THE ASSOCIATION BETWEEN INTRACRANIAL HAEMORRHAGE AND SKULL FRACTURE IN TRAUMA PATIENTS AT THE HOSPITAL UNIVERSITI SAINS MALAYSIA (HUSM).

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Dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Medicine
(Radiology)

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SUPERVISOR:
DR WIN MAR @ SALMAH JALALUDDIN

Acknowledgement

In the name of Allah, the most beneficent and the most merciful.

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List of abbreviations

USM	Universiti Sains Malaysia
CT	Computed Tomography
MVA	Motor vehicle accident

Abstrak

Objektif

Objektif utama kajian ini adalah untuk mengetahui perkaitan di antara keretakan tulang kepala dan pendarahan di dalam kepala di kalangan pesakit trauma dan juga untuk mengetahui perkaitan di antara jenis keretakan tulang kepala dan jenis pendarahan di dalam kepala.

Pengenalan

Kebanyakan kematian yang berlaku di kalangan kes trauma adalah disebabkan oleh kecederaan di kepala. Penyebab utama kecederaan kepala adalah kemalangan jalan raya disusuli penyebab-penyebab lain seperti dipukul dan terjatuh dari tempat yang tinggi. Keretakan tulang kepala mungkin diikuti oleh kecederaan otak dan mungkin juga tidak. Tidak semua keretakan tulang kepala akan menyebabkan kematian. Terdapat juga kes kematian yang disebabkan kecederaan kepala tetapi tiada keretakan tulang kepala. Beberapa kajian terdahulu mendapati bahawa kebarangkalian berlaku pendarahan di dalam kepala adalah lebih tinggi di kalangan pesakit yang ada keretakan tulang kepala berbanding dengan pesakit yang tiada keretakan tulang kepala.

Kaedah

Kajian ini adalah kajian retrospektif untuk kes-kes kecederaan kepala yang dilaksanakan di antara Jun 2014 sehingga Disember 2014. Satu ratus lima puluh satu pesakit yang mengalami kecederaan kepala yang berumur 18 tahun dan ke atas telah dipilih sebagai sampel untuk kajian ini. Kebenaran etika telah diperolehi daripada Jawatankuasa Etika Penyelidikan Manusisa Universiti Sains Malaysia (JEPeM). Imej-imej CT scan dianalisa menggunakan “Picture Archiving Communication System (PACS)” dan semua hasil kajian dicatat. Analisa statistik dilakukan menggunakan program SPSS (ISM SPSS software version 21).

Keputusan

Daripada 151 pesakit, 112 (74.2%) adalah lelaki dan 39 (25.8%) adalah perempuan. Kebanyakan kes kecederaan kepala yang berlaku adalah disebabkan oleh kemalangan jalan raya [n=126 (83.4%)]. Pendarahan di dalam kepala didapati sebanyak 64 (98.5%) daripada 65 pesakit yang mengalami keretakan tulang kepala, berbanding dengan 26 (30.2%) daripada 86 pesakit yang tiada keretakan tulang kepala. Daripada kajian ini didapati ada perkaitan yang signifikan di antara keretakan tulang kepala dan pendarahan di dalam kepala (p-value < 0.001). Jenis keretakan tulang kepala yang paling kerap berlaku adalah keretakan jenis "linear". Daripada hasil kajian ini juga didapati ada perkaitan yang signifikan di antara keretakan tulang kepala jenis "linear" dan pendarahan kepala "extradural" (p-value = 0.011) dan di antara keretakan tulang kepala jenis "comminuted" dan pendarahan kepala "subdural" (p-value = 0.001).

Kesimpulan

Daripada kajian ini didapati ada perkaitan yang signifikan di antara keretakan tulang kepala dan pendarahan di dalam kepala. Selain itu, hasil kajian ini juga mendapati ada perkaitan yang signifikan di antara keretakan tulang kepala jenis "linear dan pendarahan kepala "extradural" dan di antara keretakan kepala jenis "comminuted" dan pendarahan kepala "subdural".

Abstract

Objective

The main objective of this research is to study the association between skull fracture and intracranial haemorrhage in trauma patients and the association between types of skull fracture and types of intracranial haemorrhage.

Introduction

Majority of fatal trauma cases are caused by head injury. The most common cause of head injury is motor vehicle accident. Other causes include assault and fall from height. Skull fracture may or may not be accompanied by brain injury. Not all head injuries are life threatening. Some fatal head injuries may occur without the presence of skull fractures.

Previous studies showed that the incidence of intracranial haemorrhage was high in patients with skull fracture compared to patients without skull fracture.

Methodology

This was a retrospective study on the CT scan for head trauma performed between June 2014 until December 2014. A total of 151 patients with head injury aged 18 years old and above were included in this study. Ethical approval was obtained from The Human Research Ethics Committee of Universiti Sains Malaysia (JEPeM). Plain CT brain images were assessed using Picture Archiving Communication System (PACS). The findings of skull fracture and intracranial haemorrhage were documented. The statistical analysis was performed using SPSS statistical program (ISM SPSS software version 21).

Result

Out of 151 patients, 112 (74.2%) were male and 39 (25.8%) were female. Majority of the head trauma cases were caused by motor vehicle accident [n=126 (83.4%)]. Intracranial haemorrhage was found in 64 (98.5%) of the 65 patients with skull fracture, compared with 26 (30.2%) of the 86 patients without skull fracture. There was significant association between skull fracture and intracranial haemorrhage (p-value < 0.001). The most common type of fracture was linear fracture. There was significant association between linear skull fracture and extradural haemorrhage (p-value = 0.011) and between comminuted skull fracture and subdural haemorrhage (p-value = 0.001).

Conclusion

There was significant association between skull fracture and intracranial haemorrhage, linear skull fracture and extradural haemorrhage and comminuted skull fracture and subdural haemorrhage.

Introduction

Head injury, as defined by the National Advisory Neurological Diseases and Stroke Council, is a morbid state resulting from gross or subtle structural changes in the scalp, skull, and/or the contents of the skull, which is produced by mechanical forces. Majority of fatalities in trauma cases occurs due to head injury. The most common cause of head injury is motor vehicle accident (MVA). In Malaysia, the incidence of motor vehicle accident is one of the highest in the world with about 22 deaths per 100 000 (Liew *et al*, 2009).

Another common cause of head injury is assault and the pattern of injuries depends upon the type of the weapon. The next important cause of head injury is fall from height. The degree of injuries depends upon the height and side of body which hit the ground.

The range of trauma to the head varies from mild closed head injury to open skull injury and evisceration of the brain tissue. The brain is an important structure containing the vital centres of respiration and cardiac activity. It is enclosed and partially mobile within the calvarium.

Although the skull is tough and provides excellent protection for the brain, a severe impact can result in its fracture. It may be accompanied by injury to the brain. The brain can be affected directly by damage to the nervous system tissue and bleeding. The blood clots that form under the skull can also compress the underlying brain tissue.

Not all skull fractures are life threatening. Some patients can have fatal head injuries without having any skull fractures. However skull fractures may provide information about the location of an impact.

Skull fracture has several potentially dangerous sequelae. The most common is when the fracture fragment injures the meningeal artery, resulting in intracranial haemorrhage. A depressed fracture may impinge upon the brain parenchyma and the bone fragments may lacerate or penetrate the brain.

Many severe head injuries with skull fractures have variable degrees of intracranial injuries. The intracranial injuries ranging from cerebral concussion, contusion, extradural, subdural, subarachnoid haemorrhage and diffuse axonal injuries. Above all, extradural haemorrhage is a neurosurgical emergency.

A prospective study done in Hong Kong involving adolescents (11-15 years old) with skull fracture and intracranial haematoma revealed that, of the 418 admitted patients, only 26 had skull fractures, 13 of these develop intracranial haematoma (Chan *et al*, 1990). Multivariate analysis showed that skull fracture was the only independent significant risk factor in predicting intracranial haematoma in adolescents.

A study done by Macpherson *et al*, 1990 showed the relationship of intracranial contusion and haematoma with the presence, site and type of skull fracture. Of the 1383 patients with head injury, 850 patients had skull fracture, while 846 patients had intracranial haemorrhage. From their study, 601 (71%) of 850 cases with skull fracture had intracranial haemorrhage and 245 (46%) of 533 cases with no skull fracture had intracranial haemorrhage. The percentage of intracranial haemorrhage was high in patients with skull fracture compared to patients with no skull fracture. Linear fractures were more common than depressed fracture. They also found that linear fractures were more often associated with extradural and subdural haematomas than depressed fractures.

The correlation between skull fracture and intracranial lesions due to road traffic accidents was studied by Yavuz *et al*, 2003 on 500 forensic cases between the year 1998-2000. The intracranial lesions were extradural haemorrhage, subdural haemorrhage, subarachnoid haemorrhage, intracerebral haemorrhage, laceration, intraventricular haemorrhage and hygroma. They were categorized into 3 groups based on their skull radiograph and CT brain. Of the cases, 152 (30.4%) had only linear fractures, 69 (13.8%) had depressed fracture, 92 (18.4%) had linear fractures with intracranial lesions, 49 (9.8%) had depressed fractures with intracranial lesion and 138 (27.6%) had only intracranial lesion. The rate of intracranial lesion among the cases with the skull fracture was 38.9% (141/362). The rate of skull fracture among the cases with intracranial lesions was 50.3% (141/279).

Another retrospective study of forensic cases done by Munteanu *et al*, 2014 showed the patterns of head injury in lethal road traffic accidents. Of 339 cases, 176 had skull fracture. Of the 176 skull fracture cases, 139(78.9%) had intracranial haemorrhage. Of the 161 cases without skull fracture, 86(53.4%) had intracranial haemorrhage. The percentage of intracranial haemorrhage was higher in cases with skull fracture compared with cases with no skull fracture. About 50% of simple cranial vault fractures were associated with subdural or subarachnoid haemorrhages and 50% with mixed haemorrhage. Basal skull fractures were associated with mixed haemorrhage in 60% of the cases.

The main objective of this study is to find out the association between skull fracture and intracranial haemorrhage in trauma patients and the association between types of skull fracture and types of intracranial haemorrhage.

Materials and Methods

Study sample

This was a retrospective study on the cases of computed tomography (CT) scan of the head trauma performed in the Hospital Universiti Sains Malaysia (HUSM). Non probability sampling method was performed over a period of seven months from June 2014 to December 2014. Ethical approval was obtained from The Human Research Ethics Committee of Universiti Sains Malaysia (JEPeM).

Inclusion criteria:

1. Head trauma cases referred for CT scan.
2. Age 18 years old and above.

Exclusion criteria:

1. Cases due to non-traumatic intracranial haemorrhage such as haemorrhagic stroke and tumoral haemorrhage.
2. Follow-up CT scan for head injury.
3. Post surgical intervention.

Research tools

All the CT brain cases was performed using one CT scan machine; Siemens Somatom Definition AS 128-slice multidetector CT scan. Reconstructed images of both brain and bone window were transfered to the GE healthcare centricity Picture Archiving Communication

System (PACS) universal viewer version 5.0. The BARCO image display system was used to review the CT images.

Image interpretation

Evaluation of the CT images were done together by the researcher and one radiologist (13 years of experience) for all sample. All studies were evaluated in three planes, (axial, sagittal and coronal) for the presence of skull fracture and intracranial haemorrhage. They were assessed in brain parenchyma, subdural and bone windows.

Skull fracture is defined as a break in the skull bone. Skull fracture in this study was taken as fracture of the skull vault. They were classified into three types (Figure 1-4) :

1. Linear skull fracture: linear skull fracture is break in the bone that is fairly straight and involved no displacement of the bone.
2. Depressed skull fracture: depressed skull fracture is comminuted fracture in which broken bone is displaced inward.
3. Comminuted skull fracture: comminuted skull fracture is when a part of the skull bone cracks into pieces.

Intracranial haemorrhage is condition characterised by the extravascular accumulation of blood within different intracranial spaces. On the CT scan it is defined as hyperdensity with hounsfield units (HU) range of 60-80. The intracranial haemorrhage was classified into four types (Figure 1-4):

1. Extradural haemorrhage: extradural haemorrhage is bleeding occurs between inner surface of the skull and the dura matter. On the CT scan it appears as biconvex hyperdensity.
2. Subdural haemorrhage: subdural haemorrhage is accumulation of blood between dura and arachnoid membrane. On the CT scan it appears as a peripheral crescent shape collection overlying between the inner table and the cerebral hemisphere.
3. Subarachnoid haemorrhage: subarachnoid haemorrhage is bleeding in the subarachnoid spaces. On the CT scan it appears as serpentine or linear areas of hyperdensity in the subarachnoid spaces or basal cisterns.
4. Intraparenchyma haemorrhage: intraparenchyma haemorrhage is accumulation of blood in the brain parenchyma. On the CT scan it appears as hyperdensity within the brain parenchyma.

Statistical analysis

Data analysis was performed using SPSS statistical program (ISM SPSS software version 21). The association between skull fracture and intracranial haemorrhage were presented as frequency and percentage. Pearson Chi-Square test was applied. The association between types of skull fracture and type of intracranial haemorrhage also presented as frequency and percentage. Univariate analysis was performed by using Pearson Chi-Square test or Fisher's Exact test based on expected frequencies of the cells. P-value was set at 0.05.

Results

Demographic characteristic

A total of 151 patients were included in this study and 112 (74.2%) were male and 39 (25.8%) were female. The age range was from 18 to 91 with mean age of 37.42. Ethnic group comprised of 112 (95.4%) Malays, 2 (1.3%) Chinese and 5 (1.3%) from other ethnics. Majority of the trauma cases were due to motor vehicle accident [n= 126 (83.4%)] followed by fall from height [n= 16 (10.6%)] and assault [n=9 (6.0%)].

Intracranial haemorrhage in patients with and without skull fracture

Out of 151 patients, skull fracture was found in 65 (43.3%) patients and intracranial haemorrhage was found in 90 (59.6%) patients. Intracranial haemorrhage was found in 64 (98.5%) of the 65 patients with skull fracture, compared with 26 (30.2%) of the 86 patients without skull fracture (Table 1). There was statistically significant association between skull fracture and intracranial haemorrhage (Pearson Chi-Square test: p-value < 0.001) (Table 1).

The association between type of skull fracture and type of intracranial haemorrhage

Linear fracture was the most common type of skull fracture to occur followed by comminuted and depressed fractures. The number of cases of linear fractures were 52 (56.5%), of comminuted fractures were 25 (27.1%) and of depressed fractures were 15 (16.3%). Of the 52 cases of linear skull fracture, 1 case was associated with depressed fracture, 7 cases were associated with comminuted fracture, and 4 cases were associated with both depressed and comminuted fracture. The rest of 40 cases had only linear fracture. Ten cases of comminuted fractures were associated with depressed fracture and four cases had only comminuted fracture. Depressed fractures were associated with linear fracture in one case, with comminuted fracture in 10 cases and the rest of 4 cases were associated with both linear and comminuted fractures.

In the cases of linear skull fracture, 19 (36.5%) had extradural haemorrhage, 35 (67.3%) had subdural haemorrhage, 19 (36.5%) had subarachnoid haemorrhage and 34 (65.4%) had intraparenchyma haemorrhage. There was statistically significant association between linear fracture and extradural haemorrhage (p-value = 0.011) (Table 2). Linear fracture and other type of intracranial haemorrhage were statistically not significant.

In the cases of depressed skull fracture, 6 (40.0%) had extradural haemorrhage, 13 (86.7%) had subdural haemorrhage, 7 (46.7%) had subarachnoid haemorrhage and 10 (66.7%) had intraparenchyma haemorrhage. There was no statistically significant association between depressed skull fracture and all four types of intracranial haemorrhages (Table 3).

In the cases of comminuted skull fracture, 10 (40.0%) had extradural haemorrhage, 23 (92.0%) had subdural haemorrhage, 9 (36.0%) hadd subarachnoid haemorrhage and 16 (64.0%) had intraparenchyma haemorrhage. There was statistically significant association between comminuted skull fracture and subdural haemorrhage (p-value = 0.001) (Table 4).

Discussion

In this study, the majority of the patients were male (74.2%). The male to female ratio was 2.9:1. It reflects that men are generally more exposed to outdoor activities, thus they are more prone to trauma. Majority of the patients involved in trauma were young age group below 40 years old.

MVA was the most common cause of the head injury in this study. This finding is consistent with other study done by Saadat *et al*, 2011; Chan *et al*, 1990 and Perel *et al*, 2009. Increase in the number of registered vehicles due to the rapid growth in population and economy might be the reason increase in the number of MVA cases. Other reasons include the attitude of the drivers especially from the younger age group. Younger age group have competitive and playfull tendencies compared to their older counterparts.

In our study, intracranial haemorrhage was found to be high in the patients with skull fracture (98.5%) as compared with patient without skull fracture (30.2%). This finding is similar with previous study done by Macpherson *et al*, 1990 whereby, intracranial haemorrhage was found in 71% of the patient with skull fracture, compared with 46% of the patients with no skull fracture. A retrospective forensic study done in Romania by Munteanu *et al*, 2014 found high percentage of intracranial haemorrhage in cases with skull fracture (79%) compared with cases without skull fracture (53%). Comparing with these two previous studies, our study has higher percentage of intracranial haemorrhage in patient with skull fracture. The association between skull fracture and intracranial haemorrhage was statistically significant (p-value < 0.001). Only one patient with skull fracture has no intracranial haemorrhage (Table 1). This patient was a young male (age 21 year) involved in MVA and sustained linear skull fracture.

From this study we found the most common type of skull fracture was linear fracture (56.5%), followed by comminuted fracture (27.1%) and depressed fracture (16.3%). This result was in concordance with the previous study done by Macpherson *et al*, 1990. In their study, the linear fracture was 79%, followed by depressed fracture, 11.5% and both linear and depressed fracture were 9.5%. A prospective study on the risk factor to predict the development of intracranial haemorrhage in adolescents found that linear fracture occur more often than depressed fracture (Chan *et al*, 1990). It was found that, out of 13 patients with skull fracture 11 (84.6%) had liner fracture and 2 (15.4%) had depressed skull fracture. Skull vault consist of flat bones which are relatively weaker and linear fractures are more likely to develop (Yavuz *et al*, 2003). There are vertical bones in some regions of the skull such as supraorbital ridges, temporal apices and occipital protuberance which increase the strength of the skull. This might be the reason linear fractures occur more in skull vault.

They are very limited number of studies which compare the types of skull fracture and the types of intracranial haemorrhage using CT scan. In our study we found that there was significant association between linear skull fracture and extradural haemorrhage (P-value = 0.011). Comparing with the previous study done by Macpherson *et al*, 1990 their result was almost similar whereby they found significant association between linear skull fracture and extradural and subdural haemorrhage (p-value < 0.001). Another study done by Khan and Nadeem, 2008 has shown significant association between skull fracture and extradural haemorrhage. They studied only the extradural haemorrhage cases. Their study revealed that, out of 110 cases of extradural haemorrhage, 83 cases had skull fracture and 68 (62%) were linear fracture.

In depressed skull fracture, there was no significant association with all four types of intracranial haemorrhage. However we noted that subdural haemorrhage is most commonly occur (13 cases) in cases with depressed fracture, followed by intraparenchymal haemorrhage (10 cases), subarachnoid haemorrhage (7 cases) and extradural haemorrhage (6 cases). All cases of depressed fracture also had either linear or comminuted fracture or both. The previous study done by Yavuz *et al*, 2003 showed a different finding. In that study contusional haemorrhage (12 cases) was the highest in the cases of depressed skull fracture, followed by extradural haemorrhage (10 cases) and subdural haemorrhage (4 cases). No subarachnoid haemorrhage was found in their study. However their study was on fatal MVA cases whereby the cases were severe traumatic brain injury. This explain the difference in the result compared with our study. Another study by Macpherson *et al*, 1990 has shown the number of cases of intracerebral haemorrhage was high in depressed fracture (22 cases) followed by subdural haemorrhage (19 cases) and extradural haemorrhage (1 case). However their study did not include subarachnoid haemorrhage.

There was significant association between comminuted skull fracture and subdural haemorrhage (p-value = 0.001). Other types of intracranial haemorrhage were also observed in cases with comminuted fracture although their association were not statistically significant. No previous study on comminuted fracture was found for comparison. We observed that comminuted fracture cases were associated with depressed fracture whereby the bony fragments were displaced toward the brain parenchyma.

In general, extradural haemorrhage was considered as a common complication of head injury which was often associated with skull fracture. The source of bleeding is typically from a torn meningeal artery, usually the middle meningeal artery. Extradural haemorrhage with no skull fracture is usually seen in children since they have very elastic bones, which permit dura to separate from bones (Erlichman *et al*, 2010). Extradural haemorrhage with no skull fracture are very rare in adult since dura is firmly attached to inner layer of the skull (Yavuz *et al*, 2003).

Among all types of intracranial haemorrhages, extradural haemorrhage warrants an emergency neurosurgical intervention. This is because extradural haemorrhage has a greater tendency to progress early after injury, often in dramatic and rapid fashion (Chen *et al*, 2012). The prognosis for extradural haemorrhage is good as long as the blood clot is evacuated promptly. A smaller extradural haemorrhage without mass effect can be treated conservatively.

Subdural haemorrhage occurs due to stretching and tearing of bridging cortical veins. The veins rupture due to shearing forces when there is a sudden change in the velocity of the head. In comparison with extradural haemorrhage, subdural haemorrhage can occur without skull fracture. In this study we found 11 cases of subdural haemorrhage which occur in patient with no skull fracture. Compared with the previous study by Macpherson *et al*, 1990, there were 123 cases of subdural haemorrhage in patients without skull fracture. Symptomatic subdural haemorrhage need to be surgically evacuated and should be performed rapidly. Smaller subdural haemorrhages which are not causing symptoms can be observed with serial CT scan.

A limitation of the current study was the non-probability sample leads to selection bias thus limit the generalisation of this study. Future study with random sample is recommended to overcome this limitation.

In conclusion, there was significant association between skull fracture and intracranial haemorrhage and significant association between linear skull fracture with extradural haemorrhage and comminuted skull fracture with subdural haemorrhage. We recommend that patients with skull fracture should be referred to a centre with neurosurgical facility without delayed.

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Tables and figures

Table 1: Percentage of intracranial haemorrhage in patients with and without skull fracture

Skull fracture	Intracranial hemorrhage		p-value
	Yes, n (%)	No, n (%)	
Yes	64(98.5)	1 (1.5)	<0.001
No	26 (30.2)	60 (69.8)	

Table 2: Association between linear skull fracture and type of intracranial haemorrhage

Type of haemorrhage	Linear skull fracture		p-value
	Yes	No	
Extradural haemorrhage			
Yes, n (%)	19(36.5)	5 (12.8)	0.011
No, n (%)	33 (63.5)	34 (87.2)	
Subdural haemorrhage			
Yes, n (%)	35 (67.3)	24 (61.5)	0.568
No, n (%)	17 (32.7)	15 (38.5)	
Subarachnoid haemorrhage			
Yes, n (%)	19 (36.5)	12 (30.8)	0.566
No, n (%)	33 (63.5)	27 (69.2)	
Intraparenchyma haemorrhage			
Yes, n (%)	34 (65.4)	23 (59.0)	0.532
No, n (%)	18 (34.6)	16 (41.0)	

Table 3: Association between depressed skull fracture and type of intracranial haemorrhage

Type of haemorrhage	Depressed skull fracture		p-value
	Yes	No	
Extradural haemorrhage			
Yes, n (%)	6 (40.0)	18 (23.7)	0.210
No, n (%)	9 (60.0)	58 (76.3)	
Subdural haemorrhage			
Yes, n (%)	13 (86.7)	46 (60.5)	0.053
No, n (%)	2 (13.3)	30 (39.5)	
Subarachnoid haemorrhage			
Yes, n (%)	7 (46.7)	24 (31.6)	0.260
No, n (%)	8 (53.3)	52 (68.4)	
Intraparenchyma haemorrhage			
Yes, n (%)	10 (66.7)	47 (61.8)	0.724
No, n (%)	5 (33.3)	29 (38.2)	

Table 4: Association between comminuted skull fracture and type of intracranial haemorrhage

Type of haemorrhage	Comminuted skull fracture		p-value
	Yes	No	
Extradural haemorrhage			
Yes, n (%)	10 (40.0)	14 (21.2)	0.069
No, n (%)	15 (60.0)	52 (78.8)	
Subdural haemorrhage			
Yes, n (%)	23 (92.0)	36 (54.5)	0.001
No, n (%)	2 (8.0)	30 (45.5)	
Subarachnoid haemorrhage			
Yes, n (%)	9 (36.0)	22 (33.3)	0.811
No, n (%)	16 (64.0)	44 (66.7)	
Intraparenchyma haemorrhage			
Yes, n (%)	16 (64.0)	41 (62.1)	0.869
No, n (%)	9 (36.0)	25 (37.9)	

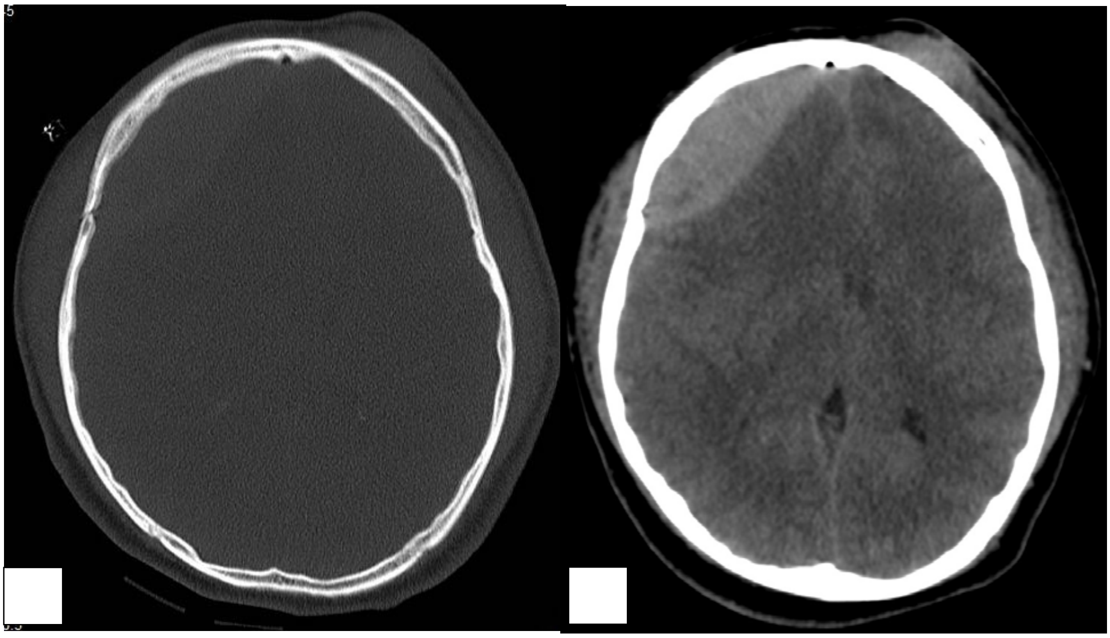

Figure 1: Axial plain CT brain of a 22-year old patient showing (a) bone window; linear fracture at the right parietal and (b) subdural window; extradural haemorrhage at the right frontal.

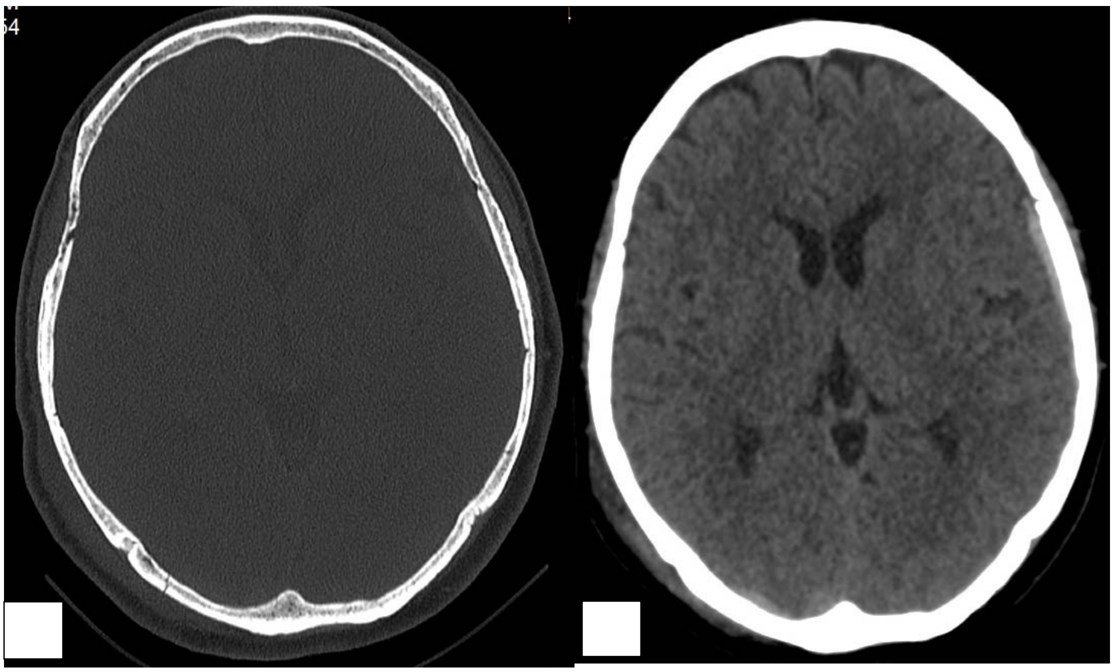

Figure 2: Axial plain CT brain of a 60-year old patient showing (a) bone window; linear fracture at the right occipital and (b) subdural window; small extradural haemorrhage at the right occipital and subdural haemorrhage at the left parietal region.

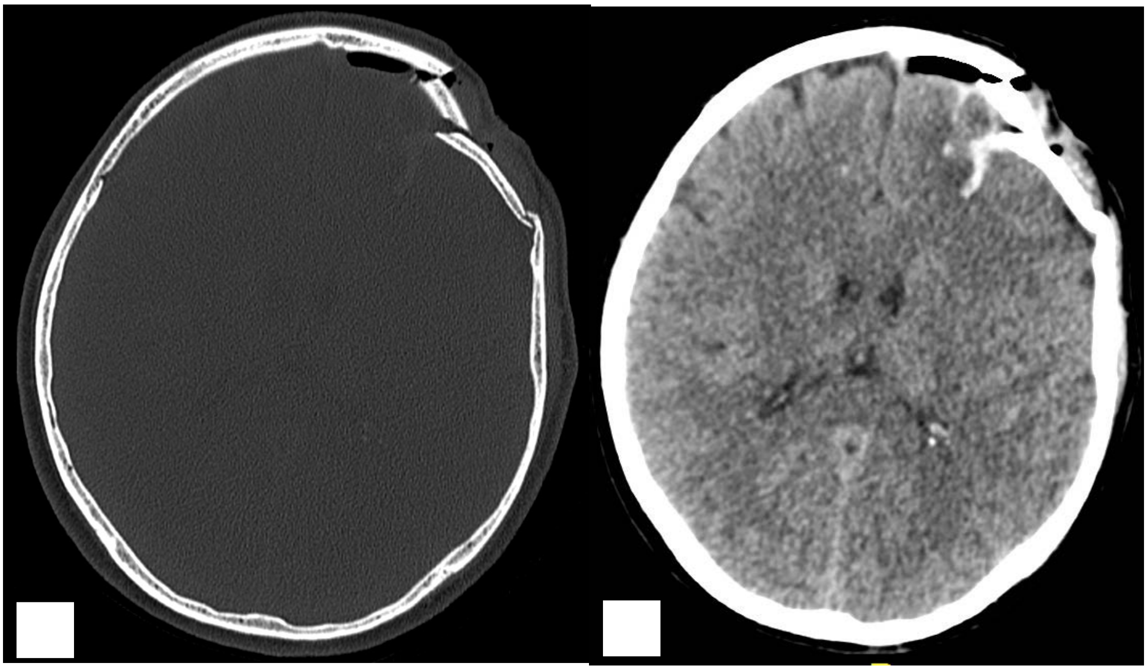

Figure 3: Axial plain CT brain of a 51-year old patient showing (a) bone window; comminuted and depressed fracture at the left frontal and (b) brain window; subarachnoid and intraparenchyma haemorrhage.

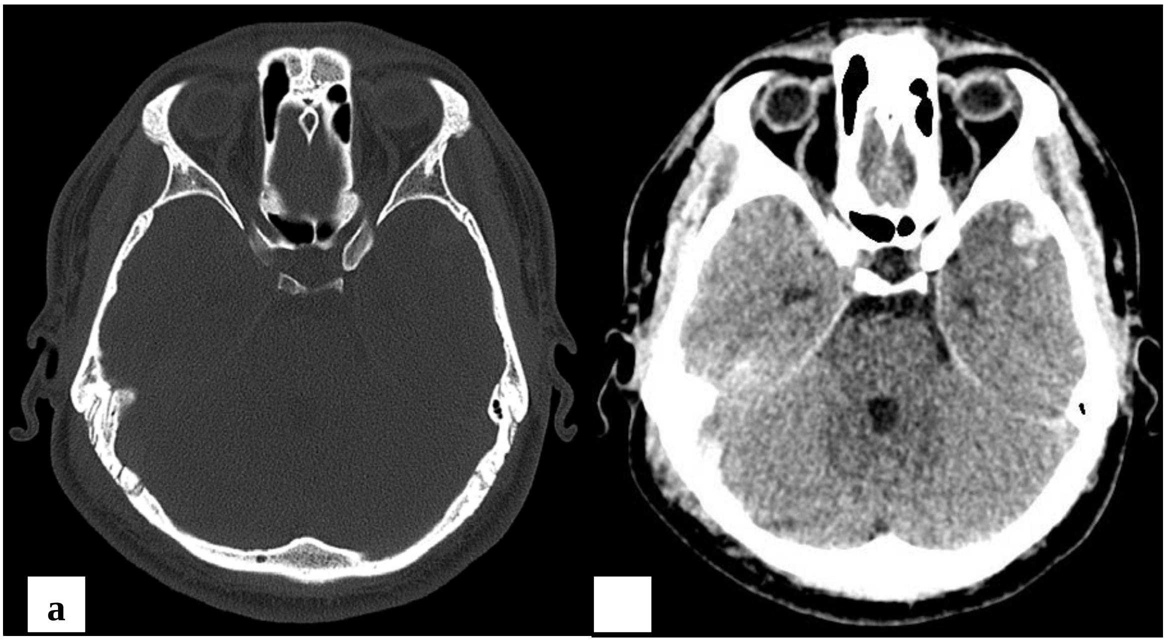

Figure 4: Axial plain CT brain of a 21-year old patient showing (a) bone window; no fracture and (b) brain window; intraparenchyma haemorrhage at the left temporal region.

Apendix 1: Elaboration of methodology

Research design and methodology

1.1 Study sample

This was a retrospective study on the cases of plain CT brain of the trauma patient which were done in Department of Radiology in Hospital Universiti Sains Malaysia (HUSM). Non probability sampling method was performed over a period of 7 months from June 2014 until December 2014. A total of 151 head injury patients age 18 years old and above in whom CT brain were indicated became the subject of the study. Ethical approval was obtained from The Human Research Ethics Committee of Universiti Sains Malaysia (JEPeM).

1.2 Inclusion and exclusion criteria

Inclusion criteria:

1. Head trauma cases referred for CT scan.
2. Age 18 years old and above.

Exclusion criteria:

1. Cases due to non-traumatic intracranial haemorrhage.
2. Follow-up CT scan for head injury.
3. Post-surgical intervention.

1.3 Research Tools:

1. Siemens Somatom Definition AS 128-slice multidetector CT scan.

2. GE healthcare centricity Picture Archiving Communication System (PACS) universal viewer version 5.0 using BARCO image display system.

Apendix 1, continued

1.4 CT brain imaging protocol

No specific patient preparation needed. Patient was place in supine position during the CT scan. Lateral scout image was performed so that angle of the gantry was parallel to a line connecting the infraorbital rim with the opisthion. Scan start from the bottom of C2 and scan through till the top of the head.

Table 1.1: CT brain protocol for head trauma in adult patient in HUSM

	Head trauma protocol for adult
Scanner	Siemens Somatom Definition Adapter Scanner (AS) 128-slice
Scan type	Helical
Detector rows	64
Slice thickness	5mm
Rotation time	1.0sec
kV/mA	120/410
FOV	Head
Recon 1	
Recon type	Soft tissue
Kernel	H31 soft medium smooth
WW/WL	80/35
Recon 2	
Recon type	Bone
Kernel	H70 hard very sharp
WW/WL	1500/450