ac.za
Student: Jed.lazarus@gmail.com

Dear Dr Enslin

PROJECT TITLE: SHUNT FAILURES AT RED CROSS WAR MEMORIAL CHILDREN'S HOSPITAL. A RETROSPECTIVE REVIEW-MMED CANDIDATE-DR JED LAZARUS

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19, dated 17 March 2020; 06 July 2020 & 01 July 2021.

Approval is granted for one year until the 30 August 2022.

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)

The HREC acknowledge that the student: Dr Jed Lazarus will also be involved in this study.

Please quote the HREC REF 522/2021 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

Signed by candidate

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.

Appendix 3: Instructions to authors (World Neurosurgery)

Most pertinent points listed below.

For full instructions:
https://www.elsevier.com/wps/find/journaldescription.cws_home/722082?generatepdf=true

Article structure

Subdivision - unnumbered sections Divide your article into clearly defined sections. Each subsection is given a brief heading. Each heading should appear on its own separate line. Subsections should be used as much as possible when crossreferencing text: refer to the subsection by heading as opposed to simply 'the text'.

Introduction State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Results

Results should be clear and concise.

Discussion This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

Essential title page information

• Title. Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• Author names and affiliations. Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower- case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.

• Corresponding author. Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.

• Present/permanent address. If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.
• Highest academic degrees for all authors. Degrees are not listed in the author line but are necessary for other purposes.
• Departmental and institutional affiliations for all authors. When providing author names and affiliations, be sure to include department/division information and not only the institution.
• Key words (3 to 7). Provide an alphabetized list of 3 to 7 key words which will appear in print and used for indexing purposes.
• Short title. Short titles are required for all article types except for Letters to the Editor, Technical Notes and invited articles. The short title should be 40 characters or less, including spaces. Abbreviations list Provide an alphabetized list of all abbreviations used in the article, with each abbreviation/acronym followed by its complete spell out.
Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself. Abstracts should be 250 words, maximum.

Original Articles, Doing More With Less, Women in Neurosurgery, Great Hospitals, Neurosurgery Nursing and Technical Notes require a structured abstract with the following headings: Objective (or Background), Methods, Results, Conclusions. Historical Vignettes and Literature Reviews require an abstract, but it can be unstructured (no headings).

Tables Number tables consecutively in accordance with their appearance in the text. Each table requires its own title. All tables should be placed in their own file, separate from the manuscript file. Avoid vertical rules. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article. Place footnotes to tables below the table body and indicate them with the following symbols in the following order: • * (asterisk) • † (dagger) • ‡ (double dagger) • § (section mark) • II (parallel mark) • ¶ (paragraph symbol) • # (number sign) • ** (etc.) • *** (etc.)

All studies listed in a table must be cited in the table and included in the complete reference list, just as if the study in question were discussed and cited in the text of the article.

References Citation in text Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication. Reference links Increased discoverability of research and high quality peer review are ensured by online links to the sources cited. In order to allow us to create links to abstracting and indexing services, such as Scopus, Crossref and PubMed, please ensure that data provided in the references are correct. Please note that incorrect surnames, journal/book titles, publication year and pagination may prevent link creation. When copying references, please be careful as they may already contain errors. Use of the DOI is highly encouraged. A DOI is guaranteed never to change, so you can use it as a permanent link to any electronic article. An example of a citation using DOI for an article not yet in an issue is: VanDecar J.C., Russo R.M., James D.E., Ambeh W.B., Franke M. (2003). Aseismic continuation of the Lesser Antilles slab beneath northeastern Venezuela. Journal of Geophysical Research, https://doi.org/10.1029/2001JB000884. Please note the format of such citations should be in the same style as all other references in the paper. Data references This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

Reference style Text: Indicate references by (consecutive) superscript arabic numerals in the order in which they appear in the text. The numerals are to be used outside periods and commas, inside colons and semicolons. For further detail and examples you are referred to the AMA Manual of Style, A Guide for Authors and Editors, 11th Edition. List: Number the references in the list in the order in which they appear in the text.