DOOR TO SKIN TIME IN PATIENTS UNDERGOING EMERGENCY TRAUMA CRANIOTOMY

By

DR KUMARAPPAN A/L CHOCKALINGAM

Dissertation Submitted in Partial Fulfilment of the Requirements for the degree of

Masters of Surgery (Neurosurgery)

UNIVERSITI SAINS MALAYSIA

2020

ACKNOWLEDGEMENTS

First and foremost, praises and thanks to God, the Almighty, for His showers of blessings throughout my research work to complete the research successfully.

I would like to express my sincere gratitude and appreciation to my dissertation supervisors Mr (Dr) Azman B Abd Rahman (Head of Department, Department of Neurosurgery, Hospital Sultanah Aminah, Johor Bahru), Professor Mr. (Dr.) Zamzuri Idris (Head of Neurosciences Department, Universiti Sains Malaysia) and Ms (Dr) Sharon Casilda Theophilus (Senior Consultant Neurosurgeon, Hospital Sultanah Aminah) for their kind assistance and guidance as well as their support in the preparation and completion of this dissertation. Their dynamism, vision, sincerity and motivation have deeply inspired me. It was a great privilege and honour to work and study under their guidance.

I also would like to thank the founder of the Neurosurgical Residency Training Programme in Universiti Sains Malaysia, Professor Dato' Mr. (Dr.) Jafri Malin Abdullah and Professor Dato' Mr. (Dr.) Abdul Rahman Izani Ghani (Senior Consultant Neurosurgeon, Universiti Sains Malaysia). Their advice and guidance have been invaluable throughout my study.

Heartfelt thanks are also expressed to Dr. Suriaraja Govindaraju and colleagues in the department of Neurosurgery in Hospital Sultanah Aminah for their support throughout this research work. I am extending my gratitude to neurosurgery clinic staffs and staffs at Unit Rekod Perubatan, Hospital Sultanah Aminah for their assistance to search for the numerous clinic notes and records which was vital for the completion of this study.

I am extremely grateful to my parents, my wife and my sons their love, prayers, patience and sacrifices. Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

CT	COMPUTED TOMOGRAPHY
DAI	DIFFUSE AXONAL INJURY
ED	EMERGENCY DEPARTMENT
EDH	EXTRADURAL HAEMORRHAGE
EVD	EXTERNAL VENTRICULAR DRAIN
GCS	GLASGOW COMA SCORE
GOS	GLASGOW OUTCOME SCALE
HSAJB	HOSPITAL SULTANAH AMINAH
ICH	INTRACEREBRAL HAEMORRHAGE
ICU	INTENSIVE CARE UNIT
MOH	MINISTRY OF HEALTH
NHDU	NEURO HIGH DEPENDENCY UNIT
OR	ODD'S RATIO
OT	OPERATING THEATRE
SDH	SUBDURAL HAEMORRHAGE
TBI	TRAUMATIC BRAIN INJURY

ABSTRAK

Latar Belakang dan Objektif

Kecederaan otak traumatik dijangka menjadi punca ketiga utama kematian dan hilang upaya di seluruh dunia dalam 2020[1]. Ia meletakkan beban yang besar ke atas penjagaan kesihatan terutama di negara-negara membangun seperti Malaysia. Bagi subset pesakit dengan kecederaan otak dengan pendarahan intrakranial yang kritikal, pembedahan segera menjadi asas rawatan. Walaupun semua usaha dilakukan untuk memastikan pesakit mendapat pembedahan tepat pada waktunya, seringkali kami dapati bahawa terdapat penangguhan yang tidak disengajakan dalam pengurusan pesakit ini. Kajian ini bertujuan menilai prestasi pusat pembedahan saraf rujukan di Malaysia, mengkaji kesulitan yang dihadapi dan mencadangkan cara-cara untuk meningkatkan prestasi.

Kaedah

Ini adalah kajian retrospektif yang dilakukan di HSAJB antara 1 Januari 2019 dan 31 Disember 2019. Semua pesakit dengan kecederaan otak traumatik yang dimasukkan ke HSAJB dengan penemuan otak CT yang tidak normal yang memerlukan kraniotomi kecemasan telah dimasukkan ke dalam kajian ini. Senarai pesakit yang menjalani kraniotomi kecemasan atau kranektomi dikenalpasti dari daftar bilik bedah. Data demografi dan data klinikal yang diperlukan diambil dari nota-nota klinikal. Data yang diperoleh dimasukkan ke dalam perisian komputer Statistical Package for Social Science (SPSS) versi 22. Pembahagian data dianalisis dengan statistik nonparametrik.

Keputusan

Sebanyak 154 pesakit yang menjalani kraniotomi kecemasan untuk kecederaan otak traumatik sepanjang tempoh kajian dimasukkan dalam kajian ini. Secara keseluruhan, masa ‘Door to Skin’ adalah 605 minit, masa ‘Door to CT’ adalah 131 minit, masa ‘CT to

Review' adalah 274 minit, masa 'Review to Booking' adalah 20 minit, waktu 'Booking to OT' adalah 90 minit dan waktu 'OT to Skin' adalah 62 minit . Pesakit yang dimasukkan secara langsung ke HSAJB mempunyai keseluruhan masa 'Door to Skin' selama 459 minit. Semasa discaj, terdapat sejumlah 102 pesakit (66.23%) dengan hasil yang kurang memuaskan. Semasa melakukan regresi logistik yang, kami mendapati bahawa polytrauma, episod hipotensi, pesakit yang berventilasi, kecederaan otak teruk 'Severe TBI' dan masa 'Door-Skin' semuanya berkaitan dengan hasil yang kurang memuaskan. 'Adjusted OR' untuk masa 'Door to Skin' adalah 1.005 dengan 95% CI (1.002-1.008). Oleh itu, untuk setiap minit penundaan pada masa 'Door to Skin' terdapat 1.005 kali peningkatan kemungkinan hasil kurang memuaskan sewaktu discaj. Sewaktu susulan pada 6 bulan, jumlah pesakit dengan hasil yang kurang memuaskan berkurang kepada 58 pesakit (37.66%). Kami mendapati bahawa tanpa mengira ciri klinikal pesakit, setiap minit kelewatan 'Door to Skin' menyebabkan peningkatan 1.008 (1.005 -1.011, CI 95%) kali ganda unutk hasil yang kurang memuaskan pada 6 bulan.

Kesimpulan

Masa 'Door to Skin' berkadar langsung dengan hasil kurang memuaskan pada pesakit dengan kecederaan otak traumatik. Walaupun menjadi pusat rujukan neurosurgeri dan trauma serantau, masih terdapat kelewatan yang ketara dalam pengurusan pesakit yang menyebabkan pembedahan kecemasan kerap tertunda. Usaha yang bersungguh-sungguh dari semua pihak yang terlibat dalam perawatan trauma dengan protokol neurotrauma yang mantap adalah penting untuk mengurangkan kelewatan ini.

Kata kunci

Kecederaan otak traumatik, kraniotomi trauma kecemasan, masa 'Door to Skin', sistem trauma teratur

ABSTRACT

Background and Objective

Traumatic brain injury (TBI) is predicted to be the third leading cause of death and disability worldwide in 2020[1]. It places a significant burden on health care especially in developing countries like Malaysia. For a subset of patients' with TBI with significant intracranial bleed, urgent surgical intervention remains the mainstay of treatment. Although all efforts are taken to ensure that patients received surgical intervention in a timely manner, often we find that there are inadvertent delays in management of these patients. This study aims to evaluate the performance of neurosurgery referral centre in Malaysia, review the possible pitfalls and propose ways to improve performance

Methods

This is a retrospective study conducted in HSAJB between 1st January 2019 and 31st December 2019. All patient with traumatic brain injury admitted to HSAJB with abnormal CT brain findings requiring urgent craniotomy was enrolled in this study. A list of patients who underwent emergency craniotomy or craniectomy from our operating theatre registry. The demographic data and required clinical data were extracted from the clinical notes. The data obtained were entered into computer software Statistical Package for Social Science (SPSS) version 22. Data distributions were described with nonparametric statistics.

Results

A total of 154 patients who were subjected to emergency trauma craniotomy during the duration of study was included in this study. Overall, the median Door to Skin times were 605 minutes, Door to CT time was 131 minutes, CT to Review time was 274 minutes, Review to Booking time was 20minutes, Booking to OT time was 90 minutes and OT to

Skin time was 62 minutes. Patients who were directly admitted to HSAJB had an overall median Door to Skin time of 459 minutes. At discharge, there were a total of 102 patients (66.23%) with poor outcome. On performing simple logistic regression, we found that the polytrauma, hypotensive episode, ventilated patients, severe TBI and Door-Skin times were all significantly associated with poor outcomes. The adjusted OR for Door to Skin times was 1.005 with 95% CI (1.002-1.008). Hence, for every minute delay in Door to Skin time, there was 1.005 time increase likelihood of having poor outcome during discharge. During the 6 months follow up, the number of patients with poor outcome reduced to 58 patients (37.66%). We found that regardless of patients' clinical characteristic, every minute delay in Door to Skin led to 1.008 (1.005 -1.011, CI 95%) times increase in having poor outcome at 6 months.

Conclusion

Door to Skin time is directly proportional to poor outcomes in patients with TBI. Despite being the regional neurosurgical and trauma referral centre, there are still significant delays in patient management leading to delayed surgical intervention. Concerted efforts from all parties involved in trauma care with established neurotrauma protocol are essential in eliminating this delay.

Keywords

Traumatic brain injury, emergency trauma craniotomy, door to skin time, door to CT time, organised trauma system

1. INTRODUCTION & LITERATURE REVIEW

Traumatic brain injury (TBI) is projected by the World Health Organization to become the third leading cause of death and disability in the year 2020[1]. It places a significant burden on health care especially in developing countries like Malaysia. TBI. For a subset of patients with TBI and significant intracranial bleed, urgent surgical intervention remains the mainstay of treatment.

According to brain trauma foundation recommendation, traumatic brain injury patient with acute extradural, subdural haemorrhage and post fossa mass lesion with requiring surgical intervention should undergo surgery as soon[2]. However, there has been no specific time cut off given in the guidelines. Although it seems reasonable to predict that patient who undergoes earlier surgery will have better outcomes, study thus far revealed mixed results[3–8].

It is important to note that traumatic brain injury includes a diverse population of patients with multiple confounding factors such as age, the severity of injury, GCS score, type of intracranial bleed, other concomitant injuries all which could affect their outcome. As such it is difficult to isolate the effect of timing of surgery with regards to patients' outcome. However, two landmarks study are often quoted to emphasize the need for urgent surgical evacuation is by Mendelow et al. and Seeling et al. Mendelow concluded that delay in evacuation extradural haemorrhage led to increased morbidity and mortality in which delays of more than 2 hours were found to be unacceptable[9]. These findings were further reinforced with a study done on 60 patients with traumatic extradural haemorrhage who were grouped into surgical evacuation within 1 hour, surgical evacuation between 1-6 hours and beyond 6 hours. The study found that the frequency favourable outcome was significantly higher in the group of patients whose surgery was performed within 1 hour[10].

In traumatic subdural haemorrhage, Seeling et al. found that delay from injury to operation was the factor of greatest therapeutic importance. They found patients who underwent surgery within the 4 hours of injury had a 30% mortality rate, as compared with 90% in those who had surgery after four hours[6]. However, one study found that shorter time to surgery may not result in better outcomes. Moreover, they found that faster time to surgery resulted in a worse outcome which they postulated to be due to lack of pre-stabilization and resuscitation prior to surgery[4]. Earlier surgery has been associated with better outcomes especially in patients' with moderate and severe traumatic brain injury with signs of herniation (ie anisocoria, motor posturing)[2]. As such all efforts should be taken to ensure that patients who require intervention are operated promptly.

The causes that lead to delay in definitive surgery in patients with traumatic brain injury are multifactorial. It can be broadly divided into organisational related, medical-related or patient-related. In a study done over 7 years to identify delays in orthopaedic emergency surgery found that organisational related causes are the most common(81%) cause for delay[11]. Although this result could not be generalised into neurosurgery practice or our local setting, identifying such causes organisational delay if any will allow room for improvement in terms of service and outcome among neurosurgery patient.

A retrospective review of patients undergoing emergency trauma craniotomy was carried out in a level 1 trauma centre in Canada to determine the intra-hospital delays. The overall median time elapsed between arrival to ED and surgical skin incision was 150 minutes[12]. They concluded that many factors contribute to this delay, including performing imaging and transfer to and preparation in the OR[12]. In another study done in United Kingdom to evaluate time from injury to neurosurgical intervention, in patients presenting to a district hospital, the fastest time from injury to intervention was 8.5 hours

while the mean was 22hours[13]. This was found to be beyond the UK national guidance which advocates injury to knife time of less than 4 hours.

In our current setting, Hospital Sultanah Aminah (HSAJB) is the only government hospital in the state of Johor which provides neurosurgical services. The neurosurgery department of HSAJB has been at the forefront of management of traumatic brain-injured patients in the region. There is a total of 14 government hospital in Johor with only 6 equipped with CT scanners. Generally, once patients arrive in the emergency department of the initial hospital, they are assessed and stabilized. The need for CT is determined by the ED team.

The neurosurgical team is usually consulted once the CT brain is done when patients are directly admitted to HSAJB or referred from a facility where CT brain is available. If a CT scanner is not available, the patient is then transferred to HSAJB or the nearest hospital where a CT scanner is available. Once the CT brain is performed, the patient is evaluated by the on-call neurosurgical team decision made on the need for surgical evacuation of the intracranial bleed as per standard protocols. Patients who are subjected to urgent craniotomy or craniectomy are subsequently admitted to neuro HDU or ICU for close monitoring and observation. Patients are either discharged home or transferred to other facilities once stable. They are then followed up as outpatient in our neurosurgery clinic.

In our experience, we find that there is a significant time elapsed between trauma and surgery in patients requiring urgent surgical evacuation of an intracranial mass lesion. Not only patient requiring inter-hospital transfer face delay in arriving at our centre in view large geographic coverage compounded with the limited resource. There is significant time elapsed within the facility before a patient requiring emergency craniotomy undergone surgical evacuation. This study would shed light on the

performance of regional neurosurgery centre in terms of delays in performing trauma craniotomies, review the possible pitfalls and propose ways to improve performance and outcome.

2. STUDY PROTOCOL

This is a retrospective study conducted in a single centre. The research objectives to evaluate the performance of a regional neurosurgery centre in terms of delay in emergency trauma craniotomy. This study subjects consist of all patients who underwent emergency trauma craniotomy in Hospital Sultanah Aminah Johor Bahru between 1st January 2019 till 31st December 2020. This study was approved by the Malaysian Medical Research Ethical Committee (MREC). [NMRR ID: 19-1794-48781]

Patients who fulfil the inclusion and exclusion criteria will be selected and included in the study. The inclusion criteria for this study are as follows: All patient with traumatic brain injury admitted to HSAJB with abnormal CT brain findings (Intra-axial lesions: contusion, traumatic intracranial haemorrhage, extradural haemorrhage, subdural haemorrhage, DAI) and requiring urgent neurosurgical intervention (craniotomy, craniectomy). Patients who were initially managed medically but later required surgery for clinical or radiological deterioration, patients who underwent craniectomy for elevated intracranial pressure after ICP monitoring and patient who underwent surgery without intracranial mass lesion (compound or depressed fractures) were excluded from this study.

In this retrospective study, we aim to evaluate the time taken from patients arriving at the door of the first healthcare facility till the start of the definitive neurosurgical procedure and to identify factors which lead to delay in the continuum of

care. We recruited a list of patients who underwent emergency craniotomy or craniectomy from our operating theatre registry and their respective records were traced from the record office. Those who met our inclusion and exclusion criteria were filtered. The details required including patients' demographic data, mechanism of injury, clinical findings at admission, CT scan findings, and outcome were collected and fill into a data collection sheet.

Sample Size

Universal sampling was used in this study. All patients who underwent emergency trauma craniotomy or craniectomy in Hospital Sultanah Aminah from 1st of January 2019 to 31st December 2019 were included in the study based on the inclusion and exclusion criteria stated above.

Declaration of Interest Conflict

There was no conflict of interest in this study. All patients with traumatic brain injury were managed as per traumatic brain injury guidelines. There were neither any adverse effects nor direct benefits for participants of this study. However, the study outcome may help us understand the factor resulting in prolong door to skin time which may be used to improve delivery in future.

This study was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki (2013) and the Malaysian Good Clinical Practice Guideline (2016). Approval was obtained before the initiation of this study. This is a retrospective study and therefore no patient consent is required.

Names of subjects will be kept on a password-protected database and will be linked only with a study identification number during this research. The patient identification number instead of patient identifiers will be used on datasheets. All data

will be entered into a computer that is password protected. Names of patients will not be disclosed, and all will be changed into identification number instead. On the completion of the study, data in the computer will be copied to a USB drive and other soft copies will be erased while the hardcopy data will be kept and locked in the office cabinet located in the Department of Neurosurgery, Hospital Sultanah Aminah for 2 years, after which, the data will be removed permanently.

TITLE PAGE

DOOR TO SKIN TIME IN PATIENT UNDERGOING EMERGENCY TRAUMA CRANIOTOMY

Kumarappan CHOCKALINGAM[1, 2], Noor Azman AR[2], Zamzuri IDRIS[1], Sharon THEOPHILUS[2]

[1] *Department of Neurosciences, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia*

[2] *Department of Neurosurgery, Hospital Sultanah Aminah Johor Bahru, 80100 Johor Bharu, Malaysia*

Correspondence:

DR KUMARAPPAN CHOCKALINGAM
MD (UNIMAS) MRCSI
Department of Neurosurgery,
Hospital Sultanah Aminah Johor Bahru

3.2 Abstract

Background and Objective

Traumatic brain injury (TBI) is predicted to be the third leading cause of death and disability worldwide in 2020[1]. It places a significant burden on health care especially in developing countries like Malaysia. For a subset of patients with TBI with significant intracranial bleed, urgent surgical intervention remains the mainstay of treatment. Although all efforts are taken to ensure that patients received surgical intervention in a timely manner, often we find that there are inadvertent delays in management of these patients. This study aims to evaluate the performance of neurosurgery referral centre in Malaysia, review the possible pitfalls and propose ways to improve performance

Methods

This is a retrospective study conducted in HSAJB between 1st January 2019 and 31st December 2019. All patient with traumatic brain injury admitted to HSAJB with abnormal CT brain findings requiring urgent craniotomy was enrolled in this study. A list of patients who underwent emergency craniotomy or craniectomy from our operating theatre registry. The demographic data and required clinical data were extracted from the clinical notes. The data obtained were entered into computer software Statistical Package for Social Science (SPSS) version 22. Data distributions were described with nonparametric statistics.

Results

A total of 154 patients who were subjected to emergency trauma craniotomy during the duration of study was included in this study. Overall, the median Door to Skin times were 605 minutes, Door to CT time was 131 minutes, CT to Review time was 274 minutes, Review to Booking time was 20minutes, Booking to OT time was 90 minutes and OT to Skin time was 62 minutes. Patients who were directly admitted to HSAJB had an overall

median Door to Skin time of 459 minutes. At discharge, there were a total of 102 patients (66.23%) with poor outcome. On performing simple logistic regression, we found that the polytrauma, hypotensive episode, ventilated patients, severe TBI and Door-Skin times were all significantly associated with poor outcomes. The adjusted OR for Door to Skin times was 1.005 with 95% CI (1.002-1.008). Hence, for every minute delay in Door to Skin time, there was 1.005 times increase likelihood of having poor outcome during discharge. During the 6 months follow up, the number of patients with poor outcome reduced to 58 patients (37.66%). We found that regardless of patients' clinical characteristic, every minute delay in Door to Skin led to 1.008 (1.005 -1.011, CI 95%) times increase in having poor outcome at 6 months.

Conclusion

Door to Skin time is directly proportional to poor outcomes in patients with TBI. Despite being the regional neurosurgical and trauma referral centre, there are still significant delays in patient management leading to delayed surgical intervention. Concerted efforts from all parties involved in trauma care with established neurotrauma protocol are essential in eliminating this delay.

Keywords

Traumatic brain injury, emergency trauma craniotomy, door to skin time, door to CT time, organised trauma system

3.3 Introduction

Traumatic brain injury (TBI) is projected by the World Health Organization to become the third leading cause of death and disability in the year 2020[1]. It places a significant burden on health care especially in developing countries like Malaysia. For a subset of patients with TBI with significant intracranial bleed, urgent surgical intervention remains the mainstay of treatment.

Two landmarks study are often quoted to emphasize the need for urgent surgical evacuation in extradural haemorrhage and subdural haemorrhage are by Mendelow et al. and Seeling et al. Mendelow et al found that delay in evacuation extradural haemorrhage led to increased morbidity and mortality in which delays of more than 2 hours were found to be unacceptable[9]. Where else, in traumatic subdural haemorrhage, Seeling et al. reported that patients who underwent surgery within the 4 hours of injury had a 30% mortality rate, as compared with 90% in those who had surgery after four hours[6]. In the guidelines for surgical management for traumatic brain injury by brain trauma foundation, although it is advocated that patients should be subjected to surgical evacuation of the mass lesion as soon as possible, no time cut off was stated[2].

Similarly, in Malaysia, there has been no consensus on how soon a traumatic brain injured patient should undergo surgery. Although all efforts are taken to ensure that patients received surgical intervention in a timely manner, often we find that there are inadvertent delays in management of these patients. To date, there have been no studies in Malaysia to evaluate the performance of neurosurgery referral centre with regards to delay in emergency trauma craniotomy. This study aims to review the possible pitfalls and propose ways to improve performance and outcome.

3.4 Methodology

3.4.1 Research Design

This is a retrospective study conducted in a single centre. The research objectives to evaluate the performance of a regional neurosurgery centre in terms of delay in emergency trauma craniotomy. Approval for this study was obtained from the Medical Research & Ethics Committee of the Ministry of Health Malaysia and registered in the national register for clinical trials registration NMRR ID: 19-1794-48781.

3.4.2 Research location and duration

This study was conducted in HSAJB which is the first trauma centre to be established in Malaysia. It is the tertiary referral centre for the southern region of peninsular Malaysia which encompasses a wide range of subspecialties including neurosurgery and trauma services. Located in the state of Johor in Malaysia, The Neurosurgery Department of HSAJB is the only government neurosurgical centre in the southern region. It is equipped with 2 operative theatres, 10-beds Neuro High Dependency Unit and 2 neurosurgery wards with 30 beds. It serves the entire state of Johor covering a wide geographical area of 19,166km^2 with an estimated population of about 3.76 mil[14]. Duration of this study was from 1st January 2019 till 31st December 2019.

3.4.3 Study population and sample size

Universal sampling was used in this study. All patients who underwent emergency trauma craniotomy or craniectomy in HSAJB from 1st of January 2019 to 31st December 2019 were included in the study based on the inclusion and exclusion criteria. The inclusion criteria for this study are as follows: All patient with traumatic brain injury

admitted to HSAJB with abnormal CT brain findings (Intra-axial lesions: contusion, traumatic intracranial haemorrhage, extradural haemorrhage, subdural haemorrhage, DAI) and requiring urgent neurosurgical intervention (craniotomy, craniectomy). The exclusion criteria were; patients who were initially managed medically but later required surgery for clinical or radiological deterioration, patients who underwent craniectomy for elevated intracranial pressure after ICP monitoring and patient who underwent surgery without intracranial mass lesion (compound or depressed fractures) were excluded from this study. Those with missing or incomplete data were also excluded from this study.

3.4.4 Methods of Research

A list of patients who underwent emergency craniotomy or craniectomy was obtained from our operating theatre registry at HSAJB and their respective clinical records were traced from the record office and clinic notes. Those who met our inclusion and exclusion criteria were filtered. The demographic data and required clinical data were extracted from the clinical notes and filled into the data collection sheet (Appendix 1). The GCS and pupillary size and reactivity on arrival to the primary hospital and upon neurosurgical team review was noted. Any drop in GCS or changes in pupillary size or reactivity between arrival and neurosurgery team review was considered as clinical deterioration. Besides, the traumatic brain injury, if the patient had injury severe enough to require admission, patients were considered polytraumatized. For the purpose of this study, when there were multiple intracranial bleeds on CT, the CT findings were classified based on the lesion requiring surgical intervention.

The patients were then classified into 4 patterns of referral; patients who arrive directly to HSAJB, patients referred from specialist hospital with CT scanner, patients referred from district hospitals to HSAJB for CT scan and finally patient who had to be transferred to a secondary hospital to perform CT prior to referral to HSAJB.

The following timings were collected: Time of injury, Time of arrival at initial hospital (Door time), CT imaging (CT time), time of neurosurgery team review (Review Time), time of case being posted to anaesthesiology team (Booking Time), time when induction of general anaesthesia in OT (OT Time) and the time of skin incision (Skin Time). In addition to the above, for patients who were referred from other hospitals, the time of arrival in HSAJB (Arrival Time) was also noted. In cases where CT scan was performed and the neurosurgical team was consulted prior to transfer, the time of referral (Referral Time) and time of reply (Reply Time) by email was noted. The Door Time was determined by the arrival time registered at the first emergency department. CT Time was the time which appears on the first CT film. The Review Time is when time documented by the neurosurgical on-call team when the patient is reviewed in HSAJB while the Booking Time is when the case is posted for surgery (both this time are routinely documented in our practice). The time of induction of general anaesthesia in the operating theatre was used as the OR Time. While Skin Time was the time recorded in the operative register as the time of skin incision. We then calculated the delay between the door and CT times, between CT and review, between review and booking, between booking and OT times, between OT and skin times, and between the door and skin times. We also calculated the consultation reply time and transfer times for patients being referred from another hospital. When a reason for the delay was documented, it was also duly noted.

Glasgow Outcome Score (GOS) at discharge and during outpatient clinic follow up was routinely documented and collected for the study. For the purpose of this study, the outcome was divided into 2 groups: good outcome being GOS 4 - 5 and the poor outcome being GOS 1-3.

3.4.5 Statistical analysis

The data obtained were entered into computer software Statistical Package for Social Science (SPSS) version 22. The descriptive statistics were used in which categorical variables analysed by frequency and percentage. Numerical variables were analysed by central tendency either mean, median, standard deviation and interquartile range. Data distributions were described with nonparametric statistics. Continuous data of time interval were compared across categories using Mood's median test while nominal outcomes across categories were analysed using the chi-square method. Continuous values of time intervals were compared with ordinal/nominal outcomes using logistic fit.

3.5 Results

3.5.1 Demographic and Clinical Characteristic

A total of 226 patients underwent emergency trauma craniotomy or craniectomy during the duration of study in HSAJB and of these 154 patients selected while the remaining 72 patients were excluded. Reasons for the exclusion (Table 1) were as follows: patient with delayed clinical or radiological deterioration (34 cases), patients had no mass lesion on CT (18 cases), patients were initially managed with ICP monitoring (11 cases) and incomplete data or untraceable records (9 patients). The demographic and clinical characteristics of patients (n=154) included in this study are summarized in Table 2. Of the 154 patients who underwent emergency craniotomies, 130 patients (84.4%)

were males, while the remaining 24 patients (15.6%) were female. The mean age was 29.65 years with the youngest being 5 years old while the oldest patient was 72 years old. The most common mechanism of injury was motor vehicle 123 patients (79.9%), followed by fall 25 patients (16.2%). Approximately a third of the patients (34.4%) were polytraumatized and 25 patients (16.1%) had a hypotensive episode. At the time of neurosurgery review, 58 patients (37.7%) were ventilated and up to half or 74 patients (48.1%) had clinically deteriorated since the arrival to the hospital. Extradural haemorrhage (47.4%) and subdural haemorrhage (43.5%) were the 2 most common indication for emergency trauma craniotomies. Of the 154 patients, 98 patients (63.6%) were subjected to decompressive craniectomy while the remaining 56 patients (36.4%) underwent craniotomy and clot evacuation.

3.5.2 Referral Patterns

Out of the 154 patients, only 28 (18.2%) patients had directly arrived in HSAJB post-trauma, the remaining 124 patients (81.2%) were transferred to HSAJB from other health care facilities. Most of the patients (97, 63.0%) were referred from hospital with CT scanners. Twenty-four patients (15.6%), were transferred from hospital without CT scanners to HSAJB for diagnostic CT and were later subjected to surgery. Five patients (3.2%), had dual transfer; patients initially arrived at a hospital without CT and had to be transferred to a secondary hospital for imaging prior to transfer HSAJB for definitive surgery.

3.5.3 Time interval

The time interval for patients was divided based on the referral patterns and are given in Table 3.

3.5.3.1 Direct Admission to HSAJB

A total of 28 patients were directly admitted to HSAJB. The median door to CT time was 149 minutes. Thirteen patients had presented with GCS of less than 13, of which only 4 patients (23.1%) managed to get a CT brain within 2 hours. The commonest documented cause for delay in performing a CT was staff or equipment not available to transfer patient to radiology suite (8, 28.57%) and patient clinically unstable to be sent for radiology suite (6, 21.43%).

The median CT - Neurosurgery Review Time was 105 minutes. This was further broken down into; CT - Neurosurgery Referral Time and Neurosurgery Referral – Neurosurgery Review Time. The median delay from CT to Neurosurgery Referral was 72 minutes (IQR 47-90 minutes) while the median delay from Neurosurgery Referral – Review was 20minutes (IQR 10-38 minutes). We found CT – Neurosurgery Review time was prolonged as a result of delay in reviewing the CT films by ED team (6, 21.43%,), neurosurgery team attending to other emergency cases (3, 10.71%) and difficulty contacting neurosurgery on-call team (2,7.14%)

3.5.3.2 Hospital without CT

There was a total of 3 district hospitals within 50km radius which send their patients to HSAJB for imaging. The median Door to CT time in this group of patients (n=24) were 267 minutes. Despite having 22 patients with presenting GCS of less than 15, none of them had a CT performed within 2 hours. The median Transfer Times for these patients to reach HSAJB was 213minutes (IQR 169-243 minutes). The median time taken from arrival to HSAJB till the CT brain was performed on these patients were 40 minutes (IQR 31-65minutes). The commonest cause for delay in performing CT in this group of patients was the unavailability of ambulance or personal to transfer patients (11,

45.83%) and patients were unstable for transfer and required further stabilization (4, 16.67%).

The median time taken from CT – Neurosurgery Review was 53 minutes. The median delay of CT – Neurosurgery Referral time was 26 minutes (IQR 16-50minutes) while the median time for Neurosurgery Referral – Review was 20minutes (IQR 10-30minutes).

3.5.3.3 Hospital with CT

A total of 97 patients were transferred to HSAJB for surgical intervention. The median Door to CT for these patients were relative shorter 103 (25-681minutes) than those admitted directly to HSAJB. Thirty-three (62.3%) of the 53 patients presenting GCS of less than 13 had their CT performed within 2 hours. Two of the patients had a Door to CT time of more than 12 hours as the patients were subjected to exploratory laparotomy and had to be stabilized before performing the CT brain. For this subgroup of patients, the CT – Neurosurgery Review time was further divided into; CT- Neurosurgery Teleconsultation time, Neurosurgery Teleconsultation – Neurosurgery Reply time, Neurosurgery Reply to Arrival in HSAJB (Transfer Times) and Arrival in HSAJB-Neurosurgery Review time. The median delay from the time of CT to Neurosurgery Teleconsultation was 122minutes (IQR 83-174) while the median Neurosurgery Teleconsultation – Neurosurgery Reply time was 26minutes (IQR 10-54minutes). The usual cause for delay in getting a neurosurgery consultation is attributed to delay in surgical team reviewing the patient in their primary hospitals (10, 10.31%). The commonest cause of delay in replying the teleconsultation was due to inadequate clinical information (8, 8.25%), incomplete or wrong images (3, 3.10%) and revision of management plan (2, 2.06%).

Of the 5 hospitals with CT scanner, only one is situated within 17km from HSAJB, the remaining hospital are located between 100km and 170km away from HSAJB. The median Transfer Times for patients being transported to HSAJB was 166minutes (IQR 122-222minutes). The cause for delays in the transfer was frequently attributed to unavailability of ambulance or personal to transfer patients (26, 26.80%) and patients were unstable for transfer (13, 13.40%). The median time of Arrival in HSJAB - Neurosurgery Review was 18 minutes (IQR 8-30minutes), the shortest among the groups.

3.5.3.4 Dual Transfers

The patients from Hospital Tangkak and Hospital Mersing are routinely transferred to Hospital Batu Pahat and Hospital Sultan Ismail respectively for CT imaging prior to referral to HSAJB. In instances when the CT machine had broken down, imaging was outsourced to a nearby private hospital. There were only 5 patients from this group who underwent emergency trauma craniotomy at HSAJB. The median Door to CT time was the longest in this group; 416 minutes (IQR 298-459 minutes). The median CT – Neurosurgery Review time was 363 minutes (IQR 314-380 minutes). There was no reason for delay documented in this group of patients.

3.5.3.4 Neurosurgery Review – Skin time

From the time of neurosurgery review in HSAJB, all patients (n=154) follow similar chronology, as such their data will be presented together. The median Neurosurgery Review – Booking time was 20 minutes (IQR 15-35 minutes). The commonest cause for delay in booking for surgery was due to the need for clinical reassessment after withdrawing sedation (13,8.44%), need for repeated CT brain imaging prior to decision making (11, 7.14%) and waiting for family members consent (3, 3.90%).

The median delay of Booking – OT time was 90minutes (IQR 61-130minutes). The shortest time to OT was 20minutes whilst the longest wait for OT availability was 485minutes. Only 5 patients managed to arrive in OT within 30minutes of booking, of which 3 had mild TBI and 2 had moderate TBI. None of the severe TBI patients arrived in OT within 30minutes. There was no significant difference (x^2 3.733, dF 2, p = 0.155) when we compared the median Booking - OT times for patients with mild TBI, moderate TBI or severe TBI. The reason for delay in patients going to OT include; OT was busy with other emergency cases and unable to mobilize second OT (22, 14.29%), lack of personal or equipment to transfer patient to OT (8, 5.19%), issues in patients post-op placement (5, 3.24%) and patient deteriorated or required stabilization (3, 1.95%).

The median OT-Skin time was 62 minutes (IQR18-173minutes). The prolonged time taken from patient arrival in OT to skin incision was attributed to the difficulty in anaesthetic procedures ie; intubation, arterial lines, central venous access (16, 10.39%), patients required further stabilization prior to initiation of surgery (4, 2.60%) and 3 patients (1.95%) was subjected to emergency laparotomy prior to neurosurgery.

3.5.3.5 Door to Skin times

Overall, the median Door to Skin time was 605minutes (IQR 494-766minutes). There was only one patient (0.66%) who was operated within 4 hours of arrival to the hospital, while almost a third (49 patients, 31.82%) required more than 12 hours to surgery from the time of arrival. Factors affecting the door to skin time is described in Table 4. Based on Mood's median test analysis, the Door to Skin times was significantly associated with referral patterns ($p<0.001$), polytrauma ($p=0.007$) and hypotensive episode ($p=0.009$).

3.5.4 Correlating clinical factors to patients' outcome

Of the 154 patients, the in-hospital mortality was 16 patients (10.39%). At discharge, there were a total of 102 patients (66.23%) with poor outcome. On performing simple logistic regression, we found that the polytrauma, hypotensive episode, ventilated patients, severe TBI and Door-Skin times were all significantly associated with poor outcomes at discharge (refer to Table 5 & 6). However, after performing a multiple logistic regression test, only ventilated patients ($p<0.001$) and Door to Skin time ($p<0.001$) were significant. This indicates that ventilated patients and Door to Skin times were factors associated with poor outcome regardless of the existence of polytrauma, hypotensive episode or severe TBI. This model fits with a p-value of Homer and Lemeshow = 0.633 and Nagelkerke R2 = 0.424. The adjusted OR for Door to Skin times was 1.005 with 95% CI (1.002-1.008). Hence for every minute delay in Door to Skin time, there was 1.005 times increase likelihood of having poor outcome during discharge.

During the 6 months follow up, the number of patients with poor outcome reduced to 58 patients (37.66%), including 3 extra deaths making the total mortality 19 (12.34%). As for the poor outcome on discharge, the poor outcomes at follow up were also significantly associated with polytrauma, hypotensive episode, ventilated patients, severe TBI and Door to Skin times (refer Table 7 & 8) on simple logistic regression. However, upon performing a multivariate logistic regression test, only Door to Skin time remained significant ($p<0.001$). Hence, it could be concluded that regardless of patients' clinical characteristic, every minute delay in Door to Skin led to 1.008 (1.005 -1.011, CI 95%) times increase in having poor outcome at 6 months.

3.6 Discussion

Traumatic brain injury is predicted to be the third leading cause of death and disability worldwide in 2020[1]. In a meta-analysis done in 2014, annual incidence proportion for TBI of all ages was 295 per 100,000 worldwide[15]. However, low to middle-income countries were reported to have 3 times more case of TBI proportionally when compared to high-income countries[16]. Furthermore, South East Asian and Western Pacific region had the highest burden of disease. While the falls were the commonest cause for TBI in high-income countries, road traffic accidents were found to be the most common cause in low to middle-income countries[16]. This finding is consistent with our study in which the mechanism of injury was motor vehicle accident in 79.9% of cases. Based on the Department of Statistics Malaysia, road accidents are the fourth leading cause of death in 2018 making up 3.7% all deaths in Malaysia and it was the commonest cause of death within the age group of 15-40years[17]. As such it is sufficient to say that TBI is a major healthcare problem worldwide as well as in Malaysia.

Traumatic brain injury is dynamic in nature and consists of primary and secondary injuries. Primary brain injury occurs at the moment of impact and causes either focal or diffuse axonal damage[18]. Secondary brain injury occurs after the initial insult, in the form of hypoxia, hypovolemia and cerebral edema. While bleeding from damaged vessels is due to primary brain injury, the resultant extradural or subdural which accumulates overtime is considered part of secondary brain injury complex[19]. It important to distinguish between the two entities as primary brain injury is not reversible, however secondary brain injury is preventable as well as to a certain extent reversible if appropriately managed. Most of TBI patients could be managed without surgery. According to the National Trauma Database in United States, only 3.6% of patients with traumatic brain injury will require neurosurgical intervention[20]. However, for this subset

of patients, early surgical evacuation remains the mainstay of treatment to control intracranial pressure and prevent secondary brain insult.

The phrase 'Time is brain!' was originally coined by a neurologist to emphasize that the outcome in stroke patients are time-critical. The longer the treatment is delayed, the worse the outcome. This expression may remain valid for TBI patients. In 1978, Mendelow et. al analysed the effect of delayed treatment in extradural haemorrhage. They found that the longer the delay from the time of neurological deterioration to surgery, the higher the rate of morbidity and mortality[9]. Similar patterns were also observed in traumatic subdural haemorrhage with those operated beyond 4 hours having mortality rates of up to 90% compared to just 30% in patients operated earlier[6]. This formed the fundamental basis for recommending early surgical intervention in traumatic brain injury. Many other studies followed suit and drew up similar conclusions[4,10,21,22] stressing the importance of timely surgical intervention. Our study is in line with these studies and showed that with the passing of every extra minute in Door to Skin time, there was an increase in odds of having poorer outcome.

The accessibility to neurotrauma services is rather limited in developing countries like Malaysia and as such the delay in reaching neurosurgical care is not uncommon. To the best of our knowledge, this is the first study to evaluate the performance of a regional neurosurgery referral centre in Malaysia in handling acute neurotrauma requiring urgent surgical intervention. Therefore, it is unfortunate that we are unable to compare our timings with other hospitals within this region. There had been a few similar studies conducted in various other high and low to middle-income countries resulting in wide variations in Door to Skin time. In developed countries like United States, the median between ED admission to neurosurgical intervention was 133 minutes[23] while according to the neurotrauma database median time from injury to craniotomy was 195 minutes[20].

In Canada, the median ED to 'knife' time was reported to be 150 minutes[12], while in Europe Royal London Hospital the median time from injury to medical care was 13minutes while injury to neurosurgery was 177minutes[24]. Closer to home, in a level 1 trauma centre in Thailand, the mean time from ED arrival to skin incision was 160minutes[25] for traumatic intracranial subdural hematomas. However, it must be kept in mind that accessibility to neurotrauma service is not evenly distributed even in developed countries. Study shows even in United States, after rural injuries, the average time to initial care was 1.2 hours and it took 5 hours to reach a level 1 trauma centre[26]. In Auckland, the mean time from scene of injury to neurosurgery was 3 hours 50 minutes, while those patients transferred from other hospitals took significantly longer than 4 hours to arrive at Auckland City Hospital[27]. Even then, these figures seem unrealistic when we compare to our study where the median time for patients who were directly admitted was 459 minutes.

For most patients with head injury, CT of the head and neck is the imaging modality of choice to detect intracranial lesion. The indication for CT in TBI has been described in multiple different guidelines; Canadian CT Head Rule and New Orleans Criteria being the two most commonly quoted in literature. Based on the Malaysian guidelines on Early Management of Head Injury, the indication for an immediate scan (within 1-2 hours) amongst others includes a GCS <13 on initial management. We had a total of 69 patients with GCS <13 on initial review, however only 37 (53.6%) patients managed to get a CT done within 2 hours from the time of arrival to ED. It was notable that the Door to CT time in HSAJB being the trauma centre was longer than other hospitals which were equipped with CT scanners. The likely cause for this was the physical distance to CT machine which is located in a radiology suite away from the ED at HSAJB. From literature review, the door to CT time was reported between 45.6 minutes

to 2 hours[25,28,29]. It was shown that simple intervention including education of multidisciplinary team, education sessions for junior doctors and information sheets on prevailing guidelines managed to reduced the mean time to scan from 73 to 55 minutes[29]. In another study involving acute stroke patients, door to CT scan time within 20 minutes was increased from 47% to 74% when the CT scanner was relocated within the emergency department[30]. Alternatively, TBI patients should be prioritized for a CT scan without delay by closely coordinating with the radiology department.

We also realized that it was impossible for the three district hospitals within 50km from HSJAB to adhere to guidelines to obtain an immediate CT within 2 hours. Although the actual transfer times for these patients were not long, most of the delay occurred at initiation and making arrangements for transfer to another centre. As we found in this study the delays were predominantly caused by lack of staff members or equipment to transfer these patients. The local clinical practice guideline on head injury in adults have advocated that patients with suspected TBI should be preferably transferred from scene directly to a centre with resources necessary to resuscitate, investigate and manage any patient with polytrauma where TBI can be managed in its entirety[31]. Although this will be ideal, it will not be possible to accept all TBI patients to our centre for investigation and management as it will end up straining our already limited resources. Guidelines by Brain Trauma Foundation, recommend that patients with severe TBI should be directly transported to facilities with immediate availability of CT scan and prompt neurosurgical care[32]. Furthermore, the emphasis was placed on the need for an organized trauma care system with protocol to assist decision making regarding transfer destination. We concur there is a subset of patients who will benefit from direct transfer from scene to HSAJB bypassing the local district hospital, however further groundwork will be necessary to determine the feasibility.