FRACTURE ZONES OF QUADRILATERAL PLATE OF ACETABELUM USING THREE DIMENSIONAL COMPUTED TOMOGRAPHY IMAGES IN HOSPITAL UNIVERSITI SAINS MALAYSIA

DR AFZAL FAHIMI BIN AB RAHMAN

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF MEDICINE (ORTHOPAEDICS)

UNIVERSITI SAINS MALAYSIA

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- Colleagues and all the staff in the Orthopedics Department, HUSM.

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ABSTRAK

Pengenalan

Kepatahan tulang plat segi empat adalah sejenis kepatahan pada asetabular yang masih menjadi suatu cabaran bagi pakar bedah ortopedik. Walaupun kepatahan ini dijelaskan dengan baik oleh Klasifikasi Letournel-Judet, kepatahan tulang pada plat segiempat bersifat heterogenik pada kepatahan tulang asetabular. Kajian ini bertujuan melihat kelaziman garis patah yang melibatkan plat segi empat untuk lebih memahami morfologi kepatahan tersebut.

Kaedah Kajian

Sebanyak 68 imej CT pinggul atau pelvis dengan ketebalan hirisan 1 mm dari tahun 2011 sehingga tahun 2020 telah dinilai. Data berbentuk format DICOM diperoleh dari PACS, lalu imej 3D hemipelvis telah dibina menggunakan perisian *3D Slicer* untuk mendedahkan plat sisi empat secara menyeluruh. Antara parameter yang diukur adalah konfigurasi kepatahan tulang pada plat segi empat yang terdiri daripada penglibatan zon dalam kepatahan tulang pada plat segiempat dan arah garisan kepatahan tulang pada zon yang terlibat. Semua data yang dikumpul telah dianalisis menggunakan perisian SPSS versi 26. Ciri-ciri pesakit telah diringkaskan dalam bentuk kekerapan dan peratusan untuk data kategorikal manakala ujian Kruskal-Wallis telah dilaksanakan untuk menghasilkan data dalam bentuk min dan sisihan piawai untuk data numerikal (umur).

Keputusan

Dari 68 kepatahan tulang yang memenuhi kriteria kemasukan dalam kajian ini, majoriti kepatahan tulang melibatkan zon C atau jenis-C (n = 37; 54%), manakala selebihnya berlaku pada zon A, jenis-A (n = 29; 44%) dan zon B, jenis B (n = 2, 2%). Selain itu, corak kepatahan tulang yang paling biasa ditunjukkan ialah garis patah tulang sederhana (n = 52, 76%) dengan

kepatahan tulang jenis-A sebanyak 54% (n = 28), diikuti dengan kepatahan jenis-B sebanyak 2% (n = 1) dan kepatahan jenis-C sejumlah 44% (n = 23). Sebaliknya, konfigurasi kepatahan tulang hancur berjumlah 24% (n = 16) dalam corak kepatahan jenis-A sebanyak 6% (n = 1), kepatahan jenis-B sebanyak 6% (n = 1) dan kepatahan jenis-C sebanyak 88% (n = 14). Selanjutnya, separuh arah garis kepatahan berserenjang dengan garis arkuat (n = 34, 50%), diikuti dengan arah garis patah bercampur (n = 25, 37%) dan arah garis selari dengan garis arkuat (n = 25, 37%).

Kesimpulan

Pemerhatian morfologi kepatahan tulang pada plat segiempat dengan gabungan Klasifikasi Letournel-Judet dapat membantu pakar bedah ortopedik memahami dengan lebih mendalam kepatahan asetabular secara komprehensif dan intuitif.

Kata Kunci:

Kepatahan tulang asetabular, Plat segiempat, Pembinaan imej 3D, Garis arkuat

ABSTRACT

Introduction

Quadrilateral plate fracture is included in the acetabulum fracture and is challenging for orthopaedic surgeons. Despite the well-described Letournel-Judet classification, quadrilateral plate fracture remains a heterogenous acetabular fracture. Therefore, this study aimed to observe the prevalence of fracture line involving the quadrilateral plate to better understand the acetabular fracture morphology.

Materials and methods

A total of 68 CT images of the hip or pelvis at 1 mm slice thickness performed from 2011 until 2020 were evaluated. The DICOM format data were obtained from PACS, and 3D images of the hemipelvis were constructed using a 3D Slicer software to expose the whole aspect of the quadrilateral plate. Parameters measured include fracture configuration of the quadrilateral plate of the acetabulum, which consisted of the zone of involvement in quadrilateral plate fracture and fracture line direction related to the zone of involvement. Then, the collected data were analyzed using SPSS version 26. Patients' characteristic were summarized using frequency and percentages for categorical data, while the Kruskal-Wallis test was performed and expressed in the form of mean and standard deviation for numerical data.

Results

Based on the 68 fractures that met the inclusion criteria of this study, a majority of them occured in zone C or C-type (n=37; 54%), whereas the remaining fractures involved zone A, A-type (n=29; 44%) and zone B, B-type (n=2, 2%). Additionally, the most common fracture pattern was the simple fracture line (n=52, 76%) with A-type fracture at 54% (n= 28), B-type fracture at 2% (n=1) and C-type fracture at 44% (n=23). In contrast, the comminuted fracture configuration contributed only 24% (n=16) with A-type fracture at 6% (n= 1), B-type fracture

at 6% (n=1) and C-type fracture at 88% (n=14). Furthermore, half of the fracture line directions were perpendicular to the arcuate line (n=34, 50%), followed by mixed fracture (n=25, 37%) and parallel to arcuate line (n=25, 37%).

Conclusion

Observing fracture morphology of quadrilateral plate in combination with Letournel-Judet classification can assist orthopaedic surgeons in further understanding acetabular fractures comprehensively and intuitively.

Keywords:

Acetabular fracture, Quadrilateral plate, 3D reconstruction image, Arcuate line

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Acetabulum fracture remains a challenging management for orthopaedics surgeons. This fracture is commonly related to high-velocity trauma such as motor vehicle accidents, often involving the younger population. However, the advancement of geriatric treatment has contributed to a longer life expectancy; thus, trivial injuries that cause an acetabular fracture in older, osteoporotic patients are becoming more prevalent in recent years.

In general practice, the Letournel and Judet Classification **(Figure 1)**, established in 1980 after 22 years of research by Emile Letournel and Robert Judet, is used to categorize acetabular fractures. However, even with the inclusivity of this classification system, the quadrilateral plate remains a heterogenous group in acetabulum fracture.

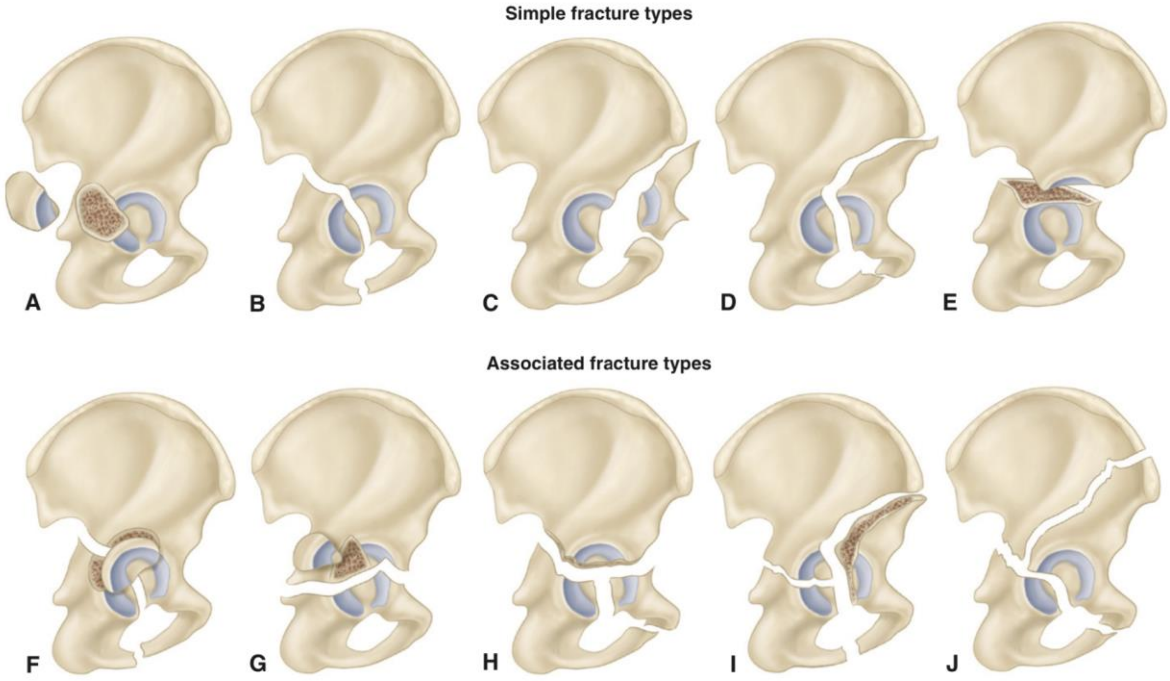

Figure 1: Letournel and Judet classification of acetabular fracture. **A,** Posterior wall fracture. **B,** Posterior column fracture. **C,** Anterior wall fracture. **D,** Anterior column fracture. **E,** Transverse fracture. **F,** Posterior column and posterior wall fracture. **G,** Transverse and posterior wall fracture. **H,** T-shaped fracture. **I,** Anterior column and posterior hemitransverse fracture. **J,** Complete both column fracture (Azar, Beaty, Campbell and Canale, 2012)

1.2 OBJECTIVE

General Objective:

To examine the fracture configuration of the quadrilateral plate of the acetabulum

Specific Objective:

1. To determine the percentage of zone of involvement in quadrilateral plate fracture
2. To determine the percentage of occurrence of fracture line in quadrilateral plate fracture
3. To determine the percentage of simple and comminuted fracture involving quadrilateral plate of acetabelum

CHAPTER 2: STUDY PROTOCOL

2.1 DISSERTATION PROTOCOL

DISSERTATION PROPOSAL

TITLE: Fractures Zones of Quadrilateral Plate of Acetabulum using Three Dimensional Computed Tomography Im'ages in Hospital Universiti Sains Malaysia

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DR. MOHD HADIZIE BIN DIN

1. INTRODUCTION

Acetabulum fracture management remains a challenge for orthopaedic surgeons. This fracture is commonly found in high-velocity trauma cases such as motor vehicle accidents, often involving the younger population. However, the advancement of geriatric treatment has contributed to a longer life expectancy; thus, acetabular fracture cases are increasing among older, osteoporotic patients usually caused by trivial injuries.

In general practice, the common classification system used for acetabulum fracture is the Letournel and Judet Classification **(Fig 1),** which was established in 1980 after 22 years of research. Despite the inclusivity of this classification, the quadrilateral plate remains a heterogenous group in acetabulum fracture.

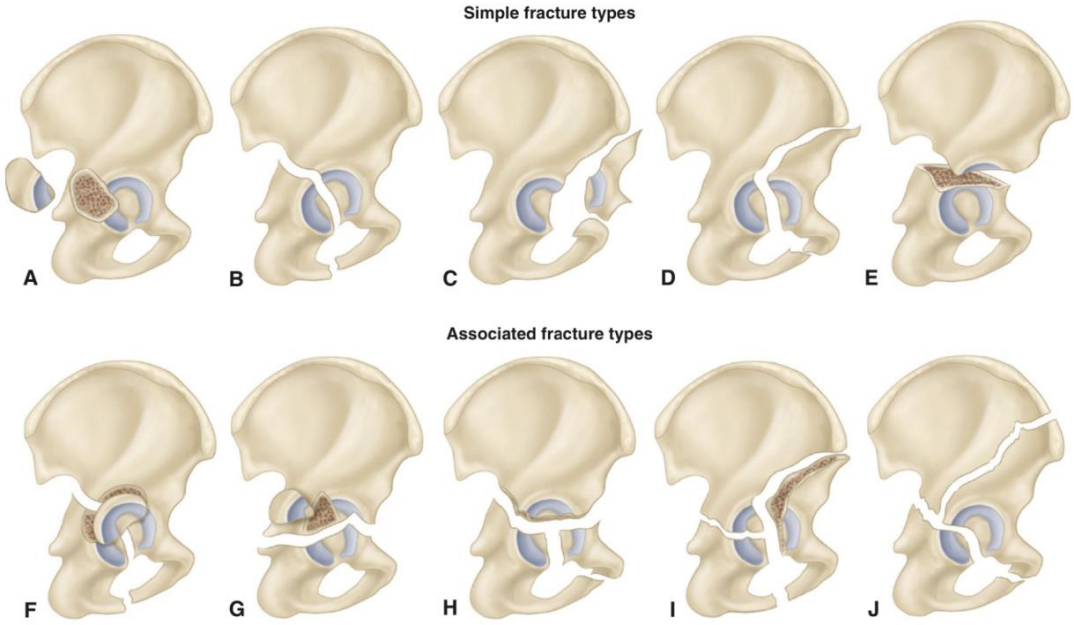

Fig 1: Letournel and Judet classification of acetabular fracture. **A,** Posterior wall fracture. **B,** Posterior column fracture. **C,** Anterior wall fracture. **D,** Anterior column fracture. **E,** Transverse fracture. **F,** Posterior column and posterior wall fracture. **G,** Transverse and posterior wall fracture. **H,** T-shaped fracture. **I,** Anterior column and posterior hemitransverse fracture. **J,** Complete both column fracture (Azar, Beaty, Campbell and Canale, 2012

2. LITERATURE REVIEW

The quadrilateral surface is the flat plate of bone that forms the lateral border of the true pelvic cavity, lying adjacent to the medial wall of the acetabulum **(Fig. 2, Fig. 3)**. The iliopectineal eminence is prominent in the anterior column that lies directly over the femoral head. Both the quadrilateral surface and the iliopectineal eminence are thin and adjacent to the femoral head, limiting the types of fixation used in these regions. (Azar, Beaty, Campbell and Canale, 2012).

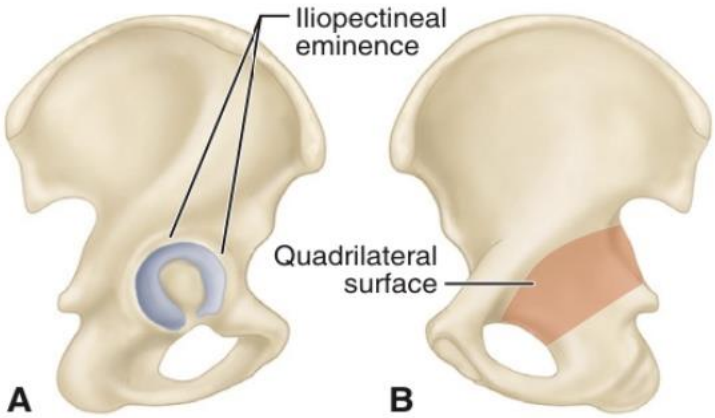

Fig. 2: A, Iliopectineal eminence overlies dome of the acetabulum. **B,** Quadrilateral surface lies adjacent to the medial wall of the acetabulum (Azar, Beaty, Campbell and Canale, 2012)

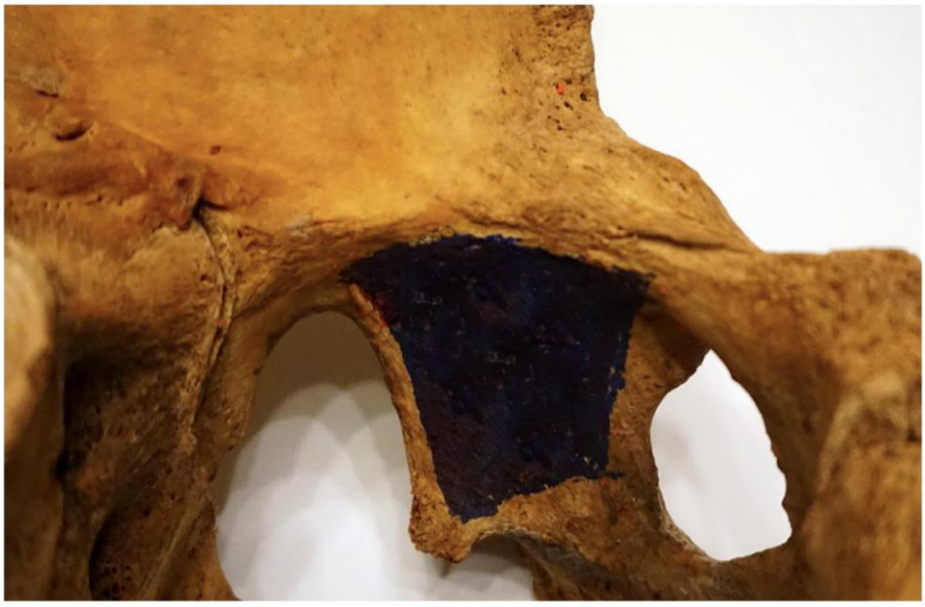

Fig. 3: Anatomical landmarks of the quadrilateral plate. The quadrilateral plate extends from the pelvic brim superiorly until a line joining the ischial spine and obturator foramen inferiorly and is bound by the greater sciatic notch posteriorly and obturator foramen anteriorly (ElNahal et al., 2018)

The teardrop **(Fig. 4)**, or U-body, is located between the anterior and posterior lips at the medial wall of the acetabulum, a landmark with two vertical limbs connected inferiorly in the conventional radiograph. The quadrilateral surface is the flat expanse of bone that forms the sidewall of the pelvic canal inferior to the pelvic brim; it extends anteriorly to the ischial spine and posteriorly to the obturator foramen (Saks, 1986),

The classification system by Judet and Letournel **(Fig. 1)** has led to improved management of these complex injuries. Nevertheless, more reviews concerning the quadrilateral plate are needed because of their heterogeneity in acetabular fracture (Yang et al., 2018).

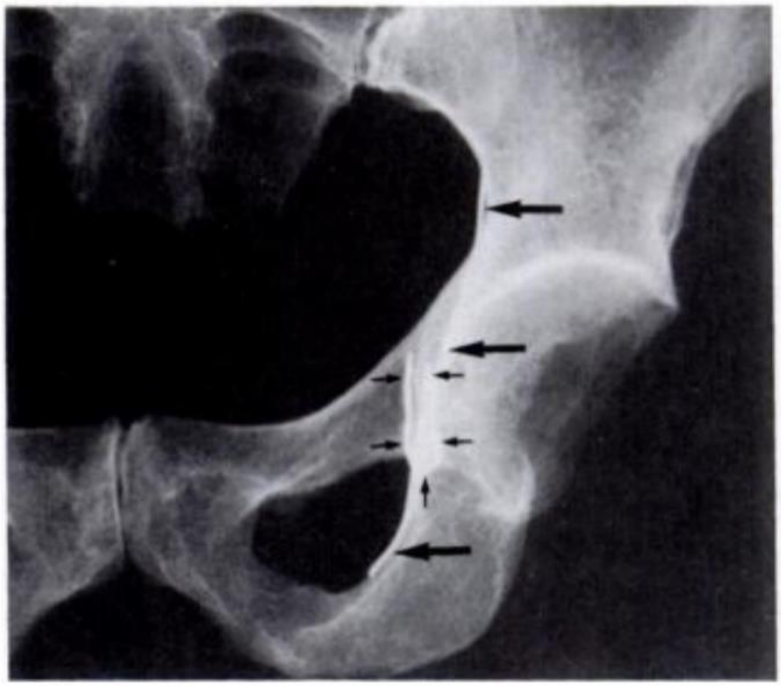

Fig. 4: AP radiograph showing the teardrop (small arrows) and the ilioischial line (large arrows). The teardrop is located along the ventral aspect of the quadrilateral surface, ventral to the ilioischial marker, though on AP radiographs, these lines overlap (Saks, 1986)

The quadrilateral plate is a relatively thin bony structure on the medial wall of the acetabulum, often not considered a parameter in most classification systems. However, central fracture dislocations of the hip with medial migration of the quadrilateral plate are most frequently associated with both-column, anterior column and posterior hemitransverse, posterior column and combined transverse or T-shaped fractures (White et al., 2013).

Quadrilateral plate fracture can be reduced indirectly by the reduction or stabilization of column fractures. However, the failure to fully understand the fracture pattern of the quadrilateral plate can lead to difficulty in achieving a congruent hip reduction, especially in those with a comminuted or free-floating medial wall fracture. Furthermore, the failure of restoring the buttress function of the medial wall and reduce the central displacement will result

in an incongruous hip and poor outcome (White et al., 2013). Thus, Yun Yang et al. (2018) recommended that quadrilateral plate fracture be further reviewed due to the heterogeneity of acetabulum fracture.

In this study, a quadrilateral plate is defined as the medial aspect area of the hip marked by the arcuate line anteriorly until the obturator foramen and extends to the ischial spine posteriorly. Quadrilateral plate border was defined as:

1. Superior: inferior to the pelvic brim
2. Anterior: arcuate line which is defined as an inferior border of articulating surface for sacrum until posterior part of iliopubic eminence
3. Anterior-inferior: posterior part of iliopubic eminence until the origin of inferior-posterior of obturator internus muscle
4. Posterior-inferior: origin inferior-posterior of obturator internus muscle until the ischial spine
5. Posterior: greater sciatic notch

Vital structures related to the quadrilateral plate are the internal pudendal artery, superior gluteal artery, sciatic nerve, pudendal nerve and muscles origin and muscles attachment.

3. PROBLEM STATEMENT AND STUDY RATIONALE

Acetabular fracture is a complex fracture that poses a major challenge for orthopaedic surgeons.

Quadrilateral plate fracture represent heterogenos group in acetabulum fracture.

There is limited literature describing the configuration of quadrilateral plate fracture, causing difficulty in assessing treatment options, especially when it involves comminution or free-floating segment of medial wall fracture.

In the current practice, quadrilateral plating by Synthes was unable to properly fix the surface anatomy of patients treated in Hospital Universiti Sains Malaysia (HUSM) due to multiple factors which need to be determine by futher study. From author perspective and hypothesis, geographically could contribute to anatomical variant base on race and gender.

This study examined the fracture configuration of the quadrilateral plate and proposed a possible classification.

4. JUSTIFICATION AND BENEFIT

To establish practical a classification system, specifically involving the quadrilateral plate in assisting better understanding towards fracture management.

5. OBJECTIVES

5.1 General objective:

To examine the fracture configuration of the quadrilateral plate of the acetabulum

5.2 Specific objective:

1. To determine the percentage of zone of involvement in quadrilateral plate fracture
2. To determine the percentage of occurrence of fracture line in quadrilateral plate fracture
3. To determine the percentage of simple and comminuted fracture involving quadrilateral plate of acetabelum

6. METHODOLOGY

6.1 Research Design

A retrospective cross-sectional study based on the Picture Archiving and Communications System (PACS) database in HUSM.

6.2 Study Area

This study was conducted in HUSM, which began its operation back in 1983. HUSM is a tertiary referral centre and teaching hospital in Kelantan, located in the east coast region of Peninsular Malaysia. It is a trauma center that accommodates many high-velocity trauma patients that undergo pelvic CT, thus, providing a sufficient number of participants that fulfilled the inclusion criteria for this study.

6.3 Study Population

6.3.1 Reference population:

HUSM patients with acetabular fractures or pelvic fractures from 1 January 2015 to 31 December 2019.

6.3.2 Target population:

Patients with acetabular fracture concomitant with quadrilateral plate admitted to HUSM from 1 January 2015 to 31 December 2019.

6.3.3 Sampling frame:

Patients with acetabular fracture who were underwent CT scan pelvis from 1 January 2015 to 31 December 2019.

6.4 Subject Criteria

6.4.1 Inclusion Criteria

1. Age equal or greater than 16 years old with complete ossified triradiate cartilage
2. Fractures involving a quadrilateral plate of the acetabulum
3. Complete imaging assessment including radiograph and computed tomography

6.4.2 Exclusion Criteria

1. Fracture line or anatomical landmark obscured by a foreign body
2. Poor quality CT data
3. CT image unavailable in PACS

6.5 Sample size estimation

Based on a previous study conducted by Yun Yang et al. (2018), the highest prevalence was 65%. Therefore, the formula used for sample estimation was as the following:

$$N = \left(\frac{Z}{E}\right)^2 P(1-P)$$

With;

E: Precision

Z = 1.96

P = 0.65

E	Width of CI	N
0.025	**0.05**	**1398**
0.05	**0.10**	**349**
0.06	**0.12**	**242**
0.07	**0.14**	**178**
0.08	**0.16**	**136**
0.09	**0.18**	**107**
0.1	**0.2**	**87**

Based on the calculation above, a total sample of 136 with a confidence interval of 84% was realistic and achievable due to the total admission of pelvic fracture patients in HUSM.

6.6 Sampling method and subject recruitment

The non-probability sampling method was used to select patients from the PACS database. Patients with acetabular fracture involving quadrilateral plate and falls that fulfilled the inclusion criteria were selected. Meanwhile, those who met the exclusion criteria were excluded from this study. Subject recruitment was not required since the data was obtained from the system.

6.7 Research tools

Three-dimensional CT images were obtained from the PACS database. Zone marking and fracture line identification was carried out by two parties: the researcher and a radiologist.

6.8 Data collection method

CT image retrieved from the PACS database. Patients participation were not required, and the data collected were subjected to strict confidentiality.

A standard pelvis image was selected from the database as a template. Then, the pelvic CT images were reconstructed in 3D. The left hemipelvis images were used as models, whereas the right hemipelvis images were flipped horizontally to obtain the corresponding mirror images.

The quadrilateral plate is defined as the medial aspect area of the hip marked by an arcuate line anteriorly until the obturator foramen, extending to the ischial spine posteriorly.

Zone A and zone B were divided by an imaginary line from the midportion of psoas minor origin muscle anteriorly at the iliopubic eminence until the tip of the ischial spine posteriorly. This zone separation means for sciatic nerve position, located in the posterior aspect zone of zone A. When the fracture line crossed zone A and zone B, the case was identified as zone C. Fracture line direction was documented as parallel, perpendicular to arcuate line or mixed. Below is the zone marking of the 3D image of the pelvis template:

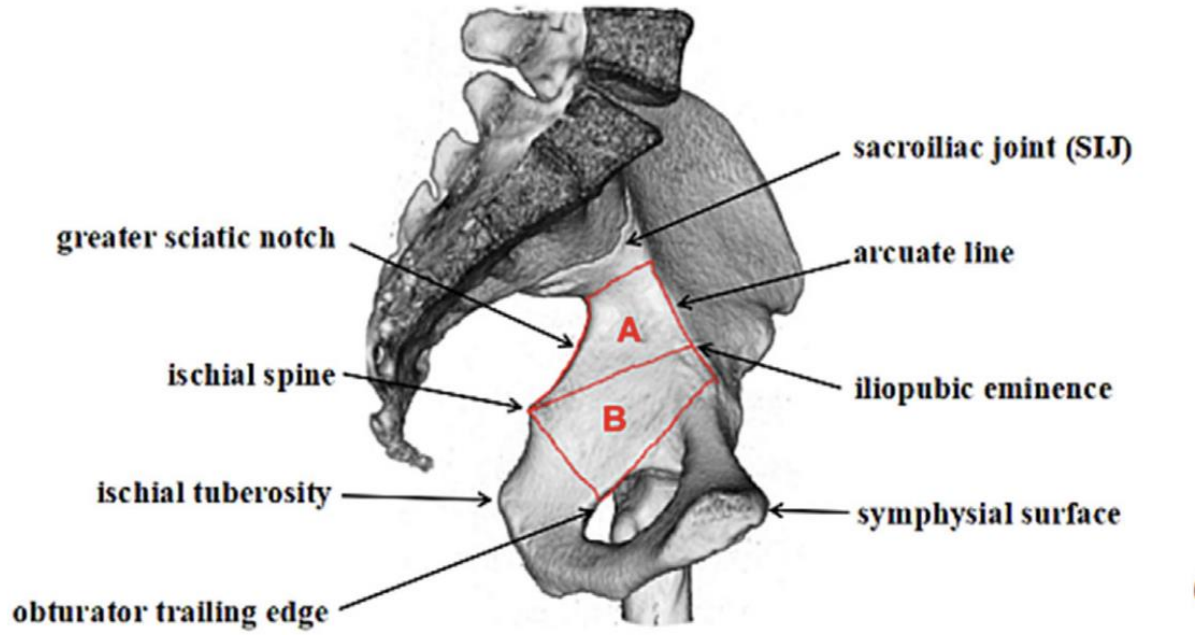

Fig. 5: Hemipelvis anatomy and quadrilateral plate marked by the redline area. (Yang et al., 2018)

Data collection sheet:

Registration number:

Age	Sex	Mechanism of injury	Side of injury	Treatment	Zone involvement	Fracture line direction

Age: age of the patient in years
Sex: male or female
Mechanism of injury: motor vehicles accident or fall or others
Side of injury: right or left hip
Treatment: operative or conservative
Zone involvement: zone A1 (simple) or A2 (comminuted), or zone B1 (simple) or B2 (comminuted), or zone C1 (simple) or C2 (comminuted)
Fracture line direction; parallel or perpendicular to arcuate line or mixed

6.9 Data analysis

The data that were collected in this study were analyzed using SPSS version 26. Descriptive statistics were used to summarize the socio-demographic characteristics of the subjects. Numerical data were presented as mean (SD) or median based on their normality distribution, whereas categorical data were presented as frequency (percentage).

6.10 Expected Results

Demographic

Variable	Result
Mean age	
Sex, n (%) **Male** **Female**	

Mechanism of injury, n (%) **Motor vehicle accident** **Fall** **Others**	
Side of injury, n (%) **Right** **Left** **Both**	
Treatment, n (%) **Operative** **Conservative**	

Zone	**Frequency, n (%)**		
Zone A	Simple (A1)		
	Comminuted (A2)		
Zone B	Simple (B1)		
	Comminuted (B2)		
Zone C	Simple (C1)		
	Comminuted (C2)		

Fracture line direction	**Frequency, n (%)**
Parallel to the arcuate line	
Perpendicular to the arcuate line	
Mixed	

6.11 Ethical consideration

Since this is an observational study using secondary data, there was no risk posed on patients. The collected data did not include identifiers such as names to protect patients' privacy.

1. **Subject availability**

   There is no vulnerability to subjects as only secondary data will be used, and the patient was treated as usual.

2. **Declaration of the absence of conflict of interest**

   There is no conflict of interest

3. **Privacy and confidentiality**

   All data were obtained anonymously and was entered into SPSS software, accessible only by the research team members. The data were presented in groups, and no participants were identified individually. All the collected data were archived strictly for five years before being destroyed as per MREC protocol.

4. **Community sensitivity and benefits**

   The data collected for this study was taken from locals patients who were treated in HUSM. Therefore, it was very useful and beneficial in attending cases of quadrilateral wall fracture.

5. **Honorarium and incentives**

   Not applicable.

7. List of abbreviations

i. CT refers to Computerized Tomography

ii. PACS refers to Picture Archiving and Communications System

iii. HUSM refers to Hospital Universiti Sains Malaysia

iv. SD refers to Standard Deviations

v. MREC refers to Medical Research and Ethics Committee

8. REFERENCES

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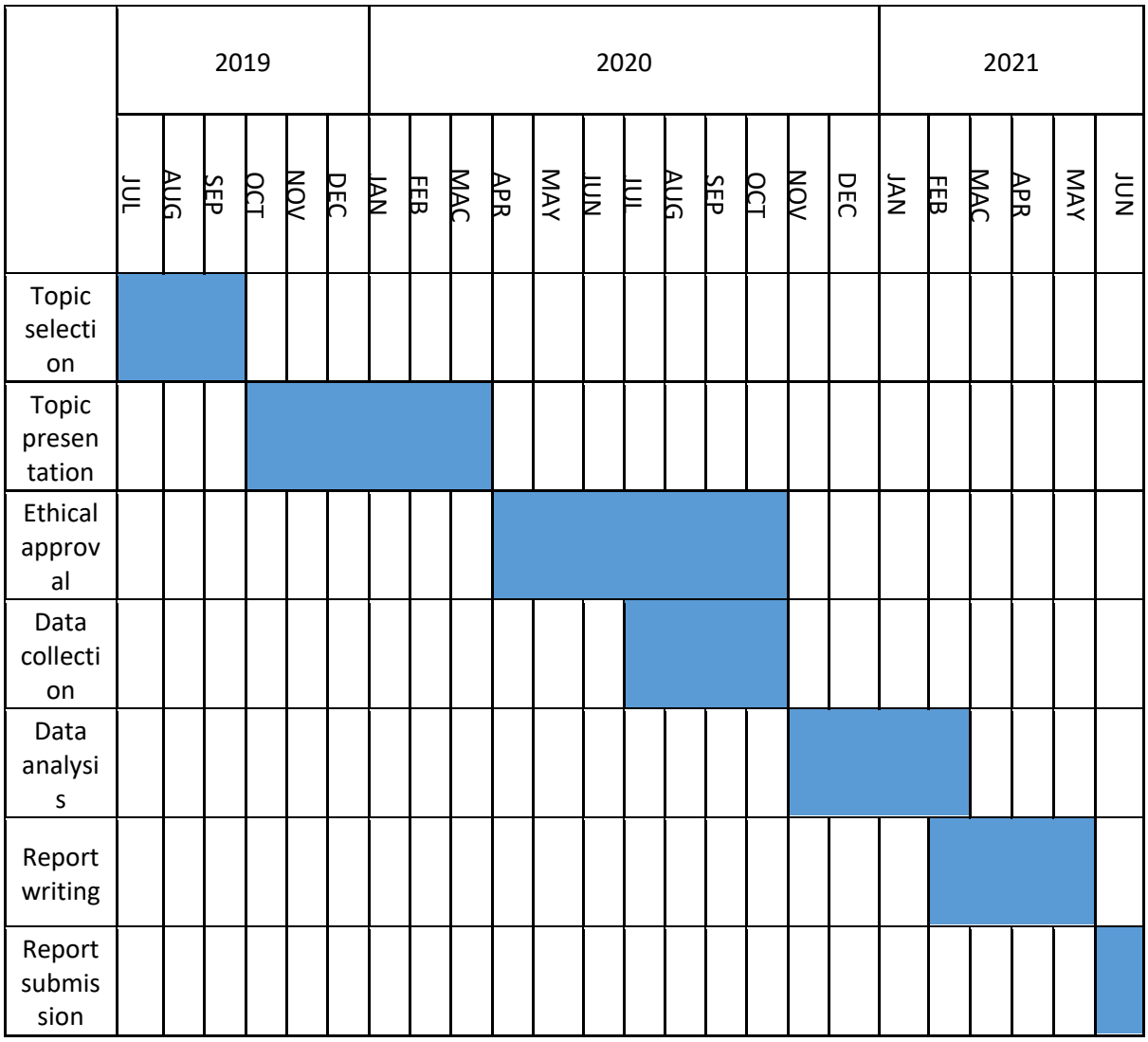
Gantt chart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MAC
APR
MAY
JUN
Topic selection
Topic presentation
Ethical approval
Data collection
Data analysis
Report writing
Report submission

2.2 ETHICAL APPROVAL LETTERS :

Jawatankuasa Etika
Penyelidikan Manusia USM (JEPeM)

Human Research Ethics Committee USM (HREC)

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16150 Kubang Kerian, Kelantan. Malaysia.
Tel. : +609 - 767 3000/2354/2362
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1st December 2020

Dr. Afzal Fahimi Ab Rahman
Department of Orthopaedics
School of Medical Sciences
Universiti Sains Malaysia
16150 Kubang Kerian, Kelantan.

JEPeM Code : USM/JEPeM/20090460
Protocol Title : Mapping Fracture Pattern of Quadrilateral Plate of Acetabelum Using Three Dimensional Computed Tomography Image in Hospital Universiti Sains Malaysia.

Dear Dr.,

We wish to inform you that your study protocol has been reviewed and is hereby granted approval for implementation by the Jawatankuasa Etika Penyelidikan Manusia Universiti Sains Malaysia (JEPeM-USM). Your study has been assigned study protocol code **USM/JEPeM/20090460**, which should be used for all communications to JEPeM-USM in relation to this study. This ethical approval is valid from **1st December 2020** until **30th November 2021.**

Study Site: Hospital Universiti Sains Malaysia.

The following researchers are also involved in this study:

1. Dr. Sahran Yahaya
2. Dr. Ahmad Tarmizi Musa
3. Prof. Dr. Wan Faisham Nu'man Wan Ismail
4. Dr. Mohd Hadizie Din

The following documents have been approved for use in the study.

1. Research Proposal

In addition to the above mentioned document, the following technical documents were included in the review on which this approval was based:

1. Patient Performa (Data Collection Sheet)

While the study is in progress, we request you to submit to us the following documents:

1. Application for renewal of ethical approval 60 days before the expiration date of this approval through submission of **JEPeM-USM FORM 3(B) 2019: Continuing Review Application Form.**
2. Any changes in the protocol, especially those that may adversely affect the safety of the participants during the conduct of the trial including changes in personnel, must be submitted or reported using **JEPeM-USM FORM 3(A) 2019: Study Protocol Amendment Submission Form.**
3. Revisions in the informed consent form using the **JEPeM-USM FORM 3(A) 2019: Study Protocol Amendment Submission Form.**
4. Reports of adverse events including from other study sites (national, international) using the **JEPeM-USM FORM 3(G) 2019: Adverse Events Report.**
5. Notice of early termination of the study and reasons for such using **JEPeM-USM FORM 3(E) 2019.**
6. Any event which may have ethical significance.

JEPeM
JAWATANKUASA ETIKA PENYELIDIKAN MANUSIA

7. Any information which is needed by the JEPeM-USM to do ongoing review.
8. Notice of time of completion of the study using **JEPeM-USM FORM 3(C) 2019: Final Report Form.**

Please note that forms may be downloaded from the JEPeM-USM website: **www.jepem.kk.usm.my**

JEPeM-USM is in compliance with the Declaration of Helsinki, International Conference on Harmonization (ICH) Guidelines, Good Clinical Practice (GCP) Standards, Council for International Organizations of Medical Sciences (CIOMS) Guidelines, World Health Organization (WHO) Standards and Operational Guidance for Ethics Review of Health-Related Research and Surveying and Evaluating Ethical Review Practices, EC/IRB Standard Operating Procedures (SOPs), and Local Regulations and Standards in Ethical Review.

Thank you.

Sincerely,

PROF. DR. HANS AMIN VAN ROSTENBERGHE
Chairperson
Jawatankuasa Etika Penyelidikan (Manusia) JEPeM
Universiti Sains Malaysia