Computed Tomographic Morphometric Analysis of Sacroiliac Region for Ventral Plating of Sacroiliac Joint in Malay Ethnicity

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LIST OF ABBREVIATIONS AND DEFINITIONS

List of abbreviations

i. CT refers to Computerized Tomography

ii. SIJ refers to sacroiliac joint

iii. SF refers to sacral foramina

iv. APC refers to anterioposterior compression

v. LC refers to lateral compression

vi. VS refers to vertical shear

vii. PACS refers to Picture Archiving and Communications System

viii. HUSM refers to Hospital Universiti Sains Malaysia

ix. SD refers to Standard Deviations

x. MREC refers to Medical Research and Ethics Committee

List of definitions

i. Malay Ethnicity is defined as anyone that is registered as a Malay in their identification card

ABSTRAK

Pengenalan

Kecederaan sendi sakroiliak yang tidak stabil, yang dirawat dengan kaedah pembedahan terus dengan memasukkan bahagian tulang yang patah ke kedudukan asalnya, dibawah penglihatan langsung, dan kemudiannya distabilkan posisi tulang tersebut dengan menggunakan implan besi yang diletakkan pada bahagian depan sendi sakroiliak, telah menunjukkan hasil yang baik. Walaubagaimanupun, morfologi bahagian sendi sakroiliak belum dikaji secara menyeluruh untuk panduan penggunaan skru apabila hendak membuat pembedahan pembaikian sendi sakroiliak. Oleh itu, kami melakukan kajian morfometrik tomografi komputer di bahagian sendi sakroiliak untuk menentukan arah dan kepanjangan yang terbaik dan selamat semasa memasang implan besi pada bahagian depan sendi sakroiliak.

Kaedah Kajian

Sebanyak 112 imej tomografi komputer tulang pelvis yang diambil pada tahun 2017, diukur selepas kecondongan sagital, kecondongan koronal dan pembetulan putaran paksi. Kami mengukur sudut sakroiliak pada kedua-dua satah paksi dan coronal yang benar, bersama-sama dengan ketebalan tulang antara sakroiliak dan sakral foramina pertama, jarak menegak dari dinding sakral bahagian atas hingga pertengahan sakral foramina pertama dan hingga pertengahan sakral foramina kedua. Semua ukuran dikira sehingga 0.1 darjah dan 0.1mm, dan analisis statistik dihitung dengan menggunakan Statistik SPSS IBM Versi 24. Ujian “t” bebas digunakan untuk menentukan perbezaan min antara sudut sendi sakroiliak

dalam satah paksi dan koronal mengikut jantina. Analisis deskriptif pembolehubah berangka dibentangkan sebagai min (sisihan piawai).

Keputusan

Sudut sudut sendi sakroiliak dalam satah paksi adalah 13.39 darjah (SD 5.51), sudut sendi sakroiliak dalam satah koronal adalah 14.17 darjah (SD 3.43), ketebalan tulang antara sendi sakroiliak dan sakral foramina pertama adalah 20.80mm (SD 3.29), Min jarak menegak dari dinding bahagian atas tulang sakrum hingga sakral foramina pertama 18.67mm (SD 5.01) dan sakral foramina kedua adalah 42.69mm (SD 5.31). Walau bagaimanapun, kajian kita menunjukkan bahawa sudut sendi salroiliak pada satah koronal didapti lebih tinggi di kalangan kaum lelaki berbanding dengan kaum wanita dengan $p = 0.02$.

Kesimpulan

Pemasangan implan besi pada bahagian depan sendi sakroiliak adalah sebaik-baiknya dengan skru bahagian tulang sakral dipasang pada sudut satah koronal kira-kira 14 darjah kearah dalam, dengan panjang skru kira-kira 37mm, dan dengan memastikan lubang skru implan besi tidak merentasi 2cm medial dari sendi sakroiliak. Ini adalah untuk mengurangkan kebarangkalian berlakunya kecederaan pada elemen saraf dan untuk mendapatkan cengakaman kuat skru ke dalam tulang.

Kata Kunci:

Sendi sakroiliak, foramina sakrum, plat ventral, trajektori, pengukuran CT

ABSTRACT

Introduction

Unstable sacroiliac joint injury treated with open reduction and internal fixation, and ventral sacroiliac joint plating has shown promising results and outcome with such injuries. The morphology of sacroiliac region however, has not been thoroughly studied in order to guide the application of screws when plating the sacroiliac joint. Hence, we performed a CT morphometric study of the sacroiliac region to determine the ideal screw trajectory and length in order to safely apply a ventral sacroiliac plate.

Materials and methods

A total of 112 Pelvic CT images performed in the year 2017 were measured after sagittal tilt, coronal tilt and axial rotation were adjusted. We measured sacroiliac joint angles on both true axial and coronal planes, along with osseus thickness between sacroiliac joint and 1st sacral foramina, vertical distance from superior sacral wall till mid level of 1st sacral foramina and till mid level of 2nd sacral foramina respectively. All parameters were measured up to 0.1^{o} and 0.1mm, and statistical analysis was performed using IBM SPSS Statistics Version 24. Independent t-test was used to determine the mean difference between sacroiliac joint angles in axial and coronal plane by gender. Descriptive analysis of the numerical variable was presented as mean (standard deviation).

Results

The mean sacroiliac joint angle in axial plane was 13.39^{o} (SD 5.51), sacroiliac joint angle in coronal plane was 14.17^{o} (SD 3.43), mean osseous thickness between sacroiliac joint and 1st sacral foramina was 20.80mm (SD 3.29), mean vertical distance from superior sacral wall till 1st sacral foramina 18.67mm (SD 5.01) and till 2nd sacral foramina 42.69mm (SD 5.31) respectively. Males however showed statistically significant higher SIJ angle in coronal plane when compared to their female counterparts with p=0.02.

Conclusion

Ventral sacroiliac joint plating would be best when done with the screw over the sacral side inserted at an angle in the coronal plane of about 14 degrees medially, with screw length of about 37mm, and with the screw hole of the plate not exceeding 2cm medially from the sacroiliac joint, to minimise injury to the neural elements and to get best bony purchase.

Key Words:

Sacroiliac joint, sacral foramina, ventral plating, trajectory, CT measurement

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

High-energy fractures involving the pelvis are often associated with damage to surrounding vital structures (major vessels, nerves & viscera) and hence can be fatal due to the massive potential blood loss. Overall mortality in pelvic trauma ranges from 10%-50%, especially in patients who present with hemodynamic instability, which tends to be indicative of a mechanically unstable pelvis.

The innominate bones of the pelvis forms a ring along with the sacrum, which is held by the symphyseal articulation at the ventral, and strong sacroiliac articulation at the dorsal. A break of this ring usually calls for high energy trauma with the basic mechanism of anterior-posterior compression (APC), lateral compression (LC), vertical shear (VS), or any combination of these.

The role of surgical treatment is to convert unstable pelvic fractures into stable ones in order to initiate early mobilization. However, it is of utmost importance to achieve anatomical reduction with adequate stability of the posterior pelvic ring to minimize chronic pain and reduce long term morbidity.

There are multiple options for definitive fixation of the sacroiliac joint such as external fixator, percutaneous or open iliosacral screw fixation, transiliac plating, ventral sacroiliac plating and others.

Ventral plating of the sacroiliac joint (SIJ) has been implemented for many years, and studies has shown that direct ventral plating to be more stable compared to other methods of fixation available also allowing easier and more anatomical reduction. However, there is limited study on the dimensions of the sacral alar on which the plate is screwed to allow safe application and to reduce possible complications.

1.2 PROBLEM STATEMENT AND STUDY RATIONALE

What is the morphology of the SIJ region that allows us to determine trajectory for safe placement of screws of a ventral SIJ plate in Malay population in Malaysia? There is insufficient study on the adult SIJ morphometry especially of the Malay population of Malaysia as there is only one study on Chinese population of China which studied the trajectory of screw placement, but even that study did not include the SIJ angle on coronal plane which deems it insufficient to conclude.

This study aims to give a deeper understanding of the anatomy of the SIJ of the Malay population in terms of the osseous window available for safe placement of screws to hold the plate in place without damaging vital structures around the area.

1.3 RESEARCH QUESTIONS

1. What is the optimal angle of inclination for screw placement over the sacral part when fixing a ventral SIJ plate in Malay population?
2. What is the ideal length of the screws for ventral SIJ plating which allows minimal risk to neural structures and maximal bony purchase in Malay population?

1.4 OBJECTIVES

General Objective:

To determine the optimal trajectory and lenght for screws when applying a ventral SIJ plate in Malays ethnicity in Malaysia.

Specific Objective:

1. To determine the ideal inclination for screw placement by
    a. Identifying the angle between SIJ & sagittal plane from an axial view of pelvic CT.
    b. Identifying the angle between SIJ & sagittal plane from the coronal view of pelvic CT.
2. To determine the osseous thickness between SIJ & 1st sacral foramina.
3. To determine the vertical distance from the superior wall of sacrum till the mid point between SIJ and 1st sacral foramina.
4. To determine the vertical distance from the superior wall of sacrum till the mid point between SIJ and 2nd sacral foramina.

CHAPTER 2: LITERATURE REVIEW

2.1 LITERATURE REVIEW

Historically, various studies have been carried out on the outcomes of conservative treatment with sacral traction or pelvic sling for displaced or unstable pelvic fractures (Tile type B & C), but shown disappointing results with patients having significant pain & difficulty in returning to work. Literature from over the last 30 years was systemically reviewed by Papakostidis et al (1) to investigate clinical outcomes of treatment of pelvic fracture through non-operative, anterior pelvic fixation, & posterior pelvic fixation. His team noticed that patients with posterior fixation fared better both anatomically (better reduction & lower malunion) & functionally (lowest incidence of severe pain & gait disturbance), leaving no doubt to the benefit of fixation of a pelvis fracture.

However, as mentioned earlier, there are various methods of fixing the SIJ, and each has their own advantages and disadvantages. Concerning biomechanical stability, Tamas Bodzay et al (2) conducted a study in 2011 comparing the stability of 4 different methods of SIJ fixation (1. Ventral Iliosacral plating, 2. Iliosacral screws, 3. Transacral plating, 4. KFI-H plating) for vertically & rotationally unstable type C pelvic ring fractures. His team deployed finite element models to reproduce these type of fractures and applied the mentioned fixation methods and subjected the models to different stresses in order to measure shifts produced between the fracture gaps & charted the results. Results showed that the ventral plating was more biomechanically stable when compared to the other methods in the study. Hence my study is designed to further assist the safe placement of screws during the ventral plating which is the more biomechanically sound choice of fixation for a vertically and rotationally unstable pelvic ring fracture.

In 1993, Ragnarsson et al (3) followed up 21 patients with 23 SIJ disruptions after fixing the injury with ventral square 2 hole plate. These patients were seen for a mean of 5 years and it was noted that apart from the ability to achieve full reduction intra-operatively, ventral plating also yielded 57% excellent overall outcome & 28% good outcome according to "Harris Hip Scoring" and thus allowed early mobility with weight bearing as this method of fixation boasts superior stability.

Vital structures have always been a concern when it came to direct ventral plating of the SIJ and hence, it has been studied thoroughly through multiple cadaveric dissections after which Sreenivasa et al & Dogan et al identified the "At Risk Area" & "Safezone" (4, 5). Sreenivasa discovered through dissection of fresh frozen cadavers, the "at risk area" where the nutrient artery that supplies the iliac bone is located, and by avoiding it, surgeons can minimize intraoperative bleeding. Keeping this in mind, Sreenivasa recommended that plates should be divergent when crossing SIJ. Dogan on the other hand analysed the L4 & L5 nerve roots and suggested "safe zone" for plating, and that plated should be cautiously placed at the bottom third of the SIJ, near the pelvic brim as the L4 root could be as close as less than a cm away.

Zhibao et al (6), in 2017 studied the angle of the SIJ in relation to the sagittal plane through CT scans and concluded that screws over the alar should be directed 30^0 medially to ensure the screw obtains the best sacral bony purchase without crossing the SIJ. However, to the authors knowledge, there has not been a study on the angle of SIJ on the coronal plane which is equally important to optimize screw placement.

CHAPTER 3: METHODOLOGY

3.1 METHODOLOGY

Research design

This is a cross-sectional study of pelvis CT archived in Picture Archiving and Communications System (PACS) database from year 2016 to 2018 from Hospital Universiti Sains Malaysia (HUSM).

Study area

The study will be conducted in HUSM which started operation in the year 1983. HUSM is a tertiary referral centre and a teaching hospital in Kelantan, at the east coast region of Peninsular Malaysia. HUSM is a trauma centre in which a majority of patient with high-velocity trauma undergo CT cervical providing sufficient number of patient fulfilling inclusion criteria for this study.

Study population

My reference population will be individuals of Malay ethnicity in Malaysia whereas my source population are individuals that presented to HUSM Emergency Department. My target population are Malay ethnicity patient that underwent CT pelvis in HUSM Emergency Department. My sampling frame will be patient CT pelvis database in PACS.

3.2 SUBJECT CRITERIA

A. Inclusion criteria

1. 18 years to 60 years old at the time of CT pelvis
2. Both genders
3. Malay ethnicity

B. Exclusion criteria

1. Presence of sacroiliac region fractures (new or old fractures)
2. Presence of congenital abnormalities of sacrum & iliac bones
3. Presence of pathology at the sacrum or iliac bones (infection or tumors)
4. Presence of any instrumentation to the pelvis
5. CT images with artefacts

3.3 SAMPLE SIZE ESTIMATION

A. Sample size for specific objective 1

i. Formula used for one sample, continuous outcome

$$n = \left(\frac{Z\sigma}{E}\right)^2$$

ii. Standard deviation (SD) from previous literature for SIJ angle (6)

a. 1st layer transverse cut : 2.4

b. 3rd layer transverse cut : 2.2

c. 5th layer transverse cut : 2.7

iii. Z = 1.96 for 95% confidence level

σ = 2.7 (highest SD was used)

E = 0.5 (margin of error of 0.5degrees)

$n = \left(\frac{1.96 \times 3.2}{0.5}\right)^2$

= 112.02

= 112 patients

B. Sample size for objective 2

i. Formula used for one sample, continuous outcome

$$n = \left(\frac{Z\sigma}{E}\right)^2$$

ii. Standard deviation (SD) from previous literature for horizontal distance (6)

a. Transverse plane layer 1 : 1.0

b. Transverse plane layer 2 : 1.0

c. Transverse plane layer 3 : 1,0

iii. Z = 1.96 for 95% confidence level

σ = 2.7 (highest SD was used)

E = 0.5 (margin of error of 0.5mm)

$$n = \left(\frac{1.96 \times 1.0}{0.5}\right)^2$$

= 15.37

= 15 patients

C. No drop out calculated as study is using data from PACS database. Therefore sample size required is 112 patients.

3.4 SAMPLING METHOD AND SUBJECT RECRUITMENT

Non-probability sampling is used to select patients from the PACS database, who is Malay ethnicity that done CT pelvis and falls into the inclusion and exclusion criteria. Subject recruitment is not required as data is obtained from the system.

3.5 RESEARCH TOOL

CT images are measured using the measurement tool of the workstation Centricity™ Universal Viewer Web Client Version 6.0 by GE Healthcare by a single person (Sarbdev Singh) for all the parameters and documented in millimetre (mm) and degrees (°), rounded up to one decimal point

3.6 DATA COLLECTION METHOD

Data will be collected by measuring CT pelvis images from the PACS database. Patients participation is not required and data will be collected with strict confidentiality. CT pelvis images will be reconstructed to obtain axial and sagittal views and measured according to the method shown in

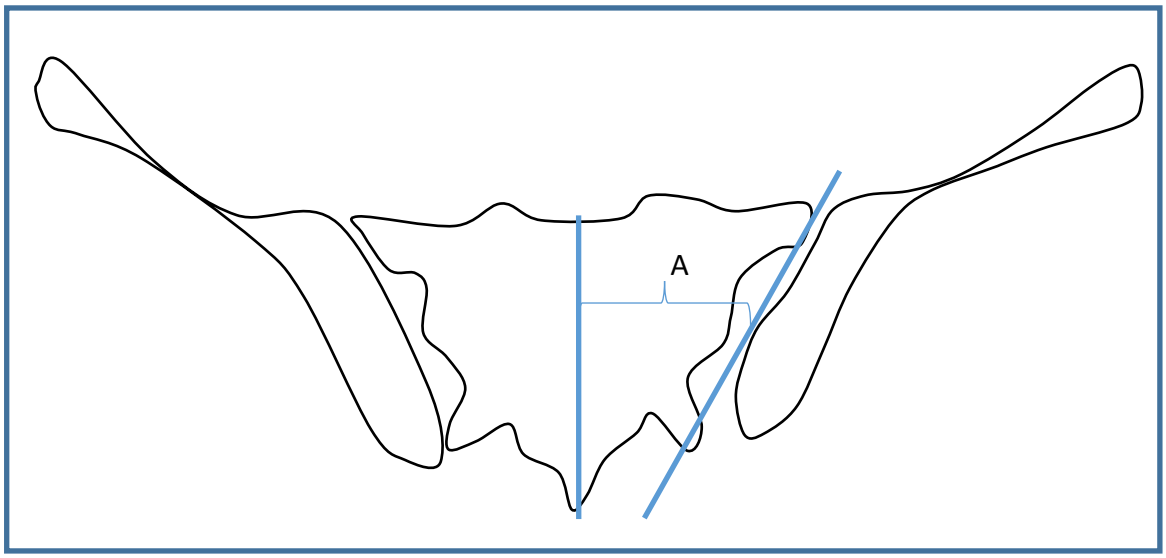

Figure 1 : Diagrammatic illustration of axial CT cut of sacroiliac joint showing measurement of A : angle between the SIJ & the sagittal plane on axial CT view

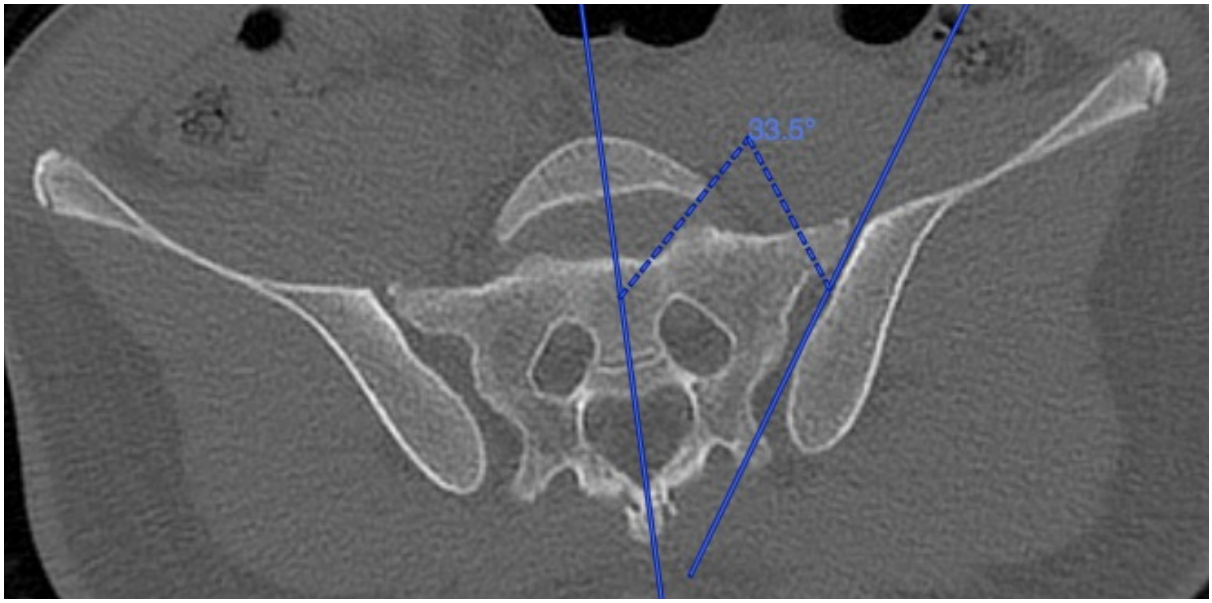

Figure 2 : An axial cut from a patients pelvic CT showing the angle between SIJ & the sagittal plane on axial CT view

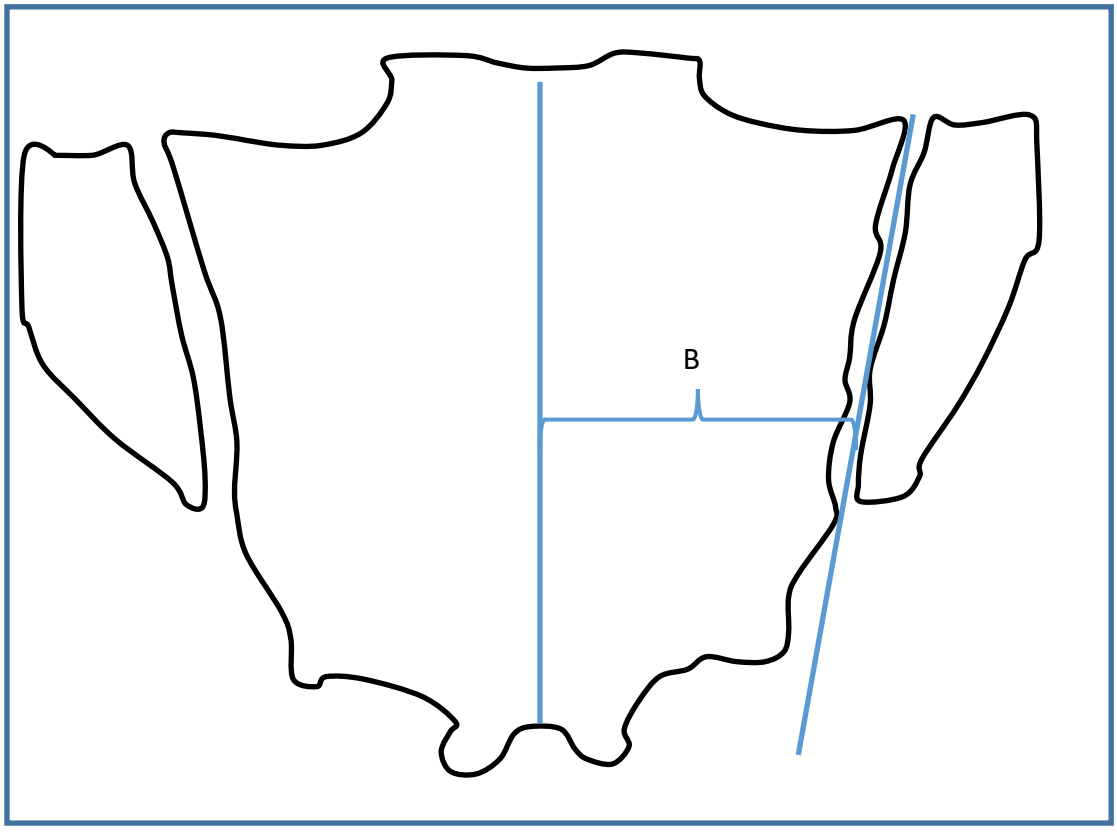

Figure 3 : Diagrammatic illustration of coronal cut of Sacral CT showing measurement of B: angle between SIJ & sagittal plane on coronal CT view

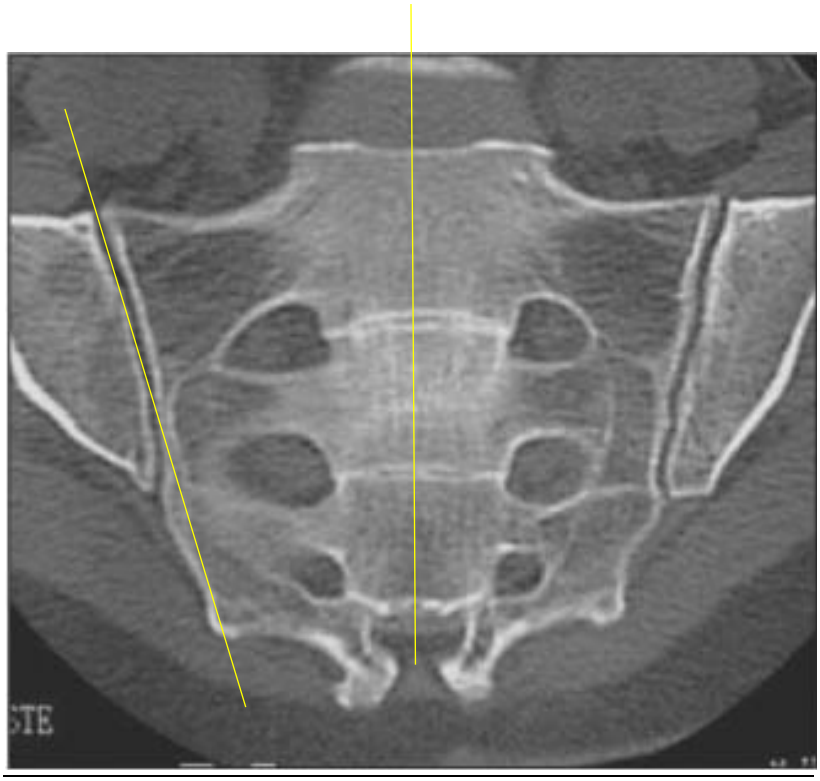

Figure 4 : A coronal cut of a patients pelvic CT showing the angle between SIJ and sagittal plane

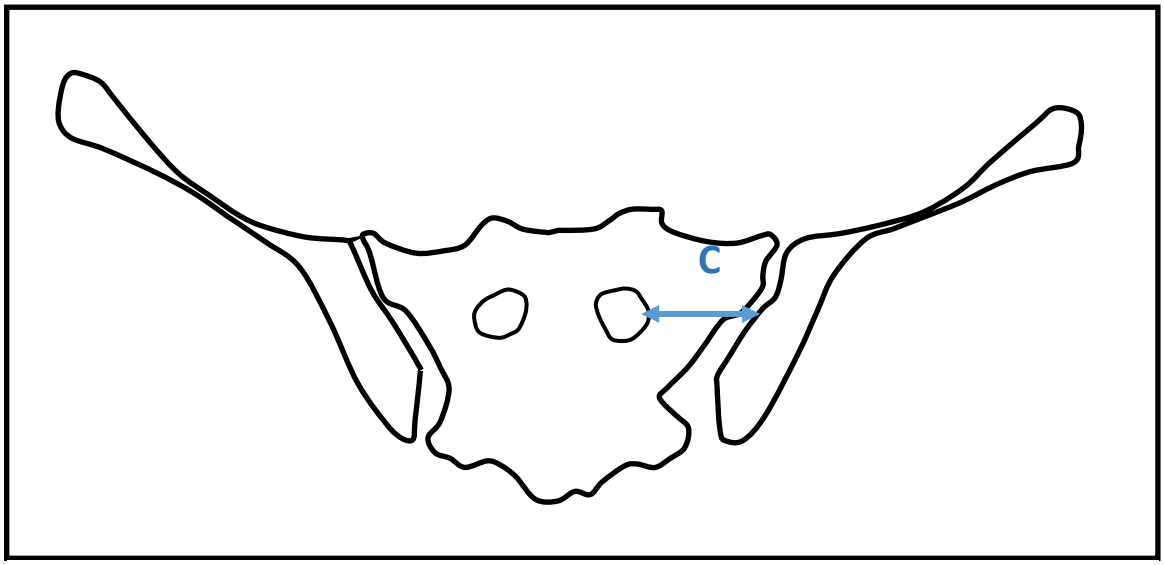

Figure 5 : Diagrammatic illustration showing measurement of C: the horizontal distance from the lateral edge of 1st sacral intervertebral foramen till the SIJ.

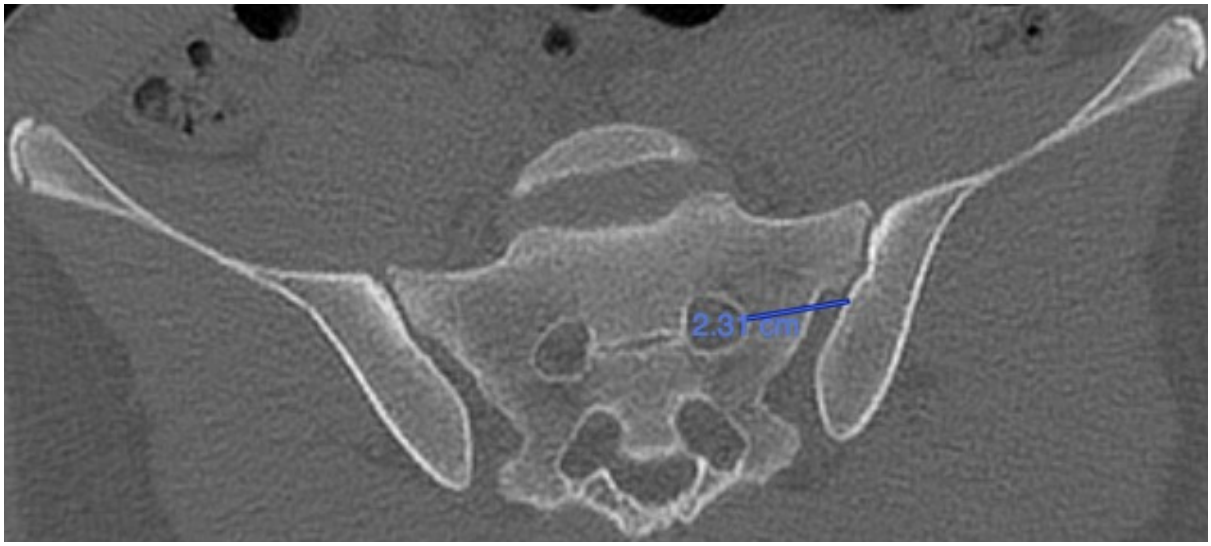

Figure 6 : An axial cut of a pelvic CT showing the horizontal distance from the lateral edge of the 1st sacral foramen till the SIJ.

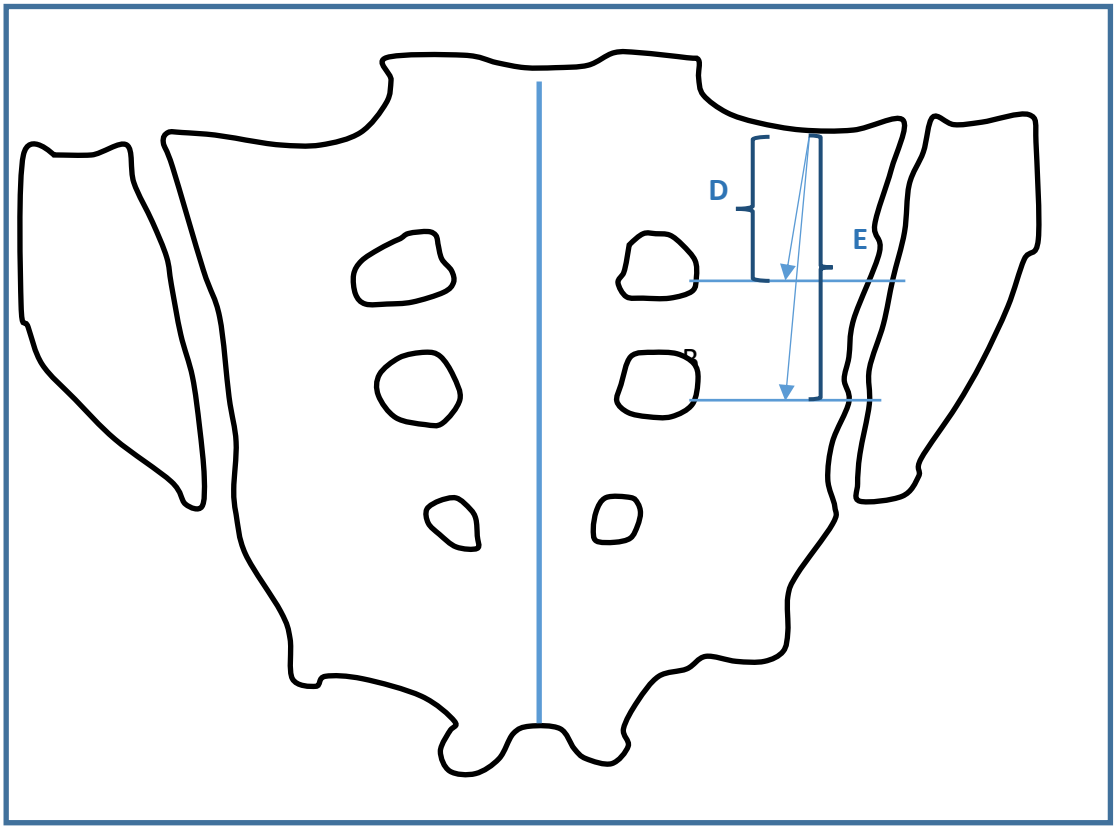

Figure 7 : Diagrammatic illustration of coronal cut of sacral CT showing distance from superior surface of sacral alar till, D: mid level of 1st sacral foramina, and E: distance till mid level of 2nd sacral foramina.

lamina bicortical diameter is measured from the outer cortex to the outer cortex,

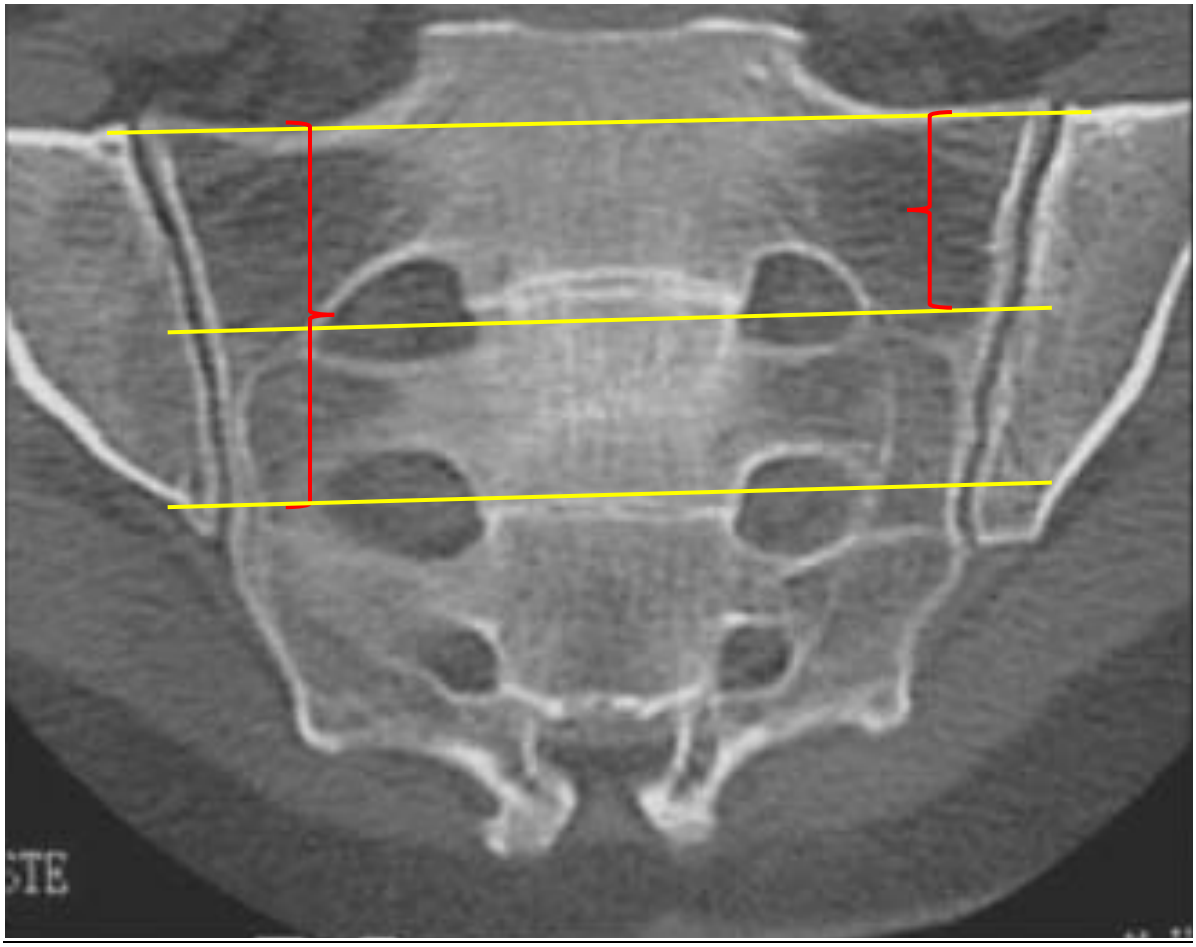

Figure 8 Coronal cut of a sacral CT showing distance from the superior surface of sacral alar till mid level of 1st and 2nd sacral foramina to depict the bony thickness for screw passage

3.7 ETHICAL CONSIDERATION

As this is an observational study using secondary data, there is no risk to patients. Data collected won't have identifiers such as name to ensure patient's privacy is well maintained.

1. **Subject vulnerability**

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

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

   There is no conflict of interest

3. **Privacy and confidentiality**

   All data collected are anonymous and will be entered into SPSS software. Only research team members can access the data. Data will be presented as grouped data and will not identify the responders individually. All collected data will be archived strictly for 5 years before being destroyed as per MREC protocol

4. **Community sensitivities and benefits**

   Not applicable

5. **Honorarium and incentives**

   Not applicable

CHAPTER 4: MANUSCRIPT

4.1 ABSTRACT

Introduction

Unstable sacroiliac joint injury treated with open reduction and internal fixation, and ventral sacroiliac joint plating has shown promising results and outcome with such injuries. The morphology of sacroiliac region however, has not been thoroughly studied in order to guide the application of screws when plating the sacroiliac joint. Hence, we performed a CT morphometric study of the sacroiliac region to determine the ideal screw trajectory and length in order to safely apply a ventral sacroiliac plate.

Materials and methods

A total of 112 Pelvic CT images performed in the year 2017 were measured after sagittal tilt, coronal tilt and axial rotation were adjusted. We measured sacroiliac joint angles on both true axial and coronal planes, along with osseus thickness between sacroiliac joint and 1st sacral foramina, vertical distance from superior sacral wall till mid level of 1st sacral foramina and till mid level of 2nd sacral foramina respectively. All parameters were measured up to 0.1^{o} and 0.1mm, and statistical analysis was performed using IBM SPSS Statistics Version 24. Independent t-test was used to determine the mean difference between sacroiliac joint angles in axial and coronal plane by gender. Descriptive analysis of the numerical variable was presented as mean (standard deviation).

Results

The mean sacroiliac joint angle in axial plane was 13.39^{o} (SD 5.51), sacroiliac joint angle in coronal plane was 14.17^{o} (SD 3.43), mean osseous thickness between sacroiliac joint and 1st sacral foramina was 20.80mm (SD 3.29), mean vertical distance from superior sacral wall till 1st sacral foramina 18.67mm (SD 5.01) and till 2nd sacral foramina 42.69mm (SD 5.31) respectively. Males however showed statistically significant higher SIJ angle in coronal plane when compared to their female counterparts with p=0.02.

Conclusion

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Key Words:

Sacroiliac joint, ventral plating, trajectory, CT measurement

4.2 INTRODUCTION

Injuries to the SIJ region resulting in unstable pelvic ring disruptions are high energy injuries which tend to present with multiple system involvement ending up with high mortality rate(7). Historically, unstable SIJ injuries has been treated with traditional traction and bed rest, resulting in severe disabilities such as chronic pain(8), non-union, malunion with limb length discrepancies, and prolonged recumbency(9-11).

With the advent of external fixator devices in the 1970's, it was soon apparent that external fixators play a vital role in the acute resuscitation period to reduce the intrapelvic volume and provide tamponade effect in order to reduce hemorrhage and stabilize patient's hemodynamic status(12). Multiple studies however, confirmed that these devices failed to contribute to adequate stabilization of an unstable pelvis (12, 13).

Multiple studies followed, emphasizing the importance of anatomical reduction of the SIJ to avoid chronic pain and to restore function (11, 13, 14). Study by McLaren (14) & Lindahl (15) showed that a mere 10mm and 5mm residual SIJ displacement respectively, resulted in poor outcome and chronic pain.

Hence, subsequent implants were aimed at providing anatomical reduction and to restore stability to an unstable pelvic fracture through direct SIJ fixation. These objectives were achieved through various fixation methods such as posterior iliosacral screw fixation, trans-sacral plating, and ventral sacroiliac plating with varying success.

Ventral plating of the SIJ boasts a more stable construct when compared to percutaneous iliosacral screw fixation, but we have noticed there is inadequate study of the morphology of this region(16, 17). We ventured to study the morphological details of the