Identifying non-value-added waste that delay emergency CT brain workflow using lean management principles.

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SUBMITTED TO THE UNIVERSITY OF CAPE TOWN
In partial fulfilment of the requirements for the degree
MMed (Radiodiagnosis)

Faculty of Health Sciences
UNIVERSITY OF CAPE TOWN

DATE OF SUBMISSION: 10 February 2020

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DECLARATION

I, Carike van Zyl, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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Publications and presentations

This work has never been published.
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Acknowledgments

I would like to thank Dr N Ahmed, Prof Dr Weimann, Prof S Beningfield, Prof M Kidd and Ms M Jooste for their assistance.

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Abstract

INTRODUCTION:

The Department of Radiology at Groote Schuur Hospital receives numerous emergency CT brain requests especially from the Emergency and Trauma departments. Improvement in emergency CT brain workflow should reduce waiting times for CT scans resulting in earlier diagnosis and treatment of these patients. Identification of the non-value-added waste (NVAW) (steps regarded as wasteful to the customer) in the CT brain workflow can be determined by use of a lean management tool namely a value stream map (VSM - a flow analysis of information required to provide service to the customer).

AIM:

The study aims to identify non-value-added waste in the CT brain workflow value stream map which may result in delay in emergency CT brain reporting.

METHOD:

This study investigated NVAW in emergency CT brain workflow for 5 working days between 08h00 to 22h00 from Monday to Friday.

Nineteen patients booked for an emergency CT brain scan by the Emergency Department (ED) only between 08h00 and 22h00 over the specific 5 day working period were randomly selected using convenience sampling. The indications for emergency CT brain scans in the sample were similar to the wider group of patients undergoing emergency CT brain scans.

A VSM identifying all the relevant steps in the emergency CT brain workflow was constructed.

The investigator accompanied each of the nineteen patients from the ED to the CT scanner and back and manually recorded the time elapsed in minutes for each separate step on the data collection sheet.

The outstanding information required was obtained from the Xiris system on the Phillips PACS (Picture Archiving and Communicating System).

The average time interval for each of the steps as indicated on the VSM was calculated, and the rate limiting step(s) which resulted in a delay in emergency CT brain reporting was identified.

RESULTS:

Overall, the longest step was the time interval from the time of completion of the scan to the generation of the report (turnaround time (TAT)) with an average time of 72.21 minutes (p value of < 0,01).

Conversely, the time interval from placing the request by the clinician on the PACS to the time of annotation by the radiologist was the shortest with an average time of 5.84 minutes.

DISCUSSION:

The lean management system was used to identify the rate limiting step(s) which resulted in delay in emergency CT brain reporting.

Possible reasons identified for the delay caused by the rate limiting step include the backlog in reporting of the large number of already scanned cases which may be due to staff constraints as only one radiologist was on duty during most of the study period.

Additional contributory factors include clinician telephonic query interruptions to radiology registrars during reporting sessions and delay in the emergency doctor authorising and facilitating transport of the patient from the emergency unit to the CT scanner.

CONCLUSION:

The value stream map tool in lean management can be utilised to identify non value added waste in emergency CT brain workflow.

1. Introduction

The Department of Radiology at Groote Schuur Hospital (GSH) receives numerous emergency/urgent CT brain requests especially from the Emergency and Trauma departments. The GSH Emergency Department (ED) has a heavy patient burden and limited bed space therefore rapid transit of patients through the system is a priority. Many patients cannot be referred to the relevant department until a more definitive diagnosis has been established. Imaging, especially cross-sectional imaging (e.g. CT, ultrasound and MRI), plays a significant role in this.

Improvement in emergency CT brain workflow should reduce waiting times for CT scans resulting in earlier diagnosis and treatment of these patients.

Identification of the non-value-added waste (NVAW) (steps regarded as wasteful to the customer) in the CT brain workflow can be determined by use of a lean management tool namely a value stream map (VSM - a flow analysis of information required to provide service to the customer).

This study investigated the non-value-added waste in emergency CT brain workflow for 5 working days between 08h00 to 22h00 from Monday to Friday.

1.1. Literature review

Continuous Quality Improvement (QI) is a cardinal feature of highly functioning health care systems. In radiology the focus of QI is to improve the efficacy of diagnostic and therapeutic processes, quality, safety, the appropriate referral for imaging and procedures as well as the management of imaging services (1).

Availability and waiting times are the major factors that influence a patient's experience of radiology services. The three main measurements of patient's waiting times are the intervals between:

a) referral and examination (pre-examination waiting time)
b) examination and the finalised radiology report (report turn-around time)
c) referral and the finalised radiology report (total radiology waiting time) (2).

Waiting time is a major indicator of the quality of care in radiology departments (2). Patients can now be diagnosed and treated earlier with lower morbidity and mortality, but the volume and complexity of work is increasing, while the workforce is not increasing sufficiently to manage the workload. The increased workload could potentially diminish the quality of care (3).

1.1.1. Emergency imaging expectations

Over the past twenty years, emergency radiology has become one of the fastest growing aspects of radiology. In the past, emergency radiology consisted of radiography and procedures and patients who needed more advanced imaging were admitted into the hospital. Prior to the development of cross-sectional imaging, radiographic and fluoroscopic examinations were utilised in the field of emergency radiology. Angiography was utilised to evaluate patients with acute vascular or central nervous system conditions. Today, with the availability of cross-sectional imaging (CT, ultrasound and MRI), the emergency radiology facility is often located in an acute diagnostic imaging centre. Recently, there has been significant growth in the utilisation of cross-sectional imaging in the field of emergency radiology, especially CT scanning (4).

Emergency imaging expectations have increased. Emergency physicians expect rapid access to high quality imaging, short waiting times, prompt reporting and 24 hour availability. Advanced imaging can lead to benefits such as a decrease in the length of stay in the emergency department or hospital and a decrease in unnecessary admissions and surgery (4).

Considering the high impact that the Emergency Department (ED) has on the quality of care delivered by a hospital and the many challenges that EDs face (e.g. overcrowding, long waiting times, increasing patient load and efforts to limit costs), innovative approaches should be used to develop safer and more efficient healthcare in this setting (5).

The main factors thought to be causing the problem of overcrowding are rising ED visits, an ageing population, few inpatient beds, the increased use of imaging in the ED and the turnaround time for results (6). The results of the emergency imaging often determine whether the patient will be admitted, to which department the patient will be admitted and whether there is a need for emergency surgical intervention (4).

Due to increasing clinical and financial pressures to reduce the waiting times for radiology examinations, many radiology departments are utilising a variety of service delivery initiatives. The scope of service delivery projects is wide and ranges from minor inexpensive changes to large costly undertakings (2).

Quality Management is a general approach to service delivery to meet the user's needs and to use the available resources more effectively**.** The goal of QM processes is to identify wastage within a system and eliminate it. It appears that QM methodologies have significant potential to improve workflow processes in radiology. There are many different approaches to quality management, including Lean, Six Sigma, continuous quality improvement methodologies and re-design of processes/ services (2).

1.1.2. Lean management system

Lean management originated from the Toyota Production System management and manufacturing policies which are designed to create opportunities for an organisation to increase its efficiency and to eliminate waste. Small improvements in performance are continuously made. The goal is to add value to service while maintaining the highest level of customer satisfaction (1).

Lean management was introduced around 1950 because of low efficacy at the Toyota Motor Company. The Toyota Production System differed significantly from its contemporaries' way of production at the time. It represented a change in the working culture and not just a tool to increase output in the production line.

The system differed in the following ways:

- it was employee-driven, calling for continuous improvement
- it focused on improving flow and minimising waste in all steps of the production process and
- the focus was on what was of value to the customer. Procedures that were not of value to the customer were eliminated (7).

Lean transformation is not a short term process, but requires ongoing commitment to improvement and adhering to lean management principles (8).

It evolved in the following years and was introduced to western industries in the 1990's. Initially it was used by production companies, but recently many public organisations have also shown interest in utilising lean management methods and hence its introduction into the health care system (7) (8).

Applications of the Toyota Production System manufacturing methodology ranged from minor interventions e.g. patient flow modification and streamlining processes to major facility redesign (9).

The flow of patients through the ED is influenced by both process and structural factors therefore making the ED ideal for the application of lean management principles. In the ED, tools from lean management target the established structures of work and the associated processes in order to remove unnecessary steps or waste encountered during the patient's journey through the ED phase of care by improving flow, reducing waiting times and increasing the efficiency of ancillary services leading to shorter turnaround times for radiology and laboratory studies and influencing the total length of stay in the ED for both the admitted and discharged patients (9).

Lean management emphasizes the analysis of processes. It is especially relevant to radiology departments which depend on a smooth workflow with minimal interruptions of equipment function and of flow of patients through the system in order to function efficiently (1).

According to the principles of lean management if an expenditure or a resource is for reasons other than creating value for the customer, it is regarded as wasteful and eliminated (10). There are many opportunities in radiology where a lean management approach can be utilised, e.g. reducing waiting times for scheduling of procedures and for reports, reducing errors, improving patient outcomes, decreasing costs, increasing staff productivity and improving customer satisfaction (8).

As waste is eliminated, costs and production times will decrease. The major forms of waste in radiology departments are activities that do not add value (referred to as Muda in lean management terminology), unplanned variations in a process (Mura) and excessive use of staff, equipment and systems (Muri) (8).

In radiology, Muda include the following:

- waiting times
- difficulty in the management and facilitation of urgent and non-urgent requests and determining which of these requests should take priority.
- difficulty in assigning slots for studies to be performed to all of the respective clinical departments and determining and monitoring what the needs of each of these departments are.
- long set up times due to the high variety of examinations that are delivered
- transport of patients, the path from the ED to the radiology department can be long and inefficient.
- difficulty in managing the periods of increased workflow associated with emergencies, which cannot always be predictable
- difficulty in ensuring acceptable reporting times which affect the referring doctor and patient's expectation and the quality of the service (5).

In a radiology department, Mura (unplanned variations in a process), e.g. equipment failure and difference among patients (e.g. comorbid diseases and differences in body habitus) may all lead to variations in the process contributing to non-value added waste (8).

In the radiology setting, examples of Muri (overuse of staff, equipment and systems) include unnecessary studies, repeated studies and overscheduling of patients for a specific time slot which all represent non-value added waste (8).

To ensure sustainable increased efficiency, a gradual continuous lean transformation of work philosophy should take place by applying lean management principles to all processes within a department. Lean management is different from other approaches as it is both a philosophy and an organizational way of life that keeps all staff members on the path of continuous improvement (1). The ultimate goal is a shift in the working culture to a culture where all workers in the department become responsible for quality and safety improvements (11) (12).

The principles of lean management include equal involvement of and respect for all staff, observing and analysing processes where they occur in the workplace (referred to as "going to the gemba"/ real place in lean management terminology), eliminating all forms of waste or non-value-added steps in the process, standardising work processes, improving the workflow, adding value for the customer and using lean graphical tools (1).

Lean management starts with equal participation of all members of staff, as frontline workers understand possible problems best and must be involved in quality improvement projects during all phases of the process (1). All members of the team are encouraged to be participate in identifying areas of waste and in suggesting solutions to eliminate the waste (13). Staff members should be involved in all the processes including planning, data collection and analysis as well as implementing and monitoring change (8). To achieve continuous change, staff should move from compliance with lean management principles to commitment to the lean process with the belief that it is adding value for the customer (1).

To achieve sustainable change using a lean initiative, all members involved in the workflow process (managers, supervisors and front-line staff members) must be involved in the discussion regarding all stages of the process (1). Staff members are not just a resource in an organisation, they are the organisation. This type of staff involvement may not usually occur in organisations with traditional management structures, especially in an academic setting, however, a teaching environment in an academic institution where scientific experimentation is embraced, provides a setting where lean management can be successfully introduced (8).

Factors that ensure the successful implementation of lean management tools include the involvement of management, readiness for change, involvement of the front-line staff, focus on workflow and quality improvement as well as making small changes that can be sustained. Such projects should be specific to the work setting. It should focus on improving customer satisfaction without increasing the staff's workload or increasing work related stress (9).

Management teams should effectively communicate the lean project to all the members of staff who will be involved in every step of the process or who may be affected by the project. Leaders of the lean management project should lead by considering the ideas of all staff members. Management should focus on creating a learning environment as lean transformation will be an ongoing process. The focus should be on establishing a mind-set for continuous improvement (8).

According to lean management principles, the management hierarchy is a "chain of support" instead of the traditional chain of command. The role of the managers is to support the growth of the staff members by assisting them in identifying the origins of the problems in their areas of work and giving them the opportunity to suggest possible solutions. Leaders participating in lean transformation should ensure that there are no penalties for a staff member if a solution that they suggested, didn't work. They should acknowledge their staff member's successes and support staff if their efforts are unsuccessful (8).

The role of communication in the implementation of a lean management project cannot be overemphasised as engaging with staff members from the start of the project will reduce resistance to change as staff members will be empowered to solve their own. Communication should be consistent, clear and frequent. Communication should be two-directional – the first part is what the leader wants to communicate and the second part is what the leader needs to hear from the staff members (8).

Visiting the workplace ("going to the gemba" in lean management terms) is encouraged for senior staff members to observe the workflow, identify safety hazards as well as to ascertain the cause for complaints and insufficiencies. Workers can demonstrate the processes in their work area as well as identify insufficiencies and be allowed to make suggestions for improvement (1) (14) (15). The work can be observed in action and the senior staff member can go directly to the source of complaints and identify the causes.

An essential principle of lean management is to eliminate waste or non-value-added steps. The eight non-value-added steps or wastes of the lean management approach are applicable to radiology and include the following:

a) overproduction (imaging a larger field of view of the anatomy than necessary)
b) transportation (unnecessary transferring of patients, equipment or personnel)
c) inventory (stock occupies physical space that costs money to rent)
d) motion (personnel have to move unnecessarily within a work area)
e) defects (field of view of imaged anatomy is too small)
f) over processing (production of superfluous reformatted images)
g) waiting (downtime of equipment)
h) skills (underutilising the skills of staff members) (1).

1.1.3. Value-stream mapping

Standardisation of work decreases variability and improves efficiency. By standardising complex work processes, variation can be minimised and may even be eliminated (8). In radiology this involves the use of flow charts and pre-procedure checklists (1).

To identify bottlenecks in the clinical environment, process management tools like value stream mapping (VSM) can be used to map the process. Value stream maps capture the process flow and identify waste and non-value-added steps and are therefore different to other process maps (1).

Value stream mapping can be defined as a lean management technique that is used to analyse the flow of materials and information currently required to forward a product or service to the customer (16). It is a diagrammatic representation of the journey through the system (17). The focus is the movement of the patient through the system, not on the individual interaction between the patients and the healthcare providers (18). VSM unites multidisciplinary teams to understand the different steps in the process of the workflow and to avoid teams thinking they know the process well enough and therefore not identifying the actual current state of the process (15).

The value stream map is a method used to identify value-added and non-value-added work (waste) in a process. It documents the time used for each step of the process and ascertains the amount of value-added and non-value added time (19).

It identifies the steps in the process, the person or people involved in each step, the task, the time it takes to do the task and the time between the individual steps (20). Value-added work can be defined as work for which the customer is willing to pay and non-value-added work as work for which the customer is not willing to pay (21).

Before setting up a value stream map, it is necessary to understand the customer's (patients and clinicians) expectations and needs. During any part of a lean process, the focus should always be on the customer and whether value is added from their perspective (1).

Service delivery is a value stream that can be mapped from both the patient's as well as from the provider's perspective. For example, correctly interpreting a CT scan may be what the radiologist considers to be of the greatest value, but the patient may consider obtaining an accurate diagnosis without unnecessary delay in obtaining an appointment for the CT study and obtaining the results to be of the most value (8).

The first step in value stream mapping is to chart the following:

- suppliers: the staff members involved in initiating the process, this includes the referring clinician and patients.
- inputs: the information entered to initiate the process, e.g. request forms
- processes: including requests, protocoling of studies, patient preparation and registration.
- outputs: the effects of the test e.g. test results.
- customers: patients as well as personnel affected by the information including physicians and radiologists (1).

The process is then observed in the workplace and mapped to at least four to eight steps to identify the stages in the process. Electronic and manual information systems should also be included in the map. Waiting times, delays and the number of patients in the queue should be identified. The times obtained is compared with baseline data (how long a process should take). Data obtained from literature may be used (1).

Once a value stream map has been created and measured, a future state value stream map can be constructed. This represents a new map of the process with elimination of the major causes of waste and is helpful to determine what changes need to be implemented, why these changes need to be made and what the future expectations are (20).

Key metrics that reflect the future state process can be measured intermittently and reviewed to ensure that the changes are sustainable (20).

1.2. Groote Schuur Hospital Radiology Department

A lean management project investigating radiology workflow was conducted in the department in 2013. The project entailed observation of the workflow of radiographers, radiologists and porters. However, there was no patient participation in the progress. Recommendations were made to the departmental management team, but the results were not published. To our knowledge a study investigating the non-value-added waste in emergency CT brain workflow has not been published in South Africa.

1.3. Study objectives

This study aims to identify non-value-added waste in the CT brain value stream map which may result in a delay in emergency CT brain reporting by:

1. Documenting the average time taken to complete each step in the value stream map.
2. Identifying and quantifying non-value added waste in the emergency CT brain workflow.
3. Proposing a future state value stream map to eliminate the non-value added waste identified in the emergency CT brain workflow.

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2. Materials and Methods

2.1. Inclusion and exclusion criteria

2.1.1. Inclusion criteria

All patients on whom an emergency CT brain scan was requested by the ED only at GSH for a one week period from Monday to Friday between 08h00 and 22h00.

2.1.2. Exclusion criteria

Patients who are booked for elective/routine CT brain scans.
Patients who are booked for an urgent non brain CT scan by the ED.
Urgent CT brain scans booked by the ED only on a Saturday, Sunday or public holiday.
Urgent CT brain scans booked between 22h00 and 08h00 on any weekday, weekend or public holiday.

2.2. Data collection

Nineteen patients who were booked for an urgent CT brain scan by the ED at GSH were randomly selected between 08h00 and 22h00 over a one week weekday period from Monday 04.06.2018 to Friday 08.06.2018 for inclusion in the study.

Convenience sampling was selected as patients may arrive while the investigator is accompanying another patient to the scanner.

The medical indications for urgent CT brain in the nineteen randomly selected sample were similar to the wider group of patients undergoing urgent CT brain scans in the ED at GSH and in particular when compared to the indications for a 5 weekday period in the preceding month of May 2018 (Figure 1).

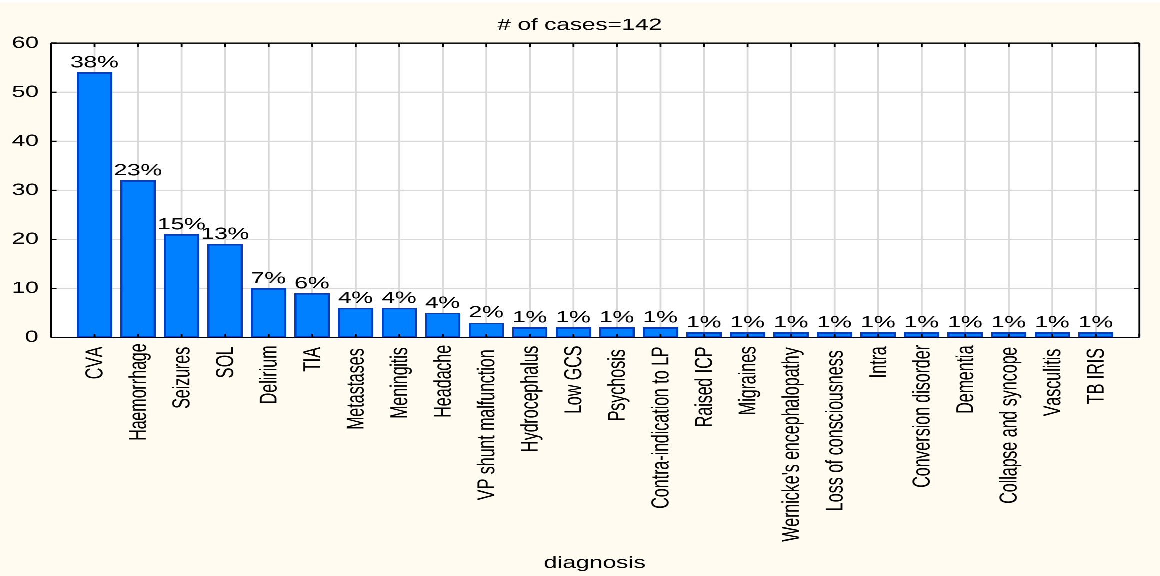


Figure 1: Indications for urgent CT brain scans for the period 07.05.2018 to 01.06.2018.

A value stream map identifying all the relevant steps in the ED urgent CT brain workflow was constructed (Addendum B). Information sessions were held by the supervisor, during which time the lean management system and the value stream map was explained in the required detail to all the relevant participants/role players in the ED urgent CT brain workflow which included emergency department doctors, nursing staff, porters as well as radiologists, radiographers, radiology porters and the Phillips PACS information technology (IT) staff. The investigator was not present at any of the supervisor driven presentations/information sessions to avoid bias.

Bias can occur as the ED and radiology staff are aware of data collection and this could potentially change their work speed. During the presentation, the supervisor emphasised that the value stream map evaluates the process and not individual personnel performances. Benefits to improving the process for individual personnel work experience were emphasised. The exact date and times of the study was not revealed during the presentation and the information session was held approximately five weeks prior to commencement of the data collection component of the study.

Prior to commencement of data collection both CT scanners were calibrated to ensure that the times recorded would be correct. The investigator's stopwatch was synchronised with the Phillips PACS Xiris system, both the radiology department's Siemens and Toshiba CT scanners and the PACS XRE (reporting system) prior to commencement of data collection.

Posters explaining that a study regarding CT workflow was being conducted were on display in the emergency and radiology departments (Addendum C).

The workflow followed for each of the selected patients are outlined below as follows:

- the urgent CT brain scan request is made on the Phillips Xiris PhyUtil system by the emergency unit doctor who telephonically contacted the radiology registrar on duty and informed him/her thereof.
- the radiology registrar then annotates the urgent CT brain scan request from the ED doctor on the Xiris on the Phillips PACS system and informs the CT radiographer thereof.
- the radiographer telephonically requested the ED staff/doctor to authorise the ED porters to transport the patient for the urgent CT brain to the CT scanner in the radiology department.
- subsequent to this, the investigator took verbal consent from the patient for the urgent CT brain if the clinical condition of the patient made verbal consent attainable, failing which, verbal consent was obtained from an accompanying family member. Unaccompanied patients who were unable to give verbal consent due to their clinical condition were nevertheless included in the study to ensure that the randomly selected sample would be representative of the wider group of ED patients undergoing urgent CT brain scans.

Information provided to the patient or accompanying family member prior to obtaining verbal consent is as indicated on Addendum D.

Ethics and hospital approval were obtained for the study.

For each randomly selected patient from the ED at GSH, the investigator recorded the following times on the data collection sheet (Addendum E):

A. Time of urgent CTB request by the ED doctor.
B. Time of annotation by the radiologist on duty of the urgent CT brain request from the ED doctor.
C. Time the CT radiographer telephonically called the ED to request the patient to be transported to the CT scanner by the ED porter.
D. Time that the ED staff authorised the porters to transport the patient to the CT scanner.
E. Time that the ED porters arrived at the CT scanner with the patient.
F. Time the CT brain scan was performed.
G. Time the CT brain scan report is made available to the ED doctor.

F + G were saved automatically by the Xiris component on the PACS.

From these recorded times, the following time intervals were calculated:

1. A – B: Difference between the time the request was annotated by the radiology registrar on duty and the time the ED doctor placed the request on the PACS.
2. B – C: Difference between the time the radiographer called for the patient and the time the radiologist on duty confirmed the request.
3. C – D: Difference between the time the radiographer called for the patient and the time the ED staff authorised the porters to transport the patient to the CT scanner.
4. D – E: Difference between the time the patient arrived at the CT scanner and the time that the ED porters were authorised to transport the patient to the CT department.
5. E – F: Difference between the time that the CT scan was performed and the time that the patient arrived in the CT department.
6. F – G: Difference between the time that the preliminary report was sent out and the time that the CT scan was performed.

The collected data for each selected patient were displayed on a data table (Addendum F).
The data were analysed and the average time for each of the above time intervals was calculated.

The time interval which demonstrated a significant time delay was identified as non-value-added waste that delayed emergency CT brain workflow.
Recommendations to improve emergency CT brain workflow were made in the form of a future state value emergency CT workflow map (Addendum F).

2.3. Statistical analysis

Mixed model ANOVA was done to compare mean waiting times between the different intervals. The patients were included as random effect, and interval as fixed effect. For post hoc testing, Fisher Least Significant Difference (LSD) was used. Normality was assessed by inspecting the normal probability plot, and found to deviate somewhat from normality. The waiting times were log transformed, to improve the normality of the waiting times.

3. Results

A total of 19 randomly selected patients were followed from Monday to Friday between 08h00 and 22h00.
Seven (7) of these patients were scanned for a possible cerebro-vascular accident (CVA).
Three (3) of these patients were scanned for a possible intracranial haemorrhage.
Two (2) patients were scanned for a possible CVA or space-occupying lesion.
Two (2) patients were scanned for possible metastases.
One patient was scanned for a possible CVA or fluctuating level of consciousness.
One patient was scanned for headache.
One patient was scanned for haemorrhage or delirium tremens or CVA.
One patient was scanned for delirium.
One patient was scanned for intracranial haemorrhage or migraine.

The time taken for every step of the urgent CT brain workflow was determined (A to G) and the time intervals between the successive steps were calculated for each patient viz. A-B, B-C, C-D, D-E, E-F and F-G.

The average time for each of the time intervals was calculated and plotted per interval (Figure 2) and a log transformation was performed (Table 1; Figure 3).

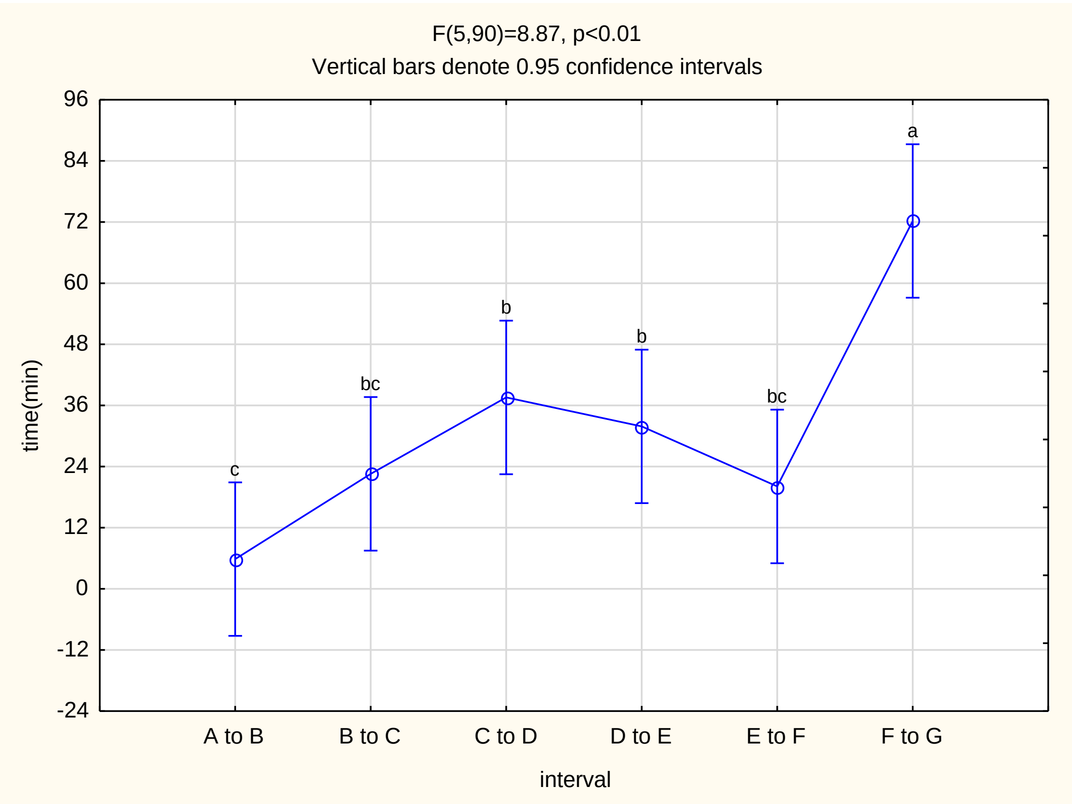


Figure 2: Summary statistics of mean (and standard deviation) times per interval

Cell No.	LSD test; variable lsmean (Table 11) Probabilities for Post Hoc Tests Error: Between MS =						
	interval	{1} 0.70375	{2} 1.1908	{3} 1.0336	{4} 1.3234	{5} 1.1055	{6} 1.791
1	A to B		0	0.04	0	0.01	0
2	B to C	0		0.32	0.4	0.59	0
3	C to D	0.04	0.32		0.07	0.65	0
4	D to E	0	0.4	0.07		0.17	0
5	E to F	0.01	0.59	0.65	0.17		0
6	F to G	0	0	0	0	0	

Table 1: Log transformed values of each average time interval

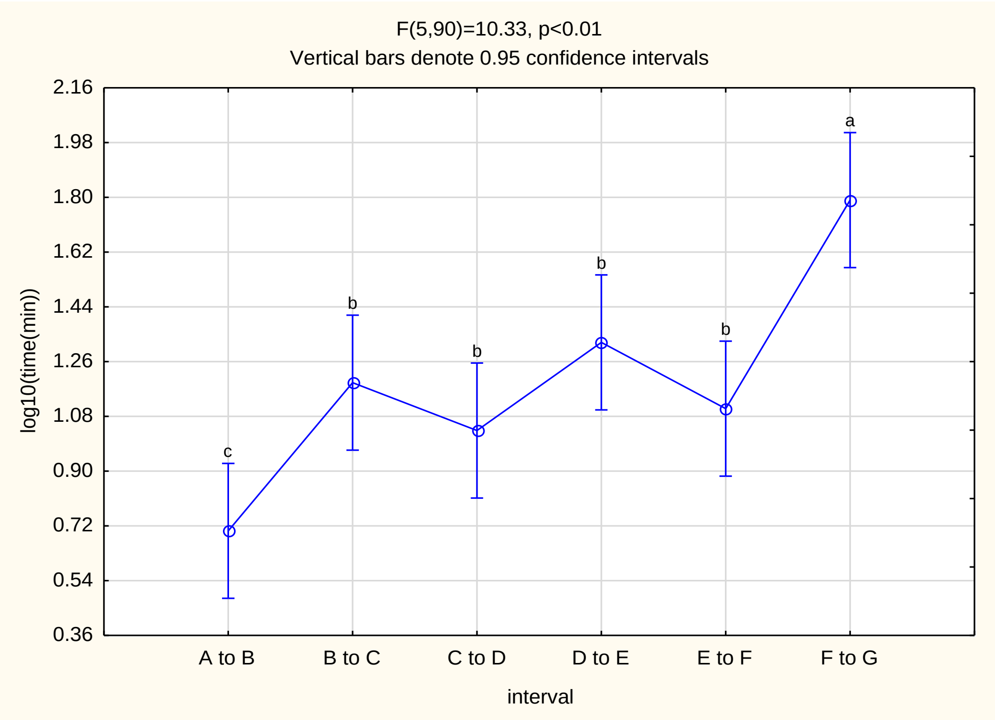


Figure 3: Summary statistics of mean (and standard deviation) times per interval (log transformed values).

The shortest time interval average of 5.84 minutes (A – B) was from the time the urgent CT brain request was placed on the PACS system to the time the radiologist on duty approved the request.

The longest time interval average of 77.21 min (F – G) was from the time the CT scan was completed to the time of completion of the provisional registrar report.

Similar time average intervals of approximately 20 minutes were noted from the time the on duty radiologist approved the urgent CT brain request to the time the radiographer telephonically requested the patient to be transferred to the CT scanner (B – C) and from the time the patient arrived at the CT scanner to the time the CT scan was performed (E – F).

A total time of 68.47 minutes (> 1 hour) lapsed from the time the radiographer telephonically requested for the patient to be transported to the CT scanner to the time the CT scan was performed (B – C) and C – D).

Average time intervals of between 30 to 40 minutes lapsed from the time the radiographer telephonically requested the patient to be transported to the CT scanner to the time the ED porters were authorised to transport the patient to the CT scanner (C – D) and the time it took the ED porters to transport the patient to the CT scanner (D – E).

In total, it took an average 190.21 minutes (> 3 hours) for an urgent CT brain scan to be completed, from the time the request was made to the time the radiologist report was generated.

4. Discussion

4.1. Results in context

Lean management is increasingly being used in healthcare settings (5) (6). Nearly all of the clinical settings attempted to adopt the lean management system with the goal of improving healthcare performance and quality of care by identifying non-value-added activities and eliminating waste. Emergency care, surgery and laboratory services were the main areas where this approach was used (5).

Many radiology departments are adopting lean methods to improve efficiency, optimize value of service and to eliminate waste (8).

Holden reviewed the implementation of lean methodology in fifteen EDs in the USA, Canada and Australia and reported generally positive outcomes and significant improvement opportunities (5).

Bucci et al reviewed nine high-quality studies in which lean management improvements in the ED were focused on the management of patient flow, hospital bed shortages and waiting times for accessing radiology. On reviewing these studies, they reported that in almost all cases improvement of performance was achieved without the need to use additional resources.
Both reviews recommended the necessity for further studies to verify the effectiveness of lean management in the ED on a large scale (5).
According to the 2016 review by Deblois and his co-workers of 149 publications from 1999 to 2015, lean management techniques have been successfully implemented in acute care settings e.g. EDs, intensive care units, ambulatory surgical centres and laboratories (22).

Amaratunga et al performed a systematic review of 23 studies utilising application lean and six sigma quality improvement methodologies in radiology and concluded that lean and six sigma methodologies have the potential to reduce costs and error and to improve quality within radiology (10).

Karstoft et al found that lean management can be successfully introduced into a Radiology department and lead to higher productivity. Value stream mapping was used to identify sources of waste, the appropriate changes were made and workflow was improved (7).

Verbano et al used lean management to reduce radiology turnaround times for the emergency department. The authors found that the radiology turnaround times for the emergency department could be significantly reduced by applying lean management principles and techniques. The sources of muda were identified and eliminated (5).

Hitti et al successfully reduced radiology transport time from the emergency department using lean methodology. The authors determined that the step with the longest turnaround time was the time from study completion to preliminary report issued by the radiologist, but this was not the focus of the study (6).

Several factors were identified as sources of non-value-added waste in the urgent CT brain workflow (Addendum F).

For time interval A – B, incorrect patient data provided at the time of placing the request on the PACS in one particular case was found to be a source of non-value-added waste.

Telephonic versus non-telephonic requests from the ED medical staff did not have a significant impact on the time the on duty radiologist approved the request.

Two main factors were identified as possible sources of non-value-added waste for time interval B – C. These included radiology staff shortage during break times and lack of communication between the on duty radiologist and radiographer.

Numerous sources of non-value-added waste were noted during the C – D time interval. These were patient overload, unstable patients, staff shift change, ED staff delay in implementing radiographer request, incorrect patient location, ED staff not answering the radiographer’s call and numerous porter requests. This resulted in a prolonged average time interval of 37.58 minutes.

The D – E average time interval of 31.89 minutes was influenced by some similar sources of non-value-added waste as for the C – D time interval as well as additional factors viz. additional unallocated porter duties, unavailability of ED nursing staff to accompany patient to the CT scanner, delay be ED staff in authorising porters to transport the patient to the CT scanner, patient unavailability (for various reasons) for transportation by the porters at the appropriate time as well as failure by ED staff to locate equipment needed to accompany the patient during transportation to the CT scanner.

The major source of non-value-added waste for the E – F time interval was the backlog of patients already waiting to be scanned at the time of arrival of the patient from the emergency department for the urgent CT brain scan.

The most significant source of non-value-added waste in the urgent CT brain workflow was identified during the F – G time interval. Several factors were identified which contributed to the prolonged average time interval of 72.21 minutes. These were the backlog of previously scanned CT brain scans awaiting reports, delay in transfer of images by the radiographer to the PACS for reporting by the on duty radiologist, repeated telephonic interruptions of the on duty radiologist resulting in a delay in CT brain reporting as well as shortage of radiology reporting staff.

4.2. Limitations of this study

Convenience sampling is one limitation of this study. At least 30 patients were to be included in the study over the 5 day period, however, as there was only one investigator, only 19 patients were included in the study.

4.3. The way forward: Future state value stream map

A future state value stream map was constructed which includes recommendations to eliminate non-value-added waste and improve emergency CT brain workflow.

The recommendations are as follows:

- step D (ED staff authorises the ED porter to bring the patient to the CT scanner) is considered to be a source of non-value-added waste and has been eliminated from the value stream map. Instead it is proposed that the radiographer should be allowed to call the ED porter directly to authorise transport of the patient to the CT scanner.
- a dedicated radiologist to be allocated to report only emergency CT brain scans.
- a dedicated radiologist to be allocated to manage phone calls. This radiologist can also manage any queries from the radiographers regarding protocoling.

5. Conclusion

The value stream map tool in the lean management system can be utilised to identify non-value-added waste in emergency CT brain workflow.

The most significant source of non-value-added waste that delays emergency CT brain workflow in the ED at Groote Schuur Hospital was identified to be the average time required to generate a report for an emergency CT brain from the time of completion of the CT brain scan, which was established to be 72.21 minutes.

A future state value stream map has been constructed to eliminate the major causes of waste.

A follow up study is recommended once the proposed changes are made to the emergency CT brain workflow.

Appendix A: Ethics Clearance Certificate

GROOTE SCHUUR HOSPITAL
Enquiries: Dr Bernadette Eick
E-mail : Bernadette.Eick@westerncape.gov.za

Professor E. Weimann
MMS: Paediatrics & Neonatology

E-mail: Edda.Weimann@westerncape.gov.za / carikevzt@gmail.com

Dear Professor Weimann

RESEARCH PROJECT: Identifying Non-Value-Added Waste That Delay Emergency CT Brain Workflow Using Lean Management Principles (Mmed Dr Carike Van Zyl)

Your recent letter to the hospital refers.

You are granted permission to proceed with your research, which is valid until **28 February 2019.**

Please note the following:

a) Your research may not interfere with normal patient care.
b) Hospital staff may not be asked to assist with the research.
c) No additional costs to the hospital should be incurred i.e. Lab, consumables or stationary.
d) **No patient folders may be removed from the premises or be inaccessible.**
e) Please provide the research assistant/field worker with a copy of this letter as verification of approval.
f) Confidentiality must be maintained at all times.
g) Should you at any time require photographs of your subjects, please obtain the necessary indemnity forms from our Public Relations Office (E45 OMB or ext. 2187/2188).
h) Should you require additional research time beyond the stipulated expiry date, please apply for an extension.
i) Please discuss the study with the HOD before commencing.
j) Please introduce yourself to the person in charge of an area before commencing.
k) On completion of your research, please forward any recommendations/findings that can be beneficial to use to take further action that may inform redevelopment of future policy / review guidelines.
l) Kindly submit a copy of the publication or report to this office on completion of the research.

I would like to wish you every success with the project.

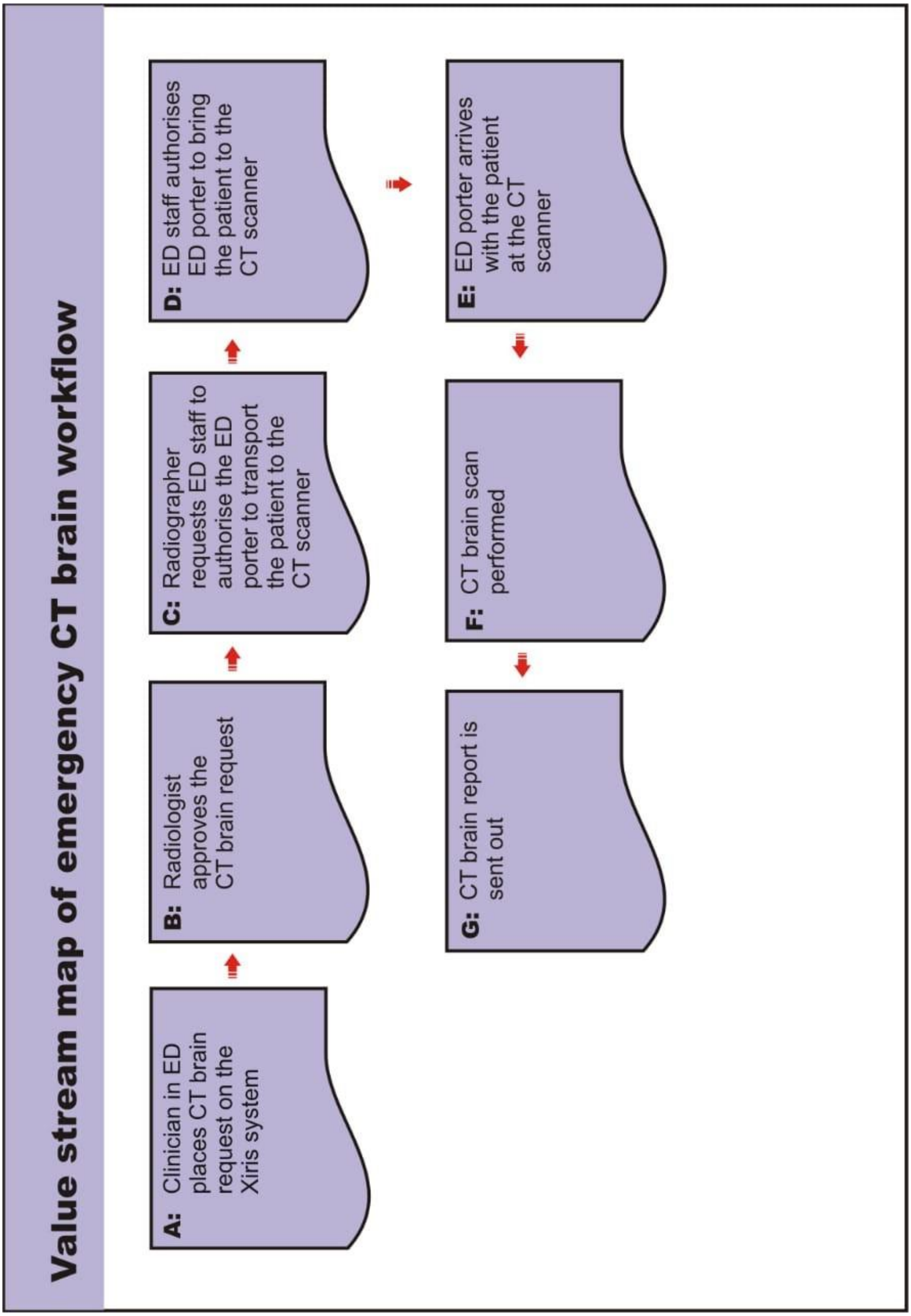
Yours sincerely

DR BERNADETTE EICK
CHIEF OPERATIONAL OFFICER
Date: 20 April 2018

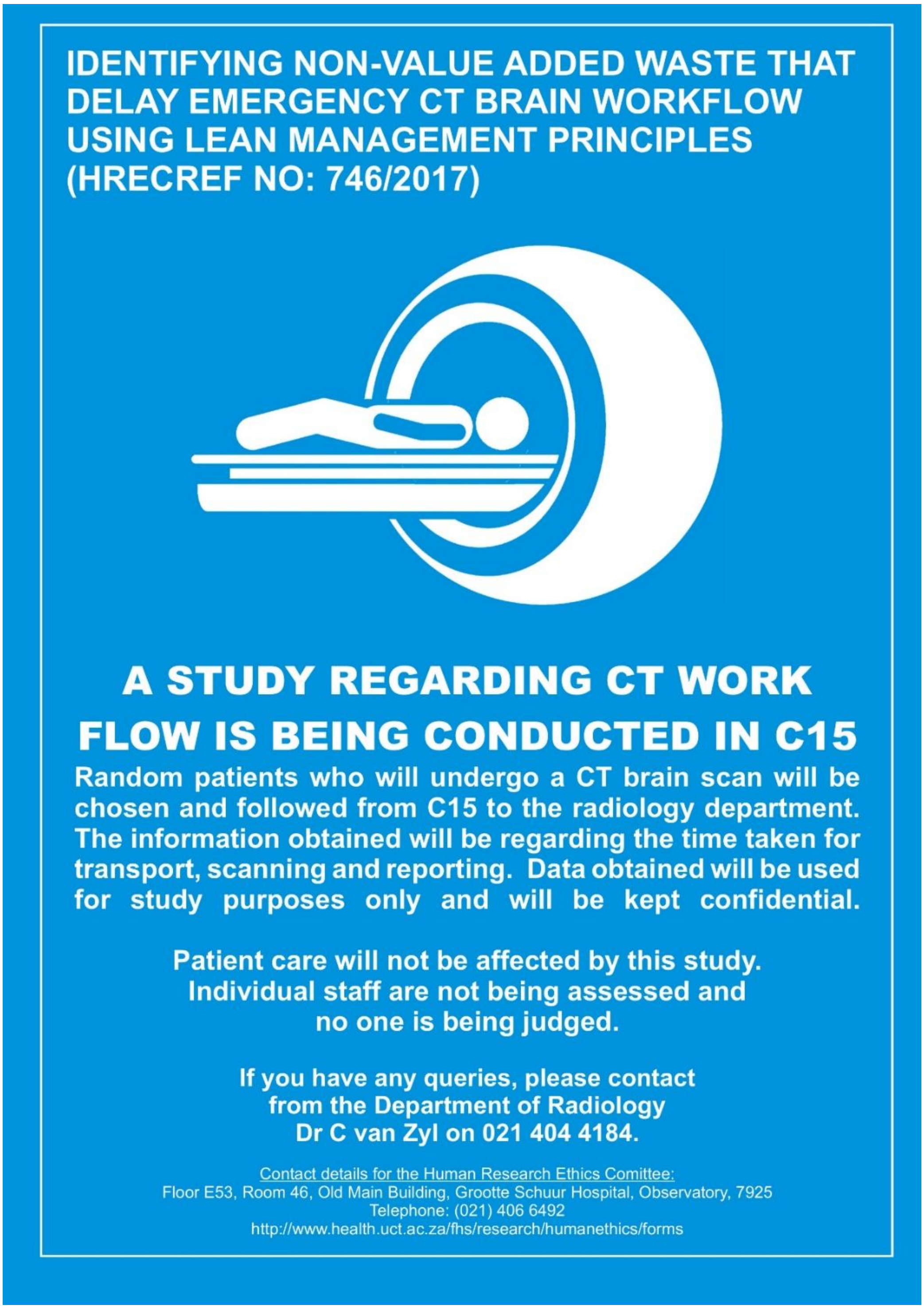
C.C. Mr L. Naidoo
Dr H. Aziz / Dr F. Conrad

G46 Management Suite, Old Main Building, Private Bag X,

Appendix B: Value stream map of emergency CT brain workflow



Appendix C: Poster used for the study:



Appendix D: Verbal consent information sheet

The information given for verbal consent was the following:

- We are trying to understand what causes a delay in obtaining CT brain scans and reports.
- The study pertains to time delay and is not about the individual patient.
- I will accompany you to the CT scanner. The time from the moment the doctor requested the scan to the time the CT scan is done and the report is available will be recorded.
- On the time sheet I will record the reason the doctor wanted the scan to be done as well as your general condition (e.g. if you needed to be accompanied by a doctor).
- Your name will not be used.
- Your care will not be affected.

Appendix E: Data collection sheet

Folder number		
Patient's history and general condition		
GCS		
Is the patient intubated?	**YES:**	**NO:**
Is it necessary for a doctor to accompany the patient to the CT scanner?	**YES:**	**NO:**
A: Time the request was placed on the Xiris system		**NOTES:**
B: Time of annotation		**NOTES:**
C: Time the radiographer requested the ED staff to authorise the ED porter to transport the patient to the CT scanner		**NOTES:**
D: Time the ED staff authorised the ED porter to transport the patient to the CT scanner		**NOTES:**
E: Time the ED porter arrived with the patient at the CT scanner		**NOTES:**
F: Time the CT scan was performed		**NOTES:**
G: Time the report was sent out		**NOTES:**

Appendix F: Data collection sheet notes

Nr	A	Notes	B	Notes	C	Notes	D	Notes	E	Notes	Scan F	Notes	ReportG
1	8H53		9H17		9H20		9H25		9H27	Patient from ICU	9H56	4 scans on system to be	10H38
										scanned first		reported at 10H03.	
2	16H15		16H16		16H36 *	16H25 ED phones engaged; called again 16H36;	17H55		18H01		18H13	Study closed at 18h25;	19H08
						Called again 17H50. Many patients in ED.						Multiple phone calls.	
						to be transported, patient in green area.						5 other studies on system to report.	
3	8H16		8H18		8H27	Patient had to be stabilised; chest x-ray	10H00	Porters are occupied in ED.	11H05		11H18	Images only through at 12H20.	14H07
						and blood gas done; wardround.		10H45 Dr spoke to porters.				Many studies to report.	
								10H52 Porters want to take pt					
								Sister cannot find portable O2.					
4	12H49		12H58	Lunch time; only 1	14H20	Other patients waiting.	14H20		14H56		15H10	Many studies to report;	17H05
				radiographer.								consultant reviewing time	
5	14H33		14H35		14H41		14H45		15H05	2 other patients	15H24	Many studies to report;	17H15
										waiting to be scanned		consultant reviewing time.	
6	17H13		17H17	17H36 No answer in ED.	17H49	18H05 patient cleaned; 18H37new shift doctors	19H40	Dr and porter brought patient.	19H56		19H56		
						examining and reviewing patients							
7	17H45	Doctor called prior	17H50		18H37	New shift's doctors examining other patients.	17H45		19H42	Dr brought pt himself	19H47	Reported immediately.	20H06
		to placing request.								No patients waiting.			
8	12H40		12H48		12H55**	ED very busy; many patients.	14H41	Porter took patient immediately	14H46		14H55	Was reported immediately.	15H11
								14H38 was called for again.				Enough staff.	
9	15H04	Request was made	15H17		15H37				16H20		16H24	CT body and 3 CT brains to be	17H33
		under a wrong number										reported.	
	16H03	Request placed with	16H04	New annotation made.	16H12	Called for patient again.	16H03					Doctor on duty still busy with the day's	
		correct number.											
10	17H15		17H18		17H22		17h20		17H44	Trauma patient is	17H53	2ultrasounds to do, 1 CT brain to report	20H45
										on bed.		19H26 Jnr locked case,	
												kept study to show senior.	
11	19H15	Doctor called when	19H17		19H26	Radiographer asked that the sister	19H30	Nurse busy taking patient's sugar	19H58		20H07	Other cases to report as well.	21H18
		placing request.				put the sticker in the porters book.		Another patient taken to x-ray,				Junior doctor on duty.	
								many patients in porters' book.					
12	9H35		9H36	Annotation states	9H57	12H17 called for patient again.	12H32		12H37		14H06	Only one doctor on duty.	15H15
				where patient is.								(were 2 doctors before 13H00)	
13	11H00		11H01	11H40 Dr put scan through	11H51		11H55		12H05	Many patients	13H42	Only 1 doctor on duty after 13h00;	14H52
				(radiographer did not						to be scanned.		were 2 coctors before 13H00.	
				know patient was accepted)									
14	17H22	Doctor called when	17H23		17H33		17H40		17H47			2 doctors on duty.	18H26
		placing request.										Not many scans to report.	
15	17H57		17H59		18H11		18H00	Clerk helped to place stickers	19H27	Brought with 2	19H33	4 scans to report.	20H15
								in porters' book		other patients.			
16	18H05		18H10		18H11		19h05		19H27	Brought with 2	19H48	4 scans to report.	20H41
										other patients.			
17	18H20		18H35		19H00		19H05	Patient was walking around.	19H40		20H00	4 scans to report.	21H24
								Porters were looking for patient.					
18	18H45		18H54				19H05		19H27	Brought with 2	19H41	4 scans to report.	20H23
19			11H12		12H11	Radiography students were taking exams	13H15		14H34	other patients.			
						in the CT scanner, pt could not be scanned earlier.							

Appendix G: Future state value stream map