VALUE OF FOLLOW-UP CT IN HEAD INJURY ASSESSMENT

Dr Jeannine Owen

A research report submitted to the Faculty of Health Sciences, University of Cape Town, in partial fulfilment of the requirements for the degree of Master of Medicine in Diagnostic Radiology

Cape Town, 2015

Declaration

I, Jeannine Margaret Owen, hereby declare that the work on which this 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.

I empower the university to reproduce, for the purpose of research, either the whole or any portion of the contents in any manner whatsoever.

Signed by candidate

Jeannine Margaret Owen

On this 27th day of April 2015

Publications and presentations

This work has never been published.

Abstract

INTRODUCTION:

The question of when and if to perform follow-up CT scanning of the brain in a patient with a proven head injury remains pertinent, and the answer is not clear cut. This is even more so compounded when one tries to compare and equate what happens in a developed country with that of a developing country such as South Africa.

AIM:

To evaluate referral patterns, associated time-delays and findings of follow-up CT as well as patient outcomes in patients with head injury at Groote Schuur Hospital.

METHOD:

A retrospective review, over a 6 month time period, of the CT scans and folders belonging to patients who underwent follow-up CT scanning of the brain after blunt trauma to the head.

RESULTS:

There were 313 follow-up studies performed in 212 patients, of which the majority, 135/313 (43.1%) were referred for neurological reasons, whilst 103/313 (32.9%) were referred for conservative management reasons and 75/313 (24%) were referred as part of their post-surgical check-up.

There were significant time delays from arrival of patients in casualty to their initial CT scan (mean 18.74 hours) as well as between the initial CT and the first follow-up scan

(mean 121.78 hours). There was a significant amount of data missing regarding the time of actual injury for many patients.

There were 74 neurosurgical interventions that took place as a result of CT scans performed. Of these, 54 (73%) took place after the initial CT scan, whilst only 20 (27%) occurred after a follow-up CT. Of those surgical interventions performed after a follow-up study, 6 (30%) were performed as a result of a scan performed for post-surgical check-up. 12 (60%) were performed as a result of a scan performed for neurological reasons. Two (10%) neurosurgical interventions occurred as a result of a scan performed for conservative management reasons (thus routine follow-up imaging).

CONCLUSIONS:

A routine single follow-up CT may be a reasonable approach with further follow-up imaging reserved for patients who have undergone surgery, those with possibly surgically manageable findings on initial CT (that do not undergo surgery) and those with new neurology. The routine use of follow-up CT beyond the first follow-up CT is unlikely to lead to a change in management when the above clinical, and prior CT findings are absent.

However, the time delays across all aspects of imaging traumatic brain injuries in our setting are unpredictable and represent a major problem in standardising when CT scans are performed.

Acknowledgements

I hereby acknowledge, and thank the following people for their invaluable contribution to this report:

Professor Savvas Andronikou (Supervisor)

Professor Steven Beningfield (Head of Department Diagnostic Radiology, Groote Schuur Hospital)

Katya Mauff (Department of Statistics, UCT)

Ushma Galal (Department of Statistics, UCT)

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Literature Review

Head trauma (whether blunt or penetrating) is a universally accepted cause of patient mortality and morbidity.

Within the USA, the large volume of patients sustaining a traumatic brain injury (TBI), is a warranted health concern resulting in over 300 000 hospitalisations per year (approximately 1.5 million cases per year) [1]. The resultant financial burden as well as the negative impact on these patients' lives is well known [1]. The majority of these patients (75%) sustain mild injuries – which is defined as a Glasgow Coma Scale (GCS) of ≥ 13 [1].

In a developing country such as South Africa, there are many factors that compound the associated morbidity and mortality rates (such as delays in patient presentation as well as restrictions within the health care budget) which often complicates decision making and according to Bezuidenhout et al. "there has been minimal research done on computed tomography of the brain (CTB) in resource-limited environments, (such as South Africa) with both human resources and equipment availability/limitations posing major challenges" to patient management [2].

Data from 2007 states that the Western Cape Province (servicing 4.8 million people) has approximately 31 diagnostic CT scanners in total, with 7 in public service and 24 in private

practice [3]. Generally, public service cares for the majority of the population in South Africa (approximately 80 %), whilst private practice services 20 % of the population [3]. The limited availability of these CT scanners is aggravated by their location which is often within the cities (central hospitals), rather than in the periphery. This means that for patients in the rural areas, there is a time-consuming transfer up the referral chain [3].

A CTB is a well-established first line imaging tool in patients who sustain a TBI [4-6] as it can be rapidly acquired and can demonstrate injuries requiring immediate neurosurgical intervention [7], including the severity as well as type of TBI sustained [8].
The use of the CT scanner does not come without risks however, which include the use of ionising radiation whose additive long-term effects are well known [9], such as increased lifetime cancer risk, cataracts as well as a negative effect on cognitive function in infants [8]. The transport of the patient to the CT scanner may in itself be problematic even requiring patient resuscitation [9], especially in severely injured patients who may be intubated and thus need oxygen and ventilatory support in-transit.

There is a universal problem, even in developed countries [10], of prioritising patients for their CT scan. The reasons for this include catering for the remaining hospital demand as well as trying to accommodate the volume of incoming trauma [10]. According to the Brain Trauma Foundation Guideline, the management of patients with traumatic brain injuries depends on injury severity [11] and ranges from medical management to decrease intra-cranial hypertension, intra-cranial pressure monitoring as well as neurosurgical evacuation of drainable bleeds [11].

One cannot directly translate recommendations designed for a developed country to that of a developing country [11] without considering the differences between the type and cause of trauma in these differing countries, the operation of trauma care systems, as well as the facilities and budget available in the managing hospitals [11]. Attempting to solve the question of when to appropriately perform a follow-up CT (FU CT) scan in a patient who has sustained a head injury, requires the examination of current practices in developing countries such as South Africa. This will improve the current protocols that are in place, especially with regards to the timing of the follow-up studies.

CT demonstrates findings for an instant in time and cannot give continuous patho-physiological information. The progression of TBI over time has been well documented [12] and thus new findings over time may very well change the management of the patient. Follow-up CT may therefore be desirable for detecting evolving pathologies that may follow after head injury. Consensus regarding the indication as well as the timing of FU CT for adults [5] as well as children [13] is lacking. Whilst unnecessary patient deterioration can be avoided by not allowing too much of a delay in follow-up scanning, it has been found that a scan performed too early after the first one may not display the full extent of the injury as it has not had enough time to evolve [14].

Most studies in the current literature include or review all levels of severity regarding TBI, and include both conservatively managed (non-operative) as well as operative follow-ups [1]. This makes any attempt to base the indication and/or need for follow-up imaging on current literature difficult.

Previous recommendations advise follow-up CT for TBI at various intervals [15], with many institutions performing routine imaging within 24 hours after the first scan [16].

Others feel that FU CT should not be routinely scheduled but rather dictated by clinical need (including changes in monitoring parameters or clinical condition) [5, 14]. Several previous studies have recommended that follow-up brain imaging is not indicated in situations where patients' neurological status remains stable (based on clinical examination), especially in those with a mild TBI [1]. Other studies report however, that follow-up brain imaging is necessary [16]. This is only possible with careful neurological examination and monitoring [7], and thus an approach of sedating patients with a low GCS may be problematic in this regard. Using the severity of the TBI may be helpful in predicting when to scan patients, with many institutions proposing the use of a change in clinical examination as an indicator for FU CT in patients with a mild head injury [14], and routine follow-up imaging in patients with severe head injuries (GCS ≤ 8) [14]. Patients with moderate TBI (GCS 9-12) remain in the grey area and recommendations are unclear [14].

The obligatory urge to admit patients with a mild TBI to ICU and to obtain routine follow-up scans, regardless of their clinical status or previous CT brain findings is well known amongst many doctors [1]. It has been previously documented that the indications for routine follow-up studies are unclear, and it was rather recommended that studies be performed which organises patients according to the severity of their TBI [9].

In a retrospective study of 179 patients, it was found that no patients with a mild TBI who remained neurologically status quo underwent neurosurgical intervention despite a worsening finding on follow-up imaging in some of them [1]. Other studies disagree with this and have proposed their own conclusions regarding the need for follow-up CT in

patients with TBI. Stein et al. performed a retrospective review on 457 patients and found that it is not cost-effective to await clinical deterioration in patients with a mild head injury where the initial scan has proven such injury, but to rather obtain a scheduled follow-up study, especially in younger patients [17]. In the older patients, there was an exponential decline in cost-effectiveness plotted against increasing patient age [18].

Dharap et al. in India, concluded that "routine follow-up CT for patients with clinically maintained status-quo is unlikely to yield any further information requiring a change in treatment" [15]. However, in the USA Oertel et al. demonstrated that there was significant worsening of an intracranial haemorrhage (ICH) on later routine follow-up CT's in approximately 50% of patients who often needed intensive monitoring [19]. Their recommendations stated that a follow-up CT scan should be performed (in patients with either a moderate or severe TBI) 4-6 hours after the initial scan, if that initial scan was performed within 4 hours of the injury and demonstrated an ICH [19]. In a study done by Park et al., a routine FU CT was also recommended to be performed within 24 hours of injury, as their results showed that 37% of patients underwent neurosurgery based on the follow-up CT findings, rather than deterioration in their neurological status [16]. Thomas et al. concluded that a routine, scheduled FU CT brain remains to be a useful clinical tool, often resulting in a change in management such as neurosurgical intervention [4].

Brown et al. in the USA performed a prospective study on 274 patients and recommended a routine FU CT in patients with severe TBI (GCS ≤ 8), as they found that a change in management took place in 50% of patients as a result of an interval change in radiological picture rather than a deteriorating clinical status [14]. In all other patients

(moderate or mild TBI), a FU CT should only be performed secondary to neurological deterioration as these FU studies are much more likely (33.3%) to result in clinical management change [14]. Velmahos et al, supports FU CT scanning in patients with a mild TBI after a decline in clinical status rather than performing a routine study [20].

In their retrospective review of 98 patients, Alahmadi et al. found that approximately 50% of conservatively managed brain contusions would have a deteriorating radiological picture during their hospital stay [18]. This coincides with the injury deterioration rates of other authors: 51% by Oertel et al., 51% by Narayan et al., and 44% by Stein et al [18]. Alahmadi et al., also found that the only statistically significant predictors of deterioration on CT were the initial brain contusion size together with a coexistent subdural haematoma [18]. This emphasizes the importance of understanding that not all patients with a radiologically deteriorating TBI have a coinciding negative change in their clinical state, nor does this equate to a change in surgical management/intervention [18]. There is a similar conclusion drawn from recent studies, that patients with a favourable GCS who have a proven small brain contusion and who have a maintained clinical status quo within the first 48 hours after injury, are unlikely to undergo neurosurgical intervention in the future [18].

According to the meta-analysis by Almenawer et al., there is no change in the management of patients with a CT proven mild TBI that results from routine FU CT scans performed within 24 hours, except when there has been a clinical deterioration in the neurological status of the patient, warranting an urgent FU CT scan to be performed [8]. Additional clinical significance is not gained by routinely acquiring a FU CT, but rather the

clinical condition and change in neurological state are the predictive factors for a change in management resulting from CT scan findings [8].

Interval deterioration on FU CT is associated with variables such as “a GCS score <15, age >65 years, a larger volume ICH, and an initial abnormal head CT which has been taken within 3.5 hours from the injury” [1] as well as “sub frontal/temporal contusions and antiplatelet therapy” [1]. This radiological deterioration however, does not equate to a change in clinical intervention as Kaups et al. were able to show that no patient required intervention without clinical deterioration, despite a worsening FU CT finding [21].

In their analysis of the literature, Stippler et al. found that relying on CT scan results alone to determine the need for management change may not be the best approach [22]. In the studies that they reviewed, it was found that neurosurgical intervention took place in 0.7% of cases (11/1574) where CT scans were performed as part of a routine follow-up protocol [22], compared to neurosurgical intervention in 42.9% of cases (24/56) where the follow-up study was performed due to a neurological decline [22]. There is support however for the use of scheduled, routine FU CT scanning in patients with the following risk factors: “initial severe GCS score, presence of coagulopathy, skull fractures traversing the middle meningeal artery or a major sinus and age > 65 years” [22].

A change in the practice of performing routine FU CT scans will highlight the need for thorough clinical evaluation of the patient, watching for changes that would indicate a follow-up scan [8]. A low threshold needs to be maintained for performing FU CT’s in the settling of subtle clinical change [8].

1.2. Aim

To evaluate referral patterns, associated time-delays and findings of follow-up CT as well as patient outcomes in patients with head injury at Groote Schuur Hospital.

1.3. Study Objectives

1. To determine the proportion of patients referred for follow-up CT scans
2. To categorise the referral pattern by clinical request
3. To determine and categorise the timing of follow-up CT scans from injury and initial CT
4. To categorize positive CT findings into outcome groups
5. To compare the referral groups with regard to the prevalence of patients in each outcome group
6. To determine if the CT findings resulted in a subsequent change in surgical management

2. Materials and Methods

This was a cross sectional, retrospective, descriptive study of follow-up CT requests and CT scan reports performed at the radiology department of Groote Schuur Hospital.

2.1. Inclusion and exclusion criteria

All patients thirteen years and older, presenting with a history of a head injury and having undergone a CT scan of the head were considered and only those who underwent a repeat / follow-up CT were included.

Exclusion criteria:

- Illegible patient notes
- Inaccessible, lost, unverified or incomprehensible report

2.2. Data collection

Groote Schuur Academic Hospital Complex (tertiary referral centre for the Western Cape) was chosen as the venue for performing the research.

The patients with a head injury referred from the Trauma Unit (C14) to the department of Radiology at Groote Schuur Academic Hospital, Cape Town for a head CT scan were accessed via the CT scanner registry.

Data was collected retrospectively over a 6-month period (where the initial scan fell within the period 1 February 2012 – 31 July 2012).

2.2.1. Procedure

The CT scan registry was accessed to obtain the names of all patients who had undergone a head CT for a head injury.

Patients who had undergone follow-up CT were extracted when multiple studies were noted on the in-house hospital PACS system.

Patient notes were used to extract relevant demographic (age, gender) and clinical data (mechanism of injury, time of injury, time of arrival in emergency room, Glasgow Coma Scale [GCS], clinical symptoms such as nausea, vomiting, headache, loss of consciousness [LOC], dizziness, change in GCS).

Patient notes were evaluated and used to categorise the patients into referral groups:

- Conservatively managed
- Surgically managed
- Patients who developed new signs and symptoms (as determined by change in the Glasgow Coma Scale, nausea, vomiting, persistent headache, focal neurological signs)

Each follow-up CT scan date (and time) was compared against the initial CT scan date (and time) to determine the interval time (as a continuous variable - hours) of follow-up CT.

CT scan **findings** were categorised **from the CT reports** into the following groups:

- Deterioration/Worsened (indicated by an increase in surface collections, midline shift, parenchymal bleeds, swelling, herniation, hydrocephalus) as documented in the CT report
- Unchanged (indicated by minimally changed or unchanged surface collections, midline shift, parenchymal bleeds, swelling, herniation, hydrocephalus)
- Improved (indicated by a measurable decrease in surface collections, midline shift, parenchymal bleeds, swelling, herniation, hydrocephalus)

Patient notes were evaluated to assess whether there was a change in surgical management as a result of each repeated scan.

2.2.2. Materials

The materials used in this study were the hard copy patient files (notes), as well as CT scan reports. The CT reports were soft copy (stored on an in-house data base and/or PACS).

2.2.3. Data analysis

Data was recorded on a data extraction tick-sheet (Appendix 1) and transferred to an excel spreadsheet for analysis.

2.3. Ethics

Data was collected anonymously and recorded on a data extraction sheet, according to a number key kept only by the primary investigator. The final results adhered to strict patient confidentiality principles. No CT scans were performed for the purpose of this research and all CT scans were those referred by clinical departments for imaging, based on their own clinical criteria. No collection of data began until the necessary ethical approval was granted.

2.4. Statistical analysis

Results were expressed as frequencies and percentages for categorical variables.

3. Results

Results are presented for each of the pre-defined objectives.

3.1. Objective 1: To determine the proportion of patients referred for follow-up CT

In total, there were 1753 patients referred for a head CT (hereafter referred to as the initial CT) following blunt trauma to the head during the study period. Of these, 20% (348/1753) were referred for a follow-up scan (hereafter referred to as FU CT1). Due to exclusion criteria **only 212 were** considered further in the study. There were 525 CT scans (including the initial CT and all follow-up scans) performed in total for these 212 patients. Thus, there were 2.5 scans (initial CT and all follow-up scans) performed per patient.

The ages of the patients included are summarised in Table 3.1.1. The mean age (in years) was 33 (standard deviation of 14 years).

Table 3.1.1: Age range (years)

	Total	Minimum	Maximum	Mean	Standard Deviation	Median	Percentile 25	Percentile 75
Age	212	15	79	33	14	28	22	41

The majority of patients were male (85.8%). The gender distribution is summarised in Table 3.1.2.

Table 3.1.2: Frequency of gender distribution

	Frequency	Percent
Female	30	14.2
Male	182	85.8
Total	212	100.0

The most common mechanism of injury in our setting was assault (55%). This was followed by motor vehicle accidents (MVA -15%), falls (13%), pedestrian vehicle accidents (PVA - 11%) and unknown/undocumented (6%) causes. One patient had a gunshot wound to the head (GSW). The mechanisms of injury and respective frequencies of these injuries are summarised in Table 3.1.3 below.

Table 3.1.3: Frequency distribution of the number of patients according to the mechanism of injury sustained

Mechanism of injury	N (%)
Assaulted	116 (54.7%)
Fall	28 (13.2%)
GSW	1 (0.5%)
MVA	32 (15.1%)
PVA	23 (10.8%)
Unknown/Other	12 (5.7%)
Total	212 (100%)

The most common CT-detected injury was skull fracture (64%), followed by contusion (57%) and swelling (57%). Subdural haematomas (SDH) were seen in 35% of patients, subarachnoid haemorrhage (SAH) in 31% and extra-dural haematomas (EDH) in 25%. Further imaging findings included midline shift (21%), pneumocranium (Pneumo - 16%), intra-ventricular haemorrhage (IVH - 7%), hydrocephalus (HCP - 7%) and parenchymal haematomas (ICH - 4%). As the injuries sustained by the patients are a combination of findings, these do not add up to 100%.

The types of CT detected injuries of the patients included in the study are summarised in Table 3.1.4.

Table 3.1.4: Distribution frequency of types of injury sustained documented by the initial CT

Injury	N = 212 (%)
Intra-cranial Haematoma (ICH)	9 (4%)
Contusion	121 (57%)
Subarachnoid Haemorrhage (SAH)	66 (31%)
Extra-dural Haematoma (EDH)	52 (25%)
Subdural Haematoma (SDH)	74 (35%)
Swelling	120 (57%)
Hydrocephalus (HCP)	15 (7%)
Midline shift	45 (21%)
Pneumocranium	34 (16%)
Intra-ventricular Haemorrhage (IVH)	15 (7%)
Skull Fracture	136 (64%)
Other	4 (2%)

There were 82 out of the 212 patients (38.7 %) who received treatment for their injury (for some patients this included the initial CT) at a referring hospital before arriving at GSH for further management. Of the 212 patients who underwent follow-up CT, there were 313 follow-up CT scans performed as summarised in Table 3.1.5 below. Thus, there were 1.5 follow-up CT scans done per patient ranging from a single follow-up scan to 6 follow-up CT scans in one patient.

Table 3.1.5: Summary of the number of patients receiving a scan per follow-up study

FU studies	Number of patients	% (out of 212)	% (out of those that had the previous scan)
FU CT 1	212	100%	100%
FU CT 2	74	35%	35%
FU CT 3	16	8%	22%
FU CT 4	7	3%	44%
FU CT 5	3	1%	43%
FU CT 6	1	0%	33%
Total	313		

There were 74 (35 %) of the patients referred for FU CT 2, 16 patients (8 %) referred for FU CT3, 7 patients (3%) referred for FU CT4, 3 patients (1 %) referred for FU CT5 and only

1 patient who was included in the study had 7 CT scans (initial scan plus 6 FU CT scans) during their hospital stay.

The reason for referral of patients for their initial CT scan following trauma was analysed. This information was available for 143/212 patients (67.5%). As patients could have a combination of symptoms and signs, the data collected does not add up to 100 %. The most common symptom/sign documented as a reason for initial CT was loss of consciousness in 55% (79/143). The symptoms/signs of the patients referred for their initial scan are summarised in Table 3.1.6 below.

Table 3.1.6: Frequency distribution of the presenting symptoms for the initial CT

Symptoms	N=143 (%)
Headache	26 (18.2%)
Nausea	8 (5.6%)
Vomiting	22 (15.4%)
Dizziness	12 (8.4%)
LOC	79 (55.2%)
Change GCS	30 (21.0%)
Other (e.g.seizure; focal neurology)	50 (35.0%)

Of the 212 patients included in the study, 210 had their GCS documented before receiving their initial CT scan (summarised in Table 3.1.7 below). 29 of these patients were received into the casualty already intubated (with GCS below 8), whilst 18 of these patients had a GCS of 8 or lower and were subsequently intubated before their initial scan.

Of the patients that were intubated, the mean GCS was 4 (Standard deviation 2). Of the patients who were not intubated, the mean GCS was 13 (Standard deviation 3). Seven patients had their GCS documented as 2T (meaning intubated and thus the score is calculated out of 10 rather than 15, allowing for the unusual finding of '2'). This is summarised in Table 3.1.7 below.

Table 3.1.7: Frequency of GCS score at the initial CT scan

GCS	Intubated		Total (N)
	No	Yes	
2	0	7	7
3	1	3	4
4	1	0	1
5	3	10	13
6	2	6	8
7	7	3	10
8	4	0	4
9	6	0	6
10	15	0	15
11	10	0	10
12	11	0	11
13	20	0	20
14	38	0	38
15	63	0	63
Total	181	29	210

3.2. Objective 2: To categorise the referral pattern by clinical request

For each follow-up CT scan, the reason for referral was divided into:

- Conservative Management (no reason for FU CT found except that the patient had an abnormal previous scan and was now 'routinely' being scanned again whilst under conservative management)
- Post surgical check-up (these patients had surgery and were now being scanned as a post-operative check)
- Neurological reasons (the patient developed new neurological signs and/or symptoms, inadequate improvement in neurological status or worsening neurological status)

Of the total of 313 FU CT studies performed, 32.9 % (103 patients) were referred for their studies under 'Conservative Management'. 43.1 % (135 patients) were referred for 'Neurological reasons' and 24 % (75 patients) were referred for a 'Post-Surgical check-up'.

Of the 212 patients referred for FU CT1, 37.7 % (80/212) were in the 'Conservative Management' group whilst 40.6 % (86/212) were in the 'Neurological Reasons' group and 21.7 % (46/212) were in the 'Post-Surgical check-up' group.

Of these patients, 35 % (74/212) had a second follow-up scan (hereafter referred to as FU CT2). Twenty-two out of the 74 (29.7 %) of the patients who had FU CT2 were referred under the banner of 'Conservative Management', whilst 51.5 % (38/74) were scanned for 'Neurological Reasons' and 18.9 % (14/74) were 'Post-Surgical check-ups'.

Of the patients who underwent FU CT2, there were 16.2 % (12/74) being scanned in the 'Conservative Management' group that had been scanned for the same reason in FU CT1. Similarly, 17.5 % (13/74) of patients scanned for 'Neurological Reasons' had been scanned for the same reason previously while 13.4 % (10/74) of patients who were scanned in the 'Post-Surgical check-up' group for FU CT2, were scanned for the same reason in FU CT1.

The referral patterns are summarised in Table 3.2.1 and 3.2.2.

Table 3.2.1: Frequency distribution for referral pattern per FU CT scan performed

CT Scan	Conservative	Neurological reasons	Post-surgical
	N (%)	N (%)	N (%)
FU CT1 (n=212)	80 (37.7%)	86 (40.6%)	46 (21.7%)
FU CT2 (n = 74)	22 (29.7%)	38 (51.5%)	14 (18.8%)
FU CT3 (n=16)	1 (6.2%)	7 (43.8%)	8 (50%)
FU CT4 (n= 7)	0 (0%)	3 (42.9%)	4 (57.1%)
FU CT5 (n=3)	0 (0%)	1 (33.3%)	2 (66.7%)
FU CT6 (n=1)	0 (0%)	0 (0%)	1 (100%)
Total = 313	103 (32.9%)	135 (43.1%)	75 (24%)

Table 3.2.2: Summary of further breakdown of referral pattern for FU CT2

FU CT1		FU CT2	
	N (%)		N (% of total undergoing FU CT2)
Conservative	80 (37.7%)	Conservative	12 (16.2%)
		Neurological	13 (17.5%)
		Post-Surgical	1 (1.4%)
		Sub-total	26 (35.1%)
Neurological	86 (40.6%)	Conservative	10 (13.5%)
		Neurological	13 (17.5%)
		Post-Surgical	3 (4.1%)
		Sub-total	26 (35.1%)
Post-Surgical	46 (21.7%)	Conservative	0 (0%)
		Neurological	12 (16.2%)
		Post-Surgical	10 (13.5%)
		Sub-total	22 (29.7%)
Total	212	Total	74 (100%)

3.3. Objective 3: To determine and categorise the timing of follow-up CT scans from the time of injury and from the time of the initial CT

Only patients who had times specified in the records (time of injury and time of arrival in the emergency department) were included in this calculation. The timing of all the CT scans performed at Groote Schuur Hospital was recorded, however in a few cases, patients had had their initial CT scan at their referring hospital (and thus this time was not available).

89 patients had available information documented for calculating the **time between injury and the initial CT scan** with an average time of 11.4 hours (Standard deviation 14.1).

90 patients had information available for calculating the time between injury and FU CT1. The reason one extra person had this information documented was because this patient

had their initial scan at a referring hospital without recording the time of the scan. The average **time between injury and FU CT1** for these patients was averaged at 96.9 hours (Standard deviation 101.8).

The time of arrival was documented for 171 patients. The mean **time from arrival** to **initial CT** scan was 18.7 hours (Standard deviation 31.9). A second calculation of **time from arrival** to **FU CT1** includes 172 patients (the extra patient again being the patient referred from another hospital with their initial CT scan) with a mean of 146.9 hours (Standard deviation 674.3). Lastly the time **from initial CT scan** to **FU CT1** was calculated for 208 patients (4 patients had information missing for their initial CT scan which was performed at another hospital) with a mean of 121.8 hours (Standard deviation 614.7).

The timing of follow-up scans from injury and initial CT is summarised in Table 3.3.1.

Table 3.3.1: Summary of the timing (in hours) from the time of injury as well as arrival in the emergency department to the respective CT scans performed

Time from…	Number of patients included	Min	Max	Mean	Standard Deviation	Median	Percentile 25	Percentile 75
*Injury to Initial CT	89	1.83	102.83	11.43	14.14	7.42	4.17	13.25
*Injury to FU CT1	90	12.25	716.00	96.85	101.75	64.00	42.00	122.17
Arrival to Initial CT	171	0.58	264.67	18.74	31.88	6.08	2.25	27.00
Arrival to FU CT1	172	7.50	8847.83	146.89	674.27	69.29	43.08	107.54
Initial CT to FU CT1	208	4.00	8846.67	121.78	614.73	51.21	35.13	85.00

*The number of patients for which 'time of injury' is available is low, which accounts for the lower mean time from injury to initial CT as well as to follow-up CT when compared to the timing from arrival to any scan.

3.4. Objective 4: To categorize positive CT findings into outcome groups

The overall finding (general impression) for each scan was documented as either improved, unchanged or worsened. Out of the 313 follow-up studies performed, 35 % (111) showed improved findings, 52.7 % (165) were unchanged and 11.8 % (37) worsened.

Regarding CT FU1 results, it was recorded that 30.7% (65/212) of these patients improved, 57.5% (122/212) were unchanged whilst 11.8% (25/212) worsened.
Of the 74 patients who had CT FU2, 44.6% (33/74) improved, 43.2% (32/74) were unchanged and 12.2% (9/74) worsened.
The CT findings categorised into overall outcome groups are summarised by Table 3.4.1 and Figures 3.4.1, 3.4.2 and 3.4.3 below.

Table 3.4.1: Distribution and frequency of the overall outcomes per follow-up CT scan performed

	Overall Outcome		
CT Scan	**Improved**	**Unchanged**	**Worsened**
	N (%)	**N (%)**	**N (%)**
FU CT1 n=212	65 (30.7%)	122 (58%)	**25 (12.0%)**
FU CT2 n =74	33 (44.6%)	32 (43.2%)	**9 (12.2%)**
FU CT3 n=16	6 (37.5%)	8 (50.0%)	**2 (12.5%)**
FU CT4 n=7	5 (71.4%)	2 (28.6%)	0 (0%)
FU CT5 n=3	1 (33.3%)	1 (33.3%)	1 (33.3%)
FU CT6 n=1	1 (100%)	0 (0%)	0 (0%)
Total (n=313)	111 (35.5 %)	165 (52.7%)	**37 (11.8%)**

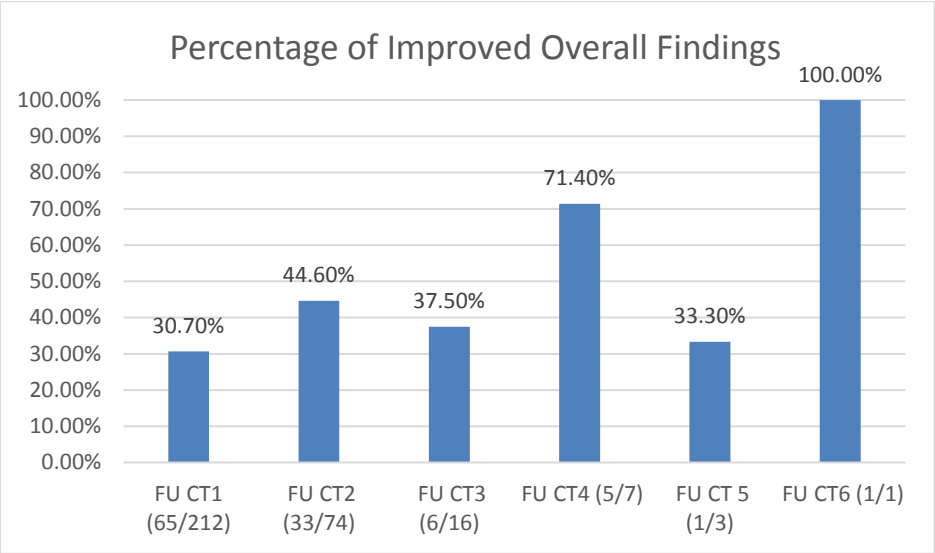


Figure 3.4.1: Frequency trend of the Improved Overall Outcome per FU CT

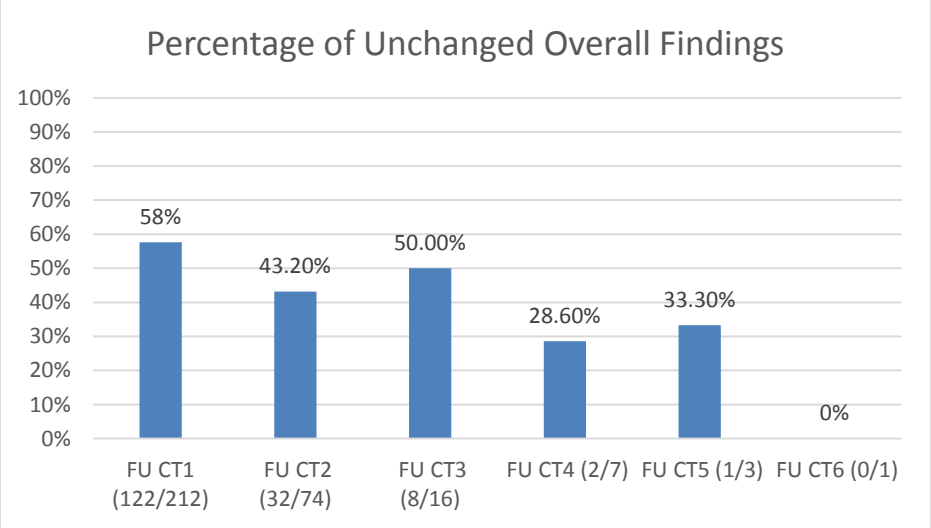


Figure 3.4.2: Frequency trend of the Unchanged Overall Outcome per FU CT

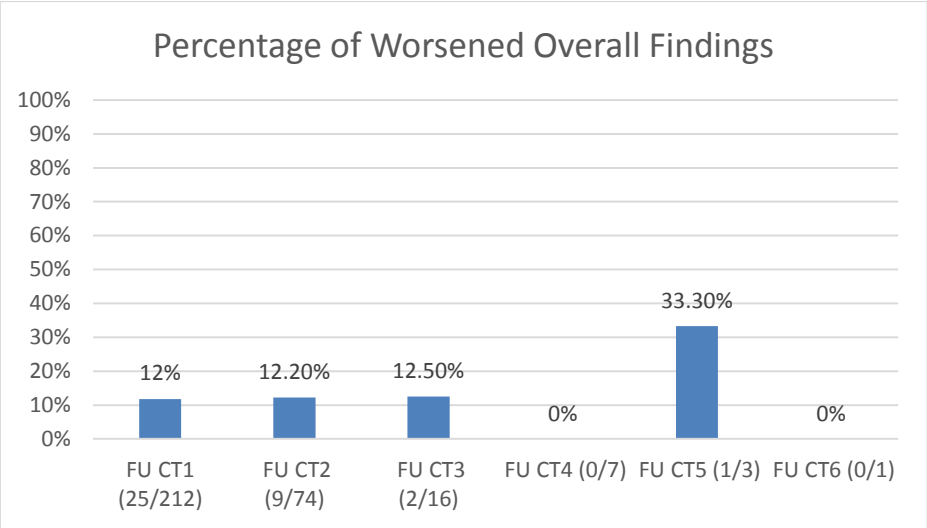


Figure 3.4.3: Frequency trend of the Worsened Overall Outcome per FU CT

The CT findings were then further categorised into those who had possibly surgically manageable findings (parenchymal haematoma, extra-dural bleed, subdural bleed and hydrocephalus). Of the 313 follow-up scans performed, **64.2 % (201)** yielded findings that fell into this category of **'possibly surgically manageable'**. The outcome of these scans was then documented.

In total, of the 201 'possibly surgically manageable' scan results, 43.8 % (88) were noted to have improved since the previous scan whilst 47.2 % (95) were unchanged and **9 % (18) had worsened**.

Of the 129 patients who had 'possibly surgically manageable' findings on FU CT1, 42.6 % (55/129) had improved findings, 49.6 % (64/129) were unchanged and **7.8% (10/129) worsened**.

Of 54 patients who had 'possibly surgically manageable' findings on FU CT2, 46.3% (25/54) of these improved, 43.6% (23/54) and **11.1% (6/54) worsened**. These findings are summarised by Table 3.4.2.

Table 3.4.2: Summary of surgically manageable CT findings

Possibly Surgically Manageable CT findings			
	Improved	**Unchanged**	**Worsened**
CT Scan	**N (%)**	**N (%)**	**N (%)**
FU CT1 N = 129	55 (42.6%)	64 (49.6%)	**10 (7.8%)**
FU CT2 N = 54	25 (46.3%)	23 (43.6%)	**6 (11.1%)**
FU CT3 N = 11	4 (36.4%)	6 (54.5%)	**1 (9.1%)**
FU CT4 N = 5	3 (60.0%)	2 (40.0%)	0 (0%)
FU CT5 N = 1	0 (0%)	0 (0%)	1 (100%)
FU CT6 N = 1	1 (100%)	0 (0%)	0 (0%)
Total n=201	88 (43.8%)	95 (47.2)	**18 (9%)**

A comparison between FU CT1 and FU CT2 was made regarding the '**overall impression'** of the CT findings.

Of the 65 patients whose findings improved in FU CT1, 20 (30.7%) still underwent FU CT2. 45% (9/20) of these showed further improvement in this FU CT2, 40% (8/20) were unchanged and **15% (3/20) worsened**.

Of the 122 patients whose findings were unchanged in FU CT1, 39 (32%) underwent FU CT2. 48.7% (19/39) of these now improved in their findings, 43.6% (17/39) were again unchanged and **7.7% (3/39) worsened**.

Of the 25 patients whose findings had worsened on FU CT1, 15 (60%) underwent FU CT2. 33.3% (5/15) now had improved findings, 46.7% (7/15) were unchanged and **20% (3/15) had worsened**.

These findings are summarised in Table 3.4.3.

Table 3.4.3: Summary of the comparison between FU CT1 and FU CT2 with respect to the Overall Outcome.

FU CT1 (n=212)		FU CT2 (n=74)	
	N (%)		N (%)
Improved	65 (30.7%)	Improved	9 (45%)
		Unchanged	8 (40%)
		Worsened	3 (15%)
		Total	20 (100%)
Unchanged	122 (57.5%)	Improved	19 (32%)
		Unchanged	17 (48.7%)
		Worsened	3 (7.7%)
		Total	39 (100%)
Worsened	25 (11.8%)	Improved	5 (33.3%)
		Unchanged	7 (46.7%)
		Worsened	3 (20%)
		Total	15 (100%)
Grand Total	212 (100%)	Grand Total	74

Considering only the 129 patients at FU CT1 who were considered to have possibly surgically manageable CT findings - 54 (41.9%) of these underwent FU CT2. **In the 55 patients with improved findings at FU CT1, 17 (31%) underwent FU CT2.** 52.9% (9/17) of these further improved, 35.3% (6/17) were unchanged and **11.8% (2/17) had worsened.** In 64 patients with unchanged findings at FU CT1, 28 (43.8%) underwent FU CT2. 42.9% (12/28) of these had improved findings, 53.8% (15/28) were again unchanged and 3.6% (1/28) had worsened. In 10 patients with worsening findings at FU CT1, 9 (90%) underwent FU CT2. Four of these patients (44.4%) had now improved, 22.2% (2/9) were unchanged and 33.3 % (3/9) had again worsened.

These findings for the first and second follow-up scans were compared and are summarised in Table 3.4.4.

Table 3.4.4: Summary of comparison between First and Second follow-up scans with respect to the possibly surgically manageable findings.

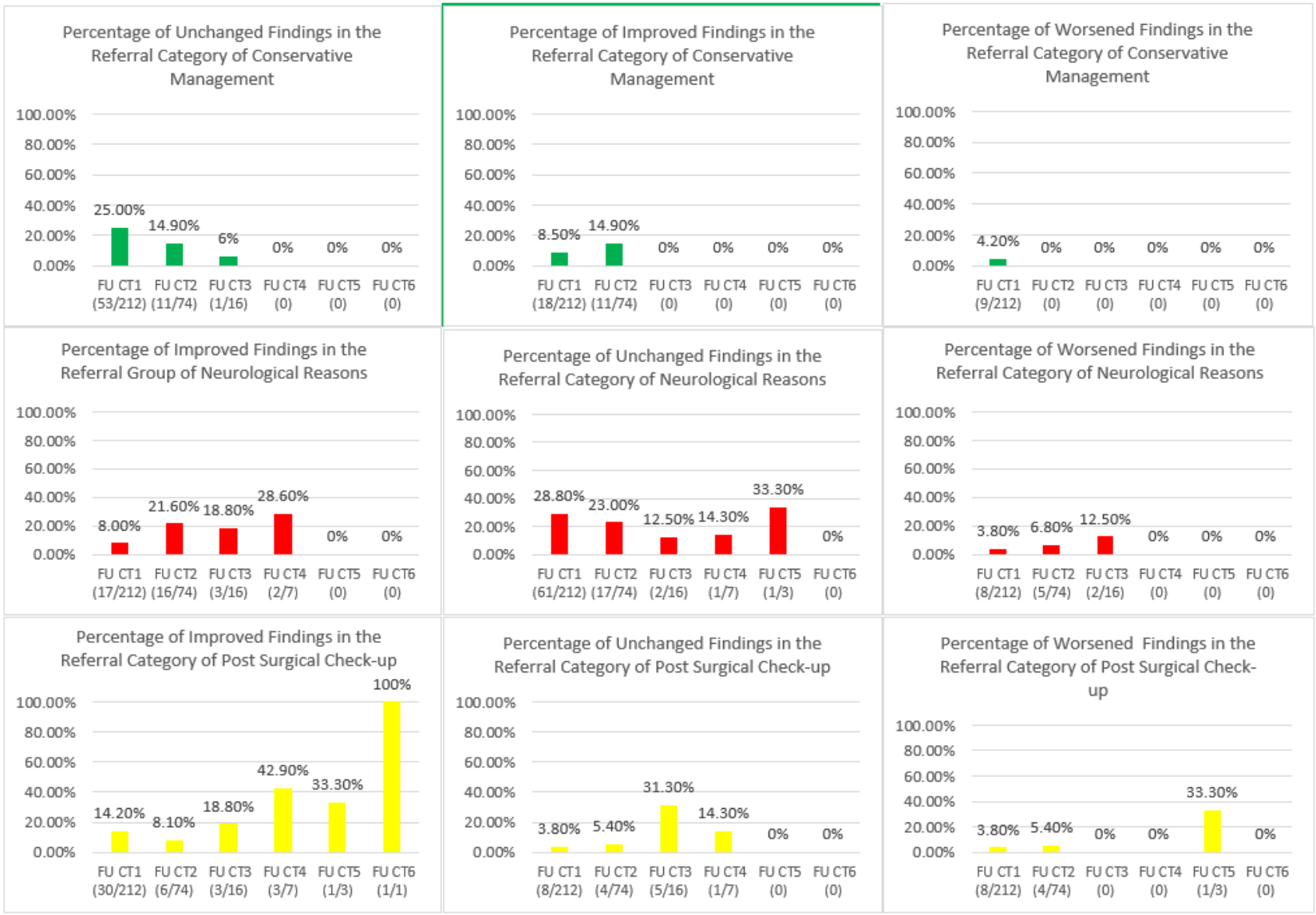
FU CT1 (n=129)		FU CT2 (n=54)	
	N (%)		N (%)
Improved	55 (42.6%)	Improved	9 (52.9%)
		Unchanged	6 (35.3%)
		Worsened	**2 (11.8%)**
		Total	17 (100%)
Unchanged	64 (49.6%)	Improved	12 (42.9%)
		Unchanged	15 (53.8%)
		Worsened	**1 (3.6%)**
		Total	28 (100%)
Worsened	**10 (7.8%)**	Improved	4 (44.4%)
		Unchanged	2 (22.2%)
		Worsened	**3 (33.3%)**
		Total	9 (100%)
Grand Total	129 (100%)	Grand Total	54

3.5. Objective 5: To compare the referral groups with regard to the prevalence of patients in each outcome group

A comparison between the referral groups with regard to the prevalence of patients in each outcome group for the respective FU CT studies is summarised in Table 3.5.1 and Figures 3.5.1 below.

Table 3.5.1: Frequency of each Referral Category according to Overall CT Outcome per FU CT

		CT Outcome: 'Worsened'				CT Outcome: 'Unchanged'				CT Outcome: 'Improved'			
FU CT number	Total	Overall	By Referral category			Overall	By Referral category			Overall	By Referral category		
			Conservative Management	Neurological Reasons	Post-surgical Check-up		Conservative Management	Neurological Reasons	Post-surgical Check-up		Conservative Management	Neurological Reasons	Post-Surgical Check-up
FU CT1	**212**	**25**	9	8	8	**122**	53	61	8	**65**	18	17	30
FU CT2	**74**	**9**	0	5	4	**32**	11	17	4	**33**	11	16	6
FU CT3	**16**	**2**	0	2	0	**8**	1	2	5	**6**	0	3	3
FU CT4	**7**	**0**	0	0	0	**2**	0	1	1	**5**	0	2	3
FU CT5	**3**	**1**	0	0	1	**1**	0	1	0	**1**	0	0	1
FU CT6	**1**	**0**	0	0	0	**0**	0	0	0	**1**	0	0	1
Grand Total	**313**	**37**	9	15	13	**165**	65	82	18	**111**	29	38	44



Figures 3.5.1: Frequency of Overall Outcome trend per FU CT chartered against each respective Referral Category

Of the 313 FU CT studies performed, 103 (32.9%) were performed for the referral 'Conservative Management' (across all FU CT scans). Importantly, 9 patients (8.7%) in this referral category were found to have 'worsening' findings that were also 'Possibly Surgically Manageable' conditions. These 9 patients imaged in the 'conservative management' category, however, make up 24% (9/37) of patients who had worsening CT findings – this group forms a high proportion of patients who worsened but all were seen at FU1. Only 2 of these patients underwent neurosurgical intervention.

3.6. Objective 6: To determine if the CT findings resulted in a subsequent change in surgical management

There were 74 (4 %) neurosurgical interventional events that took place as a result of the total 545 CT scans performed. 73 % (54/74) of these occurred after the initial scan and only 20 (27 %) were subsequent to a FU CT.

Thirteen of the 20 (65%) interventions were performed in response to the findings at FU CT1. 6 of these instances (30 %) were referred as post-surgical follow-ups, 5 patients (25%) had developed new neurological symptoms or signs as a reason for their scan whilst **2 (10 %) were scheduled for routine follow-up (conservative management).** All 13 patients had CT reports in the category "Surgically Manageable" intra-cranial pathologies. Three of the patients (15%) underwent surgery after an improvement in findings of FU CT1 in comparison to the initial scan, 5 (25%) had worsened and 5 (25%) were unchanged.

Five (25 %) of the 20 interventions that took place after FU CT scans were performed in response to the findings at FU CT2.

All of these were scanned for in the referral category “Neurological Reasons”. Two of these patients (10 %) had worsening findings on CT (both overall and surgically manageable findings), whilst 2 (10%) had improved from the previous scan. One patient (5%) had an overall unchanged CT scan but still went to theatre to elevate a skull fracture.

There were only 2 of the 20 interventions (10 %) that took place after FU CT scans that were performed in response to the findings at FU CT3. Both of these patients (100%) were scanned for changes in their neurological status, and both of these patients had a CT finding/outcome that had worsened since their previous study.

Only 2 patients out of the 313 FU CT scans (<1%) had an intervention after imaging was performed as a ‘routine’ for conservative management, and in these patients the CT report had indicated a surgically manageable finding.

Importantly, 11 (55%) of the patients undergoing neurosurgical intervention had CT outcomes that indicated improvement or unchanged appearances at FU CT 1 or 2.

Summarised in Tables 3.6.1 and 3.6.2, is the frequency of neurosurgical intervention performed with regard to the Overall Outcome as well as the Referral Category per FU CT.

Table 3.6.1: Frequency of Neurosurgical Intervention with regard to the Overall Outcome per FU CT

Overall Outcome	FU CT1 (%)	FU CT2 (%)	FU CT3 (%)
Improved	**3 (15%)**	**2 (10%)**	0 (0%)
Unchanged	**5 (25%)**	**1 (5%)**	0 (0%)
Worsened	5 (25%)	2 (10%)	2 (10%)
Total (n=20)	13 (65%)	5 (25%)	2 (10%)

Table 3.6.2: Frequency of Neurosurgical Intervention with regard to the Referral Category per FU CT

Referral Category	FU CT1 (%)	FU CT2 (%)	FU CT3 (%)
Conservative Management	**2 (10%)**	0	0
Neurological Reasons	5 (25%)	5 (25%)	2 (10%)
Post Surgical Check-up	6 (30%)	0	0
Total (n=20)	13 (65%)	5 (25%)	2 (10%)

3.7. Summary of results

1753 patients referred for a head CT in 6 months.

20% of patients had a follow-up CT.

1.5 follow-up CT scans were done per patient

313 follow-up studies in 212 patients were evaluated.

Majority of patients were male (85.8%).

Most common mechanism of injury in our setting was assault (55%).

CT findings of neurosurgical importance included subdural haematomas (SDH) in 35% of patients, extra-dural haematomas (EDH) in 25%, midline shift (21%), pneumocranium (16%), intra-ventricular haemorrhage (7%) and hydrocephalus (7%).

Just under 1/3rd of FU CT (103 CT scans) were referred as 'Conservative Management' i.e. routine.

Mean time from injury to initial CT = 11.4 hours [1/2 of a day]

Mean time from injury to FU CT1 = 96.9 hours [4 days]

Mean time from arrival at GSH to **initial CT** = 18.7 hours [3/4 of a day]

Mean time from arrival at GSH to **FU CT1** = 146.9 hours [6 days]

Mean time from initial CT scan to **FU CT1** = 121.8 hours [5 days]

12% of all FU CT scans performed showed worsening on CT – consistently about 12% of total FU scans performed at each of the F/U CT stages 1-3.

64.2% of all follow-up CT scans performed, yielded findings that fell into the category of **'possibly surgically manageable'**.

Of the 201 'possibly surgically manageable' scan results, **9% had worsened since the previous scan (a range from 8-11% for each of the first 3 FU CT scans).**

Of the 20 patients who underwent CT 2 even though findings improved in FU CT1, **15% worsened on FU CT 2.**

12% of those patients who had surgically manageable findings but had improved findings on FU CT1 still **showed worsening on CT2**.

NB: Of all FU CT studies performed, 1/3rd were performed routinely ('Conservative Management') **but 9% of these** were found to have 'worsening' findings that were also 'Possibly Surgically Manageable'.

NB: These 9 patients imaged in the 'conservative management' category, make up 24% of patients who had worsening findings on FU CT. However, all of these were seen at FU1 and only 2 of these patients underwent neurosurgical intervention.

Out of the total 545 CT scans performed, only 4 % resulted in neurosurgical intervention. Over ¼ of neurosurgical interventions were subsequent to a FU CT.
65% of neurosurgical interventions that were performed in response to the findings at FU CT were performed after FU CT1, and all had CT reports in the category 'Possibly Surgically Manageable' (10 % were scheduled for routine follow-up i.e. 'conservative management'). 35 % of neurosurgical interventions that were performed in response to the findings at FU CT 2 and 3 [i.e. needed more than one FU CT to convince the surgeons to act] were all scanned for 'Neurological Reasons' as referrals. However, more than ½ of the patients undergoing neurosurgical intervention after FU CT had CT outcomes that indicated improvement or unchanged appearances at FU CT 1 or 2.

Only 2 patients out of the 313 FU CT scans (<1%) had an intervention after imaging was performed as a 'routine' for conservative management, and in these patients the CT report had indicated a surgically manageable finding.

4. Discussion

4.1 Burden of trauma in South Africa

The number of CT scans performed during the limited study period reflects the large burden of head trauma on emergency units [8]. Of particular importance is that the most common cause of blunt trauma to the head in our study was assault, ahead of motor vehicle accidents. This study did not further classify the type or severity of assault sustained. The majority of the patients included in the study were young adult males in keeping with the demographic profile of other studies of head injury in adults [8, 9]. The referring symptoms of patients for their initial scan were variable, with approximately more than half of patients experiencing a loss of consciousness. This was by far the most common symptom.

4.2. CT findings in trauma

The 35% of patients with a subdural bleed, 25% with an extra-dural bleed, 7% with hydrocephalus (as a complication of their injury) and 9% with large parenchymal haematoma on CT are important because they are considered potentially surgically treatable findings. CT, however, demonstrates findings at an instant in time and cannot provide continuous patho-physiological information. In contrast, it has been well documented that a TBI will likely progress [12] and thus deterioration of existing pathology **or new findings on CT may justify a change the management of the patient** [6]. Follow-up CT is therefore desirable for providing longitudinal information regarding evolving pathologies that may follow after head injury. In our study, it was found that of

the neurosurgical interventions that took place after a FU CT, 25% took place with a reported improvement in findings from the previous study, whilst 30% occurred as a result of an unchanged finding and 45% took place after a worsening in FU CT findings. Failing the development of a continuous monitoring tool, follow-up CT at predetermined time intervals (i.e. routinely performed at specified intervals from the time from injury, from the time of presentation or from the time of the initial CT scan) represents the only mechanism for detecting any clinically **unsuspected** intracranial changes. Alternatively follow-up imaging can be performed in response to clinical changes/monitoring parameters or according to post-surgical principles.

4.3. Time intervals to CT scanning

Time delays between injury and arrival in casualty as well as between casualty and initial CT are highlighted by our study. Similar delays/inconsistency in time interval between the various follow-up CT scans was also noted. The literature lacks consensus regarding the indications and suggested timing of FU CT in TBI [5]. There is a universal problem, even in developed countries [10], of prioritising patients for their CT scan. The reasons for this include catering for the remaining hospital demand as well as trying to accommodate the volume of incoming trauma [10]. A number of comparable studies debate the use of **'Routine follow-up scanning'** within 24 hours with the role of secondary brain injury being increasingly recognised [16,21]. In many institutions, the **initial CT is performed early in the post-injury period with a follow-up CT performed within 24 hours** [21].
In our study, the average time between the arrival of patients in casualty to their initial CT scan was 18.7 hours. The timing between the initial and FU CT1 was averaged at 121.78 hours (5 days). If we were to apply a protocol of routine follow-up scanning, it would

almost be impossible to adhere to the recommended 24-hour follow-up period. This problem at our institution is reflected in a report by Bezuidenhout and colleagues who note that “in a developing country such as South Africa, delayed presentation and restricted healthcare budget compound morbidity and mortality rates and complicate decision making” [2].

Our postulated possible reasons for the delays in scanning at our institution include:

1) Poor access to emergency healthcare including the transport thereto / ambulance services.
2) Heavy trauma burden at tertiary healthcare facilities – with many patients to see and few doctors/nurses to see them.
3) Internal hospital transfer of very ill patients (especially intubated patients) relies on the collective presence of a multi-disciplinary team (doctor, sister, porter as well as use of mobile ventilators and oxygen supply).
4) Resource limitations in equipment - Groote Schuur Hospital does not have a dedicated CT scan for the use in trauma and all departments share the CT scanner.
5) Human resource limitations - there is only one radiographer on duty after hours who performs all CT scans.

4.4. Referral for follow-up CT

In patients who were scanned for post-surgical reasons [23] or those who had a change in their neurological status in our study, the FU CT can be considered justified. This is in line with a number of authors who feel that FU CT should be dictated by deteriorating clinical

status and not be scheduled as ‘routine’. [5, 14]. Several studies maintain that patients who have a stable neurological exam (especially those with a mild brain injury) do not require routine FU CT [1].

If the approach of only scanning patients with a change in clinical status or those who are immediately post-operative had been implemented in our hospital, it would have meant that 103 scans (32.9%) would not have been performed (those patients scanned for conservative reasons). Whilst this would have a positive savings impact on budget and resource conservation, it would also have meant that 9 of these patients (8.7%) who were scanned for conservative management and were found to have a worsening finding on their follow-up scan would not have been identified. **These 9 patients imaged in the ‘conservative management’ category, also make up 24% (9/37) of patients who had worsening CT findings – this group forms a high proportion of patients who worsened.** These 9 patients also all had potentially surgically manageable conditions. The fact that only 2 of them actually underwent neurosurgical intervention after the FU CT is not the issue as neurosurgical management is not always surgical. Other studies also found that a deteriorating FU CT scan does not always equate to neurosurgical intervention [21]. It is important to note however that further, additional follow-up CT scans in the patients with a referral of ‘conservative management’ did not yield further important findings i.e. all the 9 patients who had worsening CT findings were found at FU CT 1.

In summary only 2 patients out of the 313 FU CT scans (<1%) had an intervention after imaging was performed as a ‘ routine’ for conservative management, and in these patients the CT report had indicated a surgically manageable finding.

Importantly, 11 (55%) of the patients undergoing neurosurgical intervention had CT outcomes that indicated improvement or unchanged appearances at FU CT 1 or 2. This suggests that neurosurgeons are not relying on CT findings for surgical management choices in more than half of patients but they continue to request CT scans none-the-less.

4.5. Summary

Our follow-up scans are significantly delayed beyond 24-hour post injury period.

About ¼ of FU scans are not clinically indicated but performed as routine.

Almost ¼ of scans with worsening CT findings came from routine scanning and all were potentially surgically manageable.

However less than 1% of all FU CT scans went to surgery after routine FU imaging (i.e. conservative management).

The converse is also important i.e. that more than half of patients having surgery had FU CT outcomes that indicated no change or improvement.

4.6. Results in context

The CT scanner in GSH Cape Town is occupied by a heavy burden of imaging the heads of male patients who have sustained head injury through assault. This is warranted as there are many important positive findings, including over 1/3 of patients having subdural haemorrhages. Our timing for initial scans indicates that even though patients may be receiving scans in the regional hospitals within half a day of injury, that it takes 3/4 of a day to get an initial CT scan at GSH and 6 days to obtain a FU CT scan (which is far out of the recommended time for FU CT scanning – by 5 days).

1/5 of CT brain scans are follow-up CT scans which makes up a significant proportion of the scanner workload. These CT scans may also be warranted as the reports indicate that 64% of FU CT scans have possibly surgical manageable findings.

However, only 4% of patients who have CT scans undergo neurosurgery and more than ¼ of neurosurgery cases are performed after follow-up CT.

1/3 of follow-up CT scans are performed as a 'routine' without a clinical or surgical indication.

In favour of Routine FU CT scanning

There is a 12% worsening of findings on FU CT at each FU CT stage from the first to the third.

In patients with possible surgical manageable findings there is 9% worsening.

Even in patients where FU CT1 showed improvement and a FU CT 2 was performed anyway, there were 15% who showed worsening on CT.

In the scenario where patients with possibly surgically manageable findings that showed improvement on FU CT1, but still underwent FU CT 2, 12% showed worsening at FU CT2.

Most importantly, nearly ¼ of patients who showed worsening on FU CT were imaged routinely.

Against routine FU CT scanning

There are marked delays in CT scanning both initially and FU, most likely due to the burden on the CT scanner, and 1/5 of this is for FU CT scanning.

Of all the patients who had neurosurgery after FU CT 65% had findings of something possibly surgically manageable (i.e. known treatable findings seen on CT) and 35% had FU CT because of neurological reasons (i.e. new or worsening clinical findings).
Only 1% of all patients were imaged with FU CT as a routine procedure.

A summary of some of the current literature regarding their recommendation on whether scheduled follow-up head CT should be performed, is outlined in Table 5.4.1 below. It has been previously documented that the indications for routine follow-up studies are unclear, and it was rather recommended that studies be performed which organise patients according to the severity of their TBI [9]. This is indeed necessary for a resource-constrained environment such as GSH hospital in Cape Town, which services a population of at least 4.8 million people [3].

Table 4.5.1: Summary of current literature regarding routine repeat head CT scanning

Author	Year of Study	Number of Patients	Type of study	Recommendation of Routine Follow-up	Severity of head injury in the inclusion population Mild: GCS >12 Moderate: GCS 8-12 Severe: GCS <8	Reasoning
Washington et al	2012	321	Retrospective	No	Mild	A positive outcome occurs in most patients without needing routine FU CT scans or neurosurgical intervention.
Thomas et al	2009	1019	Retrospective	Yes	All	Neurosurgery often results from routine FU CT.
Bee et al	2009	207	Retrospective	Yes	Mild	Escalation of medical care and/or surgical management may result from scheduled FU CT in patients with a mild TBI and deteriorating radiological picture.
Sifri et al	2006	161	Prospective	No	Mild	A normal neurological exam in patients with a mild TBI precludes a routine FU CT as it does not alter patient management.
Almenawer et al	2013	445	Retrospective	No	Mild	There is no alteration in patient management resulting from routine FU CT within 24 hours in patients with a mild TBI.
Da Silva et al	2008	63	Retrospective	No	Moderate and severe	With appropriate monitoring in paediatric patients who have a severe TBI, surgery may be avoided as well as routine FU CT.
Brown et al	2007	272	Prospective	Depends on severity of TBI	All	FU CT is warranted in patients with a mild or moderate TBI following deterioration in their clinical status as the resultant radiological change is more likely to alter patient management compared to CT findings detected on routine follow-up. However in severe TBI, radiological status change rather than clinical picture often results in interventive change.
Dharap et al	2004	175	Prospective	No	All	FU CT does not result in neurosurgical intervention in patients whose clinical condition remains unchanged.
Park et al	2009	168	Retrospective	Yes	Mild and moderate	Routine FU CT should be performed within 24 hours, especially if risk factors are present, as many patients undergo a change in management based on FU CT deterioration rather than a clinical status change.
Alahmadi et al	2010	98	Retrospective	No	All	Radiological deterioration does not equal clinical worsening in a patient's status nor does it always imply resultant neurosurgical intervention. Of note, patients with a mild TBI are unlikely to require surgery if their clinical condition remains status quo.
Oertel et al	2002	142	Prospective	Yes	All	It is recommended that FU CT should be performed (in patients with either a moderate or severe TBI) 4-6 hours after an initial positive scan, if that initial scan was performed within 4 hours of the injury as routine FU CT often results in interventive change due to the deterioration in radiological findings.
Velmahos et al	2006	179	Retrospective	No	Mild	Routine FU CT is not needed in patients with a mild TBI.
Kaups et al	2004	462	Retrospective	No	Severe	Routine FU CT is not indicated without the presence of known risk factors or a change in patient condition, as there is no resultant change in patient management.
Our study	2014	212	Retrospective	No	All	A routine single FU CT may be a reasonable approach with further FU imaging reserved for patients who have undergone surgery, those with possibly surgically manageable findings on initial CT (that do not undergo surgery) and those with a change in neurological status.

4.7. Limitations of the current study

There were 348 patients referred for follow-up studies, however 212 formed the final group in the study. Many of the patients were excluded because the patient file/chart was not available for review. This is a point raised that could bias the study – as it is unknown how many of those patients would have been index cases in the study. In addition, the radiology department was undergoing transition from a film archive of studies/requests to the PACS system. Thus for some patients, the paper request form was missing and thus data was missing. These patients were also not included in the study.

Our study did not categorise patients into severity of head injury, which could be a large bias, as it is well known that in patients with a severe TBI, monitoring of clinical change is difficult post injury [14].

The CT scan reports were not critically reviewed by a second experienced person, blinded to the original findings – although each CT report was always checked by a second radiologist (registrar or consultant).

Our study did not evaluate the availability of ICU care or what exactly constitutes monitoring for all of these patients (as well as how it differs regarding the severity of injury) which according to the literature – is imperative if routine repeated CT scans are to be done away with [15,20,21].

5. Conclusion

Routine FU CT detects approximately 12% of patients with worsening radiological findings. Even in scenarios when the previous CT is improving, the next FU CT can show worsening in anything from 9% to 15%, depending on the findings on the previous CT. All those patients with worsening findings that were imaged routinely were seen on FU CT 1. In the 35% of neurosurgically managed cases after FU CT 2 and 3, had neurological reasons for referral and thus a clear surgical management plan can be made without resorting to additional FU CT scans based on clinical findings alone.

A decision needs to be made by the neurosurgeons on the need vs. the resource availability as well as the effects of timing of imaging new patients. Consideration is needed, as to which circumstances neurosurgeons will act to avoid unnecessary FU CT scanning.

A routine single FU CT may be a reasonable approach with further FU imaging reserved for patients who have undergone surgery, those with possibly surgically manageable findings on initial CT (that do not undergo surgery) and those with a change in neurological status. The routine use of FU CT beyond the first FU CT is unlikely to lead to change in management when the above clinical and prior CT findings are absent.

However, the timing of a follow-up study may be difficult to set into protocol in a setting such as ours due to the proven time delays (the current literature often recommends an initial as well as repeat CT within 24 hours of injury). The reasons for this are multi-factorial. In addition, in a situation such as ours where there are many budgetary constraints, scanning when clinically indicated rather than on a routine, scheduled basis

would have a positive impact on the healthcare budget. The patients referred being predominantly male and related to assault reflects the regional political dynamic and resources should be preserved and prioritised for those with significant injury, particularly with regard to FU CT. The time delays across all aspects of imaging in traumatic brain injuries in our setting are unpredictable and represent a major problem in standardising when CT scans are performed.

Appendix A: Ethics Clearance Certificate

UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
e-mail: nosi.tsama@uct.ac.za
www.health.uct.ac.za/research/humanethics/

9 May 2013

HREC REF: 279/2013

Dr J Owen
Dept. of Diagnostic Radiology

Dear Dr Owen

PROJECT TITLE: VALUE OF FOLLOW-UP CT IN HEAD INJURY ASSESMENT.

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

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

Approval is granted for one year until 15 May 2014.

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/research/humanethics/forms)

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

Please quote the REC. REF in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA),

Appendix B: Annual Progress Report

UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA00001537; IRB00001938) This serves as notification of annual approval, including any documentation described below.			
☑ Approved	Annual progress report	Approved until/next renewal date	15/05/2015
☐ Not approved	See attached comments		
Signature Chairperson of the HREC		Date Signed	24/04/2014

Comments to PI from the HREC

Principal Investigator to complete the following:

1. Protocol information

Date form submitted	APRIL 2013		
HREC REF Number	279/2013	Current Ethics Approval was granted until	15 MAY 2014
Protocol title	VALUE OF FOLLOW-UP CT IN HEAD INJURY ASSESSMENT		
Protocol number (if applicable)	N/A		
Are there any sub-studies linked to this study?	☐ Yes ☑ No		
If yes, could you please provide the HREC Ref's for all sub-studies? Note: A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	DR JEANNINE OWEN		
Department / Office Internal Mail Address	jeanninzowen@gmail.com		

1.1 Does this protocol receive US Federal funding?	☐ Yes	☑ No
1.2 If the study receives US Federal Funding, does the annual report require full committee approval?	☐ Yes	☐ No

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)

HUMAN RESEARCH ETHICS COMMITTEE
23 APR 2014
HEALTH SCIENCES FACULTY
UNIVERSITY OF CAPE TOWN

6. References

1. Washington, C.W. and R.L. Grubb, Jr., *Are routine repeat imaging and intensive care unit admission necessary in mild traumatic brain injury?* J Neurosurg, 2012. **116**(3): p. 549-57.
2. Bezuidenhout, A.F., et al., *The Kimberley Hospital Rule (KHR) for urgent computed tomography of the brain in a resource-limited environment.* S Afr Med J, 2013. **103**(9): p. 646-51.
3. Strachan, M., *Imbalance Between Public and Private Radiological Services in The Western Cape of South Africa*, in *Diagnostic Radiology*. 2007, University of Stellenbosch.
4. Thomas, B.W., et al., *Scheduled repeat CT scanning for traumatic brain injury remains important in assessing head injury progression.* J Am Coll Surg, 2010. **210**(5): p. 824-30, 831-2.
5. Khan, S., et al., *Evolution of traumatic intracerebral hemorrhage captured with CT imaging: report of a case and the role of serial CT scans.* Emerg Radiol, 2010. **17**(6): p. 493-6.
6. Bee, T.K., et al., *Necessity of repeat head CT and ICU monitoring in patients with minimal brain injury.* J Trauma, 2009. **66**(4): p. 1015-8.
7. Sifri, Z.C., et al., *A prospective evaluation of the value of repeat cranial computed tomography in patients with minimal head injury and an intracranial bleed.* J Trauma, 2006. **61**(4): p. 862-7.
8. Almenawer, S.A., et al., *The value of scheduled repeat cranial computed tomography after mild head injury: single-center series and meta-analysis.* Neurosurgery, 2013. **72**(1): p. 56-62; discussion 63-4.
9. Wang, M.C., et al., *Utility of repeat head computed tomography after blunt head trauma: a systematic review.* J Trauma, 2006. **61**(1): p. 226-33.
10. Smith, J.S., et al., *The role of early follow-up computed tomography imaging in the management of traumatic brain injury patients with intracranial hemorrhage.* J Trauma, 2007. **63**(1): p. 75-82.
11. Ratanalert, S., et al., *The impacts and outcomes of implementing head injury guidelines: clinical experience in Thailand.* Emerg Med J, 2007. **24**(1): p. 25-30.
12. White, C.L., S. Griffith, and J.L. Caron, *Early progression of traumatic cerebral contusions: characterization and risk factors.* J Trauma, 2009. **67**(3): p. 508-14; discussion 514-5.
13. da Silva, P.S., M.E. Reis, and V.E. Aguiar, *Value of repeat cranial computed tomography in pediatric patients sustaining moderate to severe traumatic brain injury.* J Trauma, 2008. **65**(6): p. 1293-7.
14. Brown, C.V., et al., *Indications for routine repeat head computed tomography (CT) stratified by severity of traumatic brain injury.* J Trauma, 2007. **62**(6): p. 1339-44; discussion 1344-5.
15. Dharap, S.B., et al., *Repeat CT scan in closed head injury.* Injury, 2005. **36**(3): p. 412-6.
16. Park, H.K., et al., *The clinical efficacy of repeat brain computed tomography in patients with traumatic intracranial haemorrhage within 24 hours after blunt head injury.* Br J Neurosurg, 2009. **23**(6): p. 617-21.
17. Stein, S.C., Fabbri, A., Servadei, F, *Routine serial computed tomographic scans in mild traumatic brin injury: when are they cost-effective?* J. Trauma, 2008. **65**: p.66-72

18. Alahmadi, H., S. Vachhrajani, and M.D. Cusimano, *The natural history of brain contusion: an analysis of radiological and clinical progression.* J Neurosurg, 2010. **112**(5): p. 1139-45.
19. Oertel, M., et al., *Progressive hemorrhage after head trauma: predictors and consequences of the evolving injury.* J Neurosurg, 2002. **96**(1): p. 109-16.
20. Velmahos, G.C., et al., *Routine repeat head CT for minimal head injury is unnecessary.* J Trauma, 2006. **60**(3): p. 494-9; discussion 499-501.
21. Kaups, K.L., et al., *Routinely Repeated Computed Tomogrpahy after Blunt Head Trauma: Does it Benefit Patients?* J Trauma, 2004. **56**: p.475-81.
22. Stippler, M., et al., *Utility of routine follow-up head CT scanning after mild traumatic brain injury: a systematic review of the literature.* Emerg Med J, 2012. **29**(7): p. 528-32.
23. Paci, G.M., et al., *The need for immediate computed tomography scan after emergency craniotomy for head injury.* J Trauma, 2008. **64**: p. 326-32.