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# Vascular Relationships of the Iliopubic Rami and Their Clinical Significance in Percutaneous Retrograde Fixation

Miguel Loureiro Fernandes

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2025

# Vascular Relationships of the Iliopubic Rami and Their Clinical Significance in Percutaneous Retrograde Fixation

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DESIGNAÇÃO DA ÁREA DO PROJECTO

Ciências Médicas e da Saúde - Medicina Clínica

TÍTULO DISSERTAÇÃO

Vascular relationships of the iliopubic rami and their clinical significance in percutaneous retrograde fixation

ORIENTADOR

Maria João Leite Cabral Monteiro de Almeida

COORIENTADOR (se aplicável)

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Eu, Miguel Loureiro Fernandes, abaixo-assinado, nº mecanográfico 201907085, estudante do 6º ano do Ciclo de Estudos Integrado em Medicina, na Faculdade de Medicina da Universidade do Porto, declaro que:

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À minha orientadora, Professora Maria João Leite por toda a ajuda, paciência e disponibilidade.

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Aos meus pais, irmã pela rede de segurança que me dão e por me aturarem.

Aos meus avós e tios por estarem sempre presentes de qualquer forma.

Aos meus amigos por me fazerem sentir em casa e acreditarem em mim, especialmente aos que já são família e a quem guardo eterno carinho.

À Anatomia por todos os excelente colegas e amigos que fizeram parte desta viagem, incluindo os residentes, Hélio e Professora Dulce.

**Abstract**

**Background**

Pelvic ring fractures, though relatively rare, are a significant concern in orthopedic trauma, particularly as they frequently involve the iliopubic (IP) rami. These structures are crucial for pelvic stability and locomotion. Injuries to the IP rami can lead to functional impairment and prolonged recovery. Traditional open reduction and internal fixation (ORIF) is widely used but presents challenges such as invasiveness, surgical duration, and postoperative complications. Consequently, percutaneous retrograde fixation has emerged as a less invasive alternative. However, a precise understanding of the anatomical and radiological parameters governing screw placement is essential to minimize complications and optimize outcomes.

**Questions/Purposes**

This study aims to (1) describe the morphology and anatomical variations of the IP rami, (2) define a potential safety corridor for percutaneous screw fixation, (3) analyze the relationship between the IP rami and major neurovascular structures, and (4) discuss our findings by comparing with previous reports in different populations to identify anatomic differences, patterns, and surgical important relations.

**Patients/Methods**

A retrospective cross-sectional analysis was conducted on 29 patients (25 on the left and 23 on the right totalizing 48 IP rami), using high-resolution computed tomography (CT) scans, being only possible to compare the left and right values in 19 cases, having not found significant differences between the left and right sides in any variable.

Morphometric parameters were recorded, including rami shape, diameters, and their relationship with neurovascular structures. Patients were 18 years or older, of Caucasian

descent, with adequate CT imaging. Cases with severe fractures, metabolic bone disorders, or tumors were excluded. Statistical analysis assessed variations based on sex, laterality, and fracture status. The reliability of measurements was ensured through intraclass correlation coefficients (ICC), and comparative analyses were conducted using nonparametric tests.

**Results**

(1) The most common rami shapes were triangular and trapezoidal, with circular and quadrangular shapes occurring less frequently. (2) The median narrowest diameter is significantly larger in males (8.67 mm) than in females (6.83 mm) ($p=0.011$) on the left side, which influences screw selection. (3) The obturator neurovascular bundle is located at a median distance of 3 mm from the IP rami on both the left ($p=0.976$) and right sides ($p=0.146$), highlighting the risk of neurovascular injury during fixation. The external iliac vein (EIV) is positioned approximately 5 mm from the rami, while the external iliac artery (EIA) is located at a median distance of 11 mm. Significant sex-based differences in the proximity of the external iliac vein to the IP rami on the left side were observed ($p=0.032$).

**Conclusion**

Our findings highlight the importance of preoperative planning and real-time imaging to minimize neurovascular injury risks. The proximity of the obturator neurovascular bundle and external iliac vessels to the IP rami necessitates precision in percutaneous fixation techniques. The EIV, lying closer to the rami at approximately 5 mm, presents a higher risk of iatrogenic injury than the EIA, which is positioned at 11 mm. Given anatomical variations, tailored screw selection is essential, with 6.5 mm screws generally safer for males and 4.5 mm for females. Female patients may have a higher risk of vascular injury due to their narrower IP rami and closer external iliac vessels positioning. Future research should focus on larger sample sizes

and advanced imaging techniques to refine neurovascular safety corridors and improve surgical safety. Level of Evidence: Level IV.

## Introduction

The iliopubic (IP) rami are structures that contribute for the formation of the anterior pelvic arch, essential in maintaining pelvic and trunk stability, allowing locomotion, and providing critical attachment sites for significant muscle groups that enhance lower limb mobility and support trunk stabilization [21]. Consequently, the structural integrity of these rami is paramount to the biomechanics of the human body, as any injury to this area can result in substantial pain and functional impairment [1].

Pelvic ring fractures represent between 0.3% and 6% of all fractures, but are much more common in polytrauma patients [6] and frequently involve the IP rami, which are among the most commonly affected structures when such fractures occur [14]. These fractures are predominantly observed in geriatric populations, typically because of low-energy trauma or osteoporosis [13]. Conversely, in younger individuals, high-energy traumatic incidents are the primary cause, with potentially significant morbidity if not managed properly [8, 13, 27]. Only cases with unstable fractures or tilt-like lesions demand internal stabilization, leading to the continuous evolution of surgical techniques to improve fixation efficacy [25]. Traditionally, open reduction and internal fixation (ORIF) has been employed in managing these injuries, despite its high invasiveness due to extensive dissection requirements and associated complications risks [27]. This complexity prompted a shift towards safer methods, leading to the development of the intramedullary approach, originally proposed by Lambotte in 1913 [5, 12], and later advanced by Tile, reviewed in [5] but most extensively described by Routt et al. [16, 17] . This technique reduces ORIF-related complications, is simpler to execute, preserves natural bony anatomy, minimizes blood loss and pain, shortens surgery duration, reduces infection rates, and facilitates earlier mobilization [5, 9] while providing stability [22]. Starr and colleagues also reported relatively low failure rate (15%), mostly among elderly patients, particularly women, likely due to poor bone quality in this group of patients [5]. In this setting, fluoroscopic-assisted computer navigation has been introduced to enhance procedural precision [28]. However, irrespective of technological aid, a thorough understanding of anatomy is critical to ensure procedural safety, enabling surgeons to perform the fixation accurately even when advanced navigation tools are unavailable.

Concerning the anatomical configuration of this region, recent studies on an Arabic cohort revealed that variations in the size and shape of the IP rami can substantially impact treatment strategies and implant selection for managing pelvic and acetabular fractures [9]. Consequently, understanding and describing the radiological safety corridor for screw insertion is essential. Recognizing this, we consider the retrograde percutaneous fixation technique, known for its superior fixation rates relative to the anterior approach [22], worthy of continued investigation and development to optimize its efficacy. The IP rami region has a close proximity to critical neurovascular structures, including the obturator neurovascular bundle and the external iliac vessels [10] , so its presence should be noted. Also, Thampi and collaborators verified the existence of anatomical variations in this region that may predispose to vascular complications [24]. Accordingly, precise anatomical study and a comprehensive understanding of global anatomical and radiological relationships are essential to minimize vascular injury risk during surgery [23]. This study, therefore, aims primarily to delineate and analyze the local neurovascular anatomy, specifically examining distances relevant to the external iliac vessels and obturator neurovascular bundle when performing percutaneous screw fixation for IP rami fractures. Additionally, it intends to outline the local surgical anatomy to assist in selecting the most appropriate implants for fracture fixation and to contribute to developing safe passageway guidelines for percutaneous rami fixation. This study represents one of the first analyses of the Caucasian population regarding IP rami anatomy description and relations to neurovascular structures.

## Materials and Methods

### Study Design

This study design was a cross-sectional retrospective analysis in which we aimed to describe the morphology and anatomy of the superior pubic ramus, contributing to determining a possible security hallway for percutaneous retrograde fixation. While defining safety, we were not only concerned about the rami bony limits but mainly its relation to major neurovascular references such as obturator neurovascular bundle and external iliac vessels in a Caucasian population.

The study protocol was approved by the Institutional Review Board – Ethics Committee CHUSJ (CE-393-2024).

### Sample Group

The inclusion criteria were: (1) 18 years old or older, (2) Caucasian race, (3) adequate computer topographies (CTs) in dorsal decubitus without fracture or with reduced fracture without displacement, and (4) clear visualization of obturator neurovascular bundle and external iliac vessels. CTs with prosthetic material were also included if they fulfilled the previous criteria and had clear bone limits.

The exclusion criteria were: (1) major fractures with complete distortion of pelvic girdle anatomy, (2) CTs without fracture reduction or highly comminuted fractures, (3) metabolic bone diseases, or (4) primary or secondary tumoral bone diseases.

To fulfill our objectives, we used a convenience sample. We began randomly collecting data from 50 consecutive CTs (100 superior pubic rami) from patients with suspected pelvic fractures evaluated at the emergency department of a Level 1 Trauma Center from 2007 until 2023. However, 52 of them didn't fulfill the inclusion criteria (3) and were comprised in excluding criteria (1) and (2). Excluding criteria (3) and (4) didn't exclude a single rami.

Therefore, our sample includes 29 cases, aged between 18 and 90 (median 50), representing 48 IP rami (25 on the left and 23 on the right). All included patients were Portuguese.

**Morphometric Parameters Assessment**

We used Sectra Uniview ® for our measurements. For bone-related aspects, we used the frequency "Bone". We confirmed the vessels' limits in each case in the "Abdominal /Mediastinum" frequency. When all crucial points were marked, we switched to the "Bone" frequency to collect our data. In addition, to increase data measurement quality, we simultaneously used coronal, horizontal, and sagittal views with a localizer tool, allowing us to see each point simultaneously in those plans so that we were certain about the position of our markings.

After collecting patient demographic data, we collected the rami shape and its narrowest point diameter. Regarding the shape, we defined 4 categories (1-triangular; 2-circular; 3-quadrangular; 4-trapezoid). Regarding the diameter, it was identified by consecutive measures using the largest possible fitting circle within the narrowest zone of cortical bone walls in a sagittal view **(Figure 1A).**

Secondly, we aligned the tree planes with the help of the localizer to get the most medial point of the IP rami. We could see this as the localizer would pass at the most anterior point of the pubic symphysis (PS) in a horizontal and sagittal plane. Then we would assess the better coronal plane where we were sure to be in the PS and have an optimal view of the osseous pathway by aligning the coronal frame with the horizontal one where we could see the supraacetabular portion where the screw would pass. Afterward, the axis was drawn in a coronal plane, parallel to and respecting the bone limits, until it reached the cortical bone of the iliac bone wing **(Figure 1B).** Then we could measure the cephalo-caudal angle of the predicted trajectory of the screw by subtracting 90 degrees from the obtained horizontal angle. We aimed to eliminate potential misleading angles, as some CT scans may not capture the patient in the correct position, potentially distorting the true angle.

For assessing distances related to the neurovascular obturator bundle we identified it and then drew a line from them until the intersection with the screw-predicted axis to assess the distance from the PS to them. However, for the distance to the IP rami we measured it by a perpendicular axis until it reached cortical bone (**Figure 1B)**. Regarding the acetabulum, we chose 2 points: one in the medial and the other in the lateral extremity to cover all its extension. After that, we also intersected these reference points with the screw-predicted axis (**Figure 1B)**.

The minimal thickness of the acetabular wall was measured in both coronal and sagittal planes by consecutive measures in the same coronal frame as the measures previously described (**Figure 1C).** To measure it, we aligned both coronal and sagittal planes with the horizontal one where we could see the bony portion of the acetabulum where the screw would pass and looked for the minimal thickness possible (**Figure 1C’, C´´)**. Thereafter, by marking the minimal distance possible we obtained our data.

The last measurement group is related to the external iliac vessels. Using the same axis orientation of the screw we would search the CTs coronal frame where the vessels would cross it, we measured them (with a parallel axis to the original one) (**Figures 1D and 1E**) and then transfer them to the original coronal frame**,** and proceed as we did with the measures for the distances to the PS. Concerning the vessels' distance to the IP rami we measured both in sagittal and coronal planes to also assess if they were concordant (**Figure 1F, F', F'').**

Each measurement was independently taken three times by two different observers and the median was considered. In the event of a discrepancy, a third researcher (MJA/ARP) was consulted for resolution. The values of the linear measurements are expressed in millimeters (mm).

Regarding Statistical analysis, we assessed the reliability among the three measurements with the intraclass correlation coefficient (ICC). Each measurement was described using the median of the mean values and Inter-Quartil Range (Q1-Q3).

The comparison between left and right sides, for those cases that had both measurements, was evaluated with the Wilcoxon test. The differences in measurements among male and female cases were evaluated for both the left and right sides and compared using the Mann-Whitney test. Cases with reduced fractures, with non-reduced fractures, and without fractures were evaluated for both the left and right sides and compared using the Kuskal-Wallis test and Mann-Whitney pairwise tests with Bonferroni adjustment. A significance level of 5% was considered.

## Results

As we explained before, from the initial sample, due to an absence of fulfillment of inclusion criteria or inclusion in the excluding criteria, a total of 29 cases were analyzed with a median age of 50 years (range: 18–90 years), of which 65% were male. Of these cases, 25 had measurements recorded on the left side, with the following distribution of rami shape: triangular in 32%, circular in 12%, quadrangular in 32%, and trapezoidal in 24%. Additionally, 23 cases had measurements recorded on the right side, with ramus shapes distributed as follows: triangular in 30%, circular in 35%, quadrangular in 5%, and trapezoidal in 30%.

All measurements exhibited an ICC greater than 0.9, indicating a high level of reliability among the three repeated measurements.

Table 1 presents the median and interquartile range of measurements on both the left side (n=25) and the right side (n=23). It was only possible to compare the left and right values in 19 cases (those that had both measurements) and we did not find significant differences between the left and right sides in any variable.

Tables 2 and 3 present the median and interquartile range of variables in male (n=17) and female (n=8) cases on the left side and in male (n=16) and female (n=7) cases on the left and right sides, respectively.

There were significant differences between males and females in both the sagittal acetabulum thickness ($p=0.004$ left; $p=0.018$ right) and coronal acetabulum thickness ($p=0.009$ left; $p=0.024$ right) on the right and left sides. Specifically, males exhibited higher median values than females on both sides.

Males also demonstrated higher median values for both the IP rami-external iliac vein (EIV) horizontal distance and the IP rami-EIV sagittal distance compared to females. However, this difference reached statistical significance only on the left side (p=0.032 horizontal; p=0.013 sagittal).

As for the neurovascular obturator bundle, males also have a higher median PS-cortical of iliac wing distance than females, although this difference was only statistically significant on the right side (p=0.049).

Tables 4 and 5 present the median and interquartile range of variables in cases with reduced fractures (RF), non-reduced fractures (NRF) and without fracture (non-fractured cases, NF) on the left and right sides, respectively.

Considering the left side (Table 4) significant differences in horizontal-axis (p=0.006), cephalo-caudal (p=0.006), and axis-horizontal (p=0.004) angles were observed among cases without fracture, with reduced fracture and non-reduced fracture (Figure 2).

For IP rami diameter, there was a significant difference between non-reduced and reduced fractures (p = 0.048) as well as between non-reduced and non-fractured cases (p = 0.007). However, no significant difference was found between reduced and non-fractured cases (p = 1.000). For the horizontal-axis angle, there was a significant difference between non-reduced and reduced fractures (p = 0.048) and between non-reduced and non-fractured cases (p = 0.007). However, no significant difference was found between reduced and non-fractured cases (p = 1.000).

For the cephalo-caudal angle, there was also a significant difference between non-reduced and reduced fractures ($p = 0.048$) as well as between non-reduced and non-fractured cases ($p = 0.007$), and no significant difference was found between reduced and non-fractured cases ($p = 1.000$). Similarly, in the axis-horizontal angle, significant differences were identified between non-reduced and reduced fractures ($p = 0.018$) and between non-reduced and non-fractured cases ($p = 0.009$), with no significant difference between reduced and non-fractured cases ($p = 1.000$).

Considering the right side (Table 5) no significant differences were observed among cases without fracture, with reduced fracture and non-reduced fracture.

## Discussion

Fluoroscopy is among the advancements that allow surgeons to observe screw progression in real-time, reducing but not eliminating possible complications [28]. This underscores the importance of anatomical knowledge, including major dimensions and spatial relationships, to further enhance surgical safety. Our study aimed to differentiate itself by focusing with particular interest on the neurovascular relationships of the IP rami, which we consider a key distinction relatively to the existing literature.

## Limitations

Our study presented several limitations, including a small sample size and the presence of fractures within the study group, which may have affected the generalizability of our findings. Additionally, there was a non-uniform distribution of sex among participants, potentially introducing bias. The study employed virtual trajectories of the screw rather than dedicated software, which may have impacted the precision of trajectory analysis. Another limitation was the absence of CT reconstruction, which could have provided more detailed anatomical insights. Furthermore, we did not measure the distances of the constrictions of the IP rami and the acetabulum from the PS, an important parameter for surgical planning. Finally, our measurements were limited to cephalo-caudal angles only, potentially restricting the comprehensiveness of our angular analysis.

## Morphological Characteristics

Regarding the IP rami, we found no significant difference between the left and right sides, aligning with expectations, as anatomically, both IP rami in an individual are typically similar. The findings of our study reveal that the most common morphological shapes of the rami are triangular and quadrangular on the right side, whereas circular shapes are more frequently observed on the left. The presence of shapes such as triangular, trapezoidal and quadrangular forms, suggests that adapting a straight plate to the rami or PS would be a viable option when necessary. However is important to highlight that the classical description of the morphology of the superior pubic ramus is stated as triangular with three surfaces and borders [21].

**IP rami diameter**

In our results, we did not find significant differences in IP rami diameter between sides, 8.00 mm (6.83-9.33) on the left and 7.67 mm (6.67-9.67) on the right. However, in a sex sub-analysis, on the left side, median distances of 8.67 mm (8.00-9.67) in men and 6.83 mm (5.17-7.53) in women were statistically significant, aligning with findings from other studies, as men generally have larger diameters than women. Nevertheless, even though on the right side there are no significant differences, the distance between men 8.67 mm (7.33 – 9.77) and women 6.67 (6.00-9.33) is bigger when compared to the left side. This may be due to the bigger standard deviations on the right side compared to the left. A research performed in a Caucasian population reports median diameters of 9.5 mm in men and 7.5 mm in women [15] and a study on a Chinese population demonstrate 8.76 mm in men and 7.58 mm in women [4], suggesting that these populations are similar with ours.

Despite this, the most used screw sizes are 6.5 mm, 7.0 mm, and 7.3 mm [9], though screws of this size cannot be used safely in most cases. Consequently, studies recommend 6.5 mm screws for men and 4.5 mm for women as generally safer options. Specifically, if we account for a 1-2 mm margin from the cortical bone [23], these screw sizes are suitable for most cases. Larger screws may be considered in particular cases as taller patients or in osteoporotic bone, as each case requires an individualized approach.

**PS – Cortical of iliac wing**

We found a median distance of 129 mm in men and 127 mm in women on the left side (p=0.793) and 127 mm in men and 120 mm in women on the right side (p=0.049), only the latter is statistically significant. We used a similar method of measurement as an Arabic study [9] and our right measures are similar to those of the mentioned study. However, regarding both sides' measurements, when compared to the Japanese (124.6mm for men and 123.8 for women) [23], Chinese (113,83mm for men and 105,16mm for women) [4], and Caucasian (110mm for men and 100.5mm for women) [15] populations they are bigger, having all of them also not found any statistically significant difference. Nonetheless, Ochs and colleagues (a Caucasian study) [15] used iPlan ® so their measures may be more exact and precise when compared to ours, but if the fractures don't extend to the acetabulum we don't need a screw that reaches it [20], so these differences may not have major implications in screw selection in all cases.

**Angles**

The software used for the measurements also influenced the cephalo-caudal angle, with our results showing median angles of 52º for men and 53º for women, differing from all other studies. We selected this angle due to its intuitive and easily visualizable nature [15]. An Arabic study reports averages of 49.9º for men and 42.1º for women [9], a Japanese reports 66º and 67º [9] , and a Caucasian one reports medians of 42.43º and 42.2º [15] , respectively. A Chinese study only provides a mean angle of 42.66º for both sexes [4]. This suggests similar cephalocaudal angles in all populations yet smaller than the Japanese. These differences could stem from regional anatomical variations. Comparing to the values reported in a study perfomed in a Caucasian population [15], their smaller angles may reflect higher measurement precision, as the authors defined exact screw insertion points, whereas we used a broader approach. This discrepancy may also result from our smaller sample size, as discussed in our study's limitations, or population differences. Similarly to Japanese [23] and Caucasian [15] studies, we found no significant differences between the sexes.

We also collected data regarding the presence and degree of fracture displacement, comparing NRF, RF, and conducting a sub-analysis comparing these groups with NF cases. We will discuss the distance from the neurovascular structures later.

The only significant difference we identified was in the cephalo-caudal angles on the left side, which measured 55º for NRF, 52º for RF, and 51º for NF ($p = 0.006$). This variation was predicted, as we aimed to exclude from our sample any fractures that were extremely deviated and could significantly distort normal anatomy. However, it was expected that some NRFs would present variations. As illustrated in Figure 2, the angle for NRF differs from those of RF and NF, indicating that proper closed reduction is crucial. This technique can either restore or approximate normal anatomy by ensuring correct screw placement while adhering to the precautions discussed earlier.

**Supracetabular region**

To enhance procedure safety, given that fractures may extend to the supracetabular region, we evaluated its position and thickness. The medial acetabular portion was located at a median distance of 65 mm on the left and 67 mm on the right from the PS, having not found any significant differences between sides or sexes, likely due to our limited sample size.

Regarding thickness, our study found that men had a median of 11 mm in both the sagittal and coronal planes, while women had a median of 8 mm on both sides, a statistically significant difference. An Arabic study reports an average of 8.37 mm for men and 6.45 mm for women [9], whereas a Japanese one found means of 14.2 mm for men and 11.6 mm for women [23], possibly indicating population-based anatomical differences. A Caucasian study presents medians of 11.5 mm for men and 8.5 mm for women [15], aligning closely with our findings which may validate our results. However, these findings are only useful in Nakatani type II and III fractures to have a safe periacetabular fixation and to not damage the hip joint as in Nakatani type I fractures we may not need to approach this region.

**Neurovascular Relations**

In the CT scans, we could not distinguish the nerve from the vessels, therefore we refer to the obturator canal contents as the "neurovascular obturator bundle." Due to their close anatomical relationship, an injury in this region could impact both structures.

In our study, the neurovascular obturator bundle is located at a median distance of 39 mm on the left and 40 mm on the right from the PS, with no statistically significant differences found by sex or IP rami condition. We also observed that the bundle was at a median distance of 3 mm from the IP rami on both sides and sexes, regardless of the IP rami's state, except for the non-fractured IP rami on the left, where a median distance of 2 mm was noted. However, this is not statistically significant (p=0.070).

It is crucial to consider the bundle's position during screw insertion, as even with the 2 mm safety margin, a 5 mm separation offers limited protection [26]. In cases of cortical violation, these structures can be easily compromised. Additionally, if a "corona mortis" is present, injury to this vessel can be life-threatening due to severe bleeding potential [18, 19]. A preoperative angio-CT can be valuable to identify the presence of this anastomosis and prevent injury, as each patient's anatomy varies [3].

Within the above-mentioned canal lies the obturator nerve that if injured may result in sensory loss, pain, and paresthesia extending from the medial side of the thigh to the knee, as well as impaired adduction of the ipsilateral hip joint [7]. If these structures are compromised, it can lead to increased multimorbidity post-surgery and hinder the patient's full recovery, prolonging rehabilitation. This damage also applies to non-eligible surgical patients, so hemodynamic monitoring and neurologic examination are crucial.

**External Iliac Vessels**

Regarding the external iliac vessels, their joint transverse dimensions is approximately 21 mm, and are located at a median distance of 67 mm from the PS. The EIV typically lies about 5 mm from the IP rami on both sides, with no significant differences observed. In a sex-based subgroup analysis, we found that the only significant difference was the EIV's distance to the IP rami on the left side, with women showing shorter distances compared to men, a median of 3 mm versus 7 mm (p=0.013). This difference could be due to our limited sample size, as discussed in our study's limitations, or may reflect anatomical differences between sexes, as the pelvic ring structure and the position of pelvic organs could contribute to this variation.

This finding aligns with a Japanese study, which reported shorter distances between the IP rami and EIV for women in a plane perpendicular to the screw axis, with means of 5.0 mm for men and 3.9 mm for women [23]. We hypothesize that similar differences may exist on the right side and suggest that a larger sample is needed to confirm these findings.

The EIA is located at a median distance of 80 mm from the PS on the left side and 78 mm on the right side; although no significant differences were noted, it lies 11 mm from the IP rami on both sides. In our subgroup sex analysis, in both sexes coronal and sagittal planes measures were concordant. Men had a median distance from the IP rami of 11 mm on the left and 12 mm on the right, which aligns with a Japanese study's finding of 12.2 mm in mean, while women had a median distance of 10 mm from both sides, with a Japanese study reporting 10.2 mm in mean [23]. Thus, while we did not find any significant differences, our results are consistent with those reported by the Japanese [23], validating our sample findings. Given that the EIA is a high-pressure vessel, any injury to it may lead to hypovolemic shock and mortality rates ranging from 24% to 60% [2]. Therefore, understanding its precise location may enhance surgical outcomes by providing better protection for this critical structure.

Our data also indicate that the EIV is positioned closer to the bone compared to the EIA, and due to their thinner walls, they are more susceptible to injury in the event of cortical violation, which carries a mortality rate of 55.6% to 77,8% [11].

Regarding these parameters related to the neurovascular structures, additional research with larger sample sizes is essential to further elucidate the neurovascular relationships in this region.

**Conclusion**

Nowadays, for most cases of IP rami fixation, it is recommended to use 6.5 mm screws in males and 4.5 mm screws in female patients, considering a 1-2 mm margin from the cortical bone. However, due to individual anatomical variations, this should be viewed as a general proposal, evidencing the need for customized surgical strategies. The acetabular wall thickness in the Caucasian population, according to our study and Ochs and collaborators [15], present median values of approximately 8-8.5 mm in females and 11-11.5 mm in males, which is crucial for ensuring safe periacetabular fixation in Nakatani type II and III fractures, while less relevant for type I fractures. From a practical perspective, the neurovascular obturator bundle is located at a median distance of 3 mm from the IP rami on both sides and sexes, with as little as 2 mm observed in some cases. This minimal separation underscores the need for extreme caution during screw or drill placement to avoid compromising these critical structures. The bundle passes closest to the medial portion of the IP rami, a region where cortical penetration must be strictly avoided. Similarly, the EIV lies approximately 5 mm from the IP rami, and the EIA is positioned at a median distance of 11 mm, both requiring careful consideration during surgical interventions. Fractures in this region, particularly if displaced, demand heightened vigilance due to the increased risk of life-threatening bleeding or functional impairments. Furthermore, achieving proper fracture reduction is essential for restoring the original cephalo-caudal angle.

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**Declaration of conflicting interests**

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## Figures and Tables

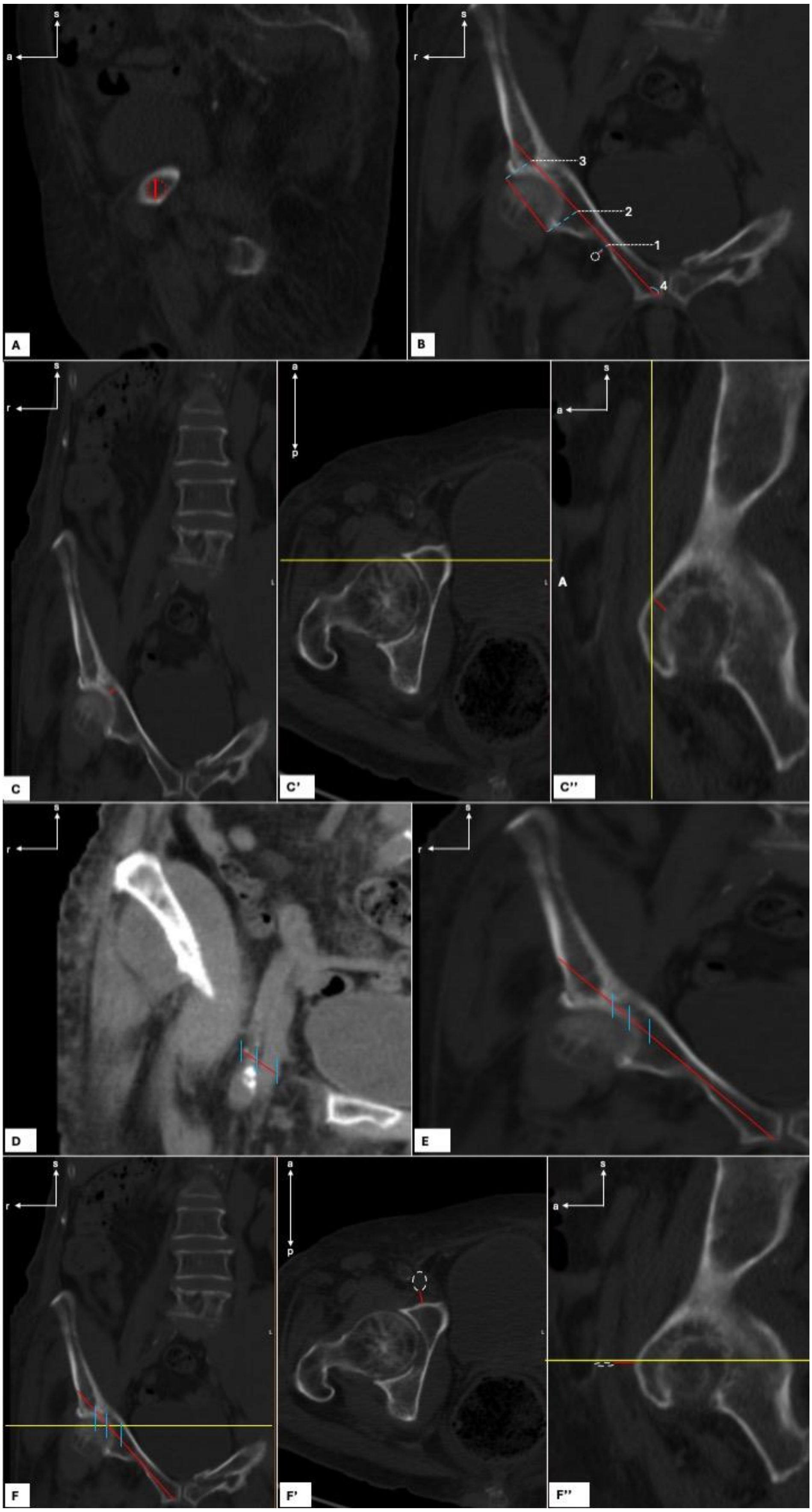

**Figure 1:** CTs Morphometric Parameters Assessment

(A) diameter of IP rami; (B) IP rami axis, neurovascular obturator bundle (white dashed circle) distance to IP rami, distances from the PS to the, neurovascular obturator bundle (1), medial and lateral limits of acetabulum (2) (3) and cephalo-caudal angle (4); (C) minimal coronal acetabulum thickness; (C’) predicted screw trajectory in acetabulum; (C’’) minimal sagittal acetabulum thickness; (D) identification of external iliac vessels; (E) position of external iliac vessels in relation to IP rami axis; (F) external iliac vein relation to IP rami axis; (F’) external iliac vein horizontal distance to IP rami; (F’’) external iliac vein sagittal (bundle (white dashed circle) distance to IP rami.

S- Superior; A- Anterior; R- Right; The yellow line represents the localizer;

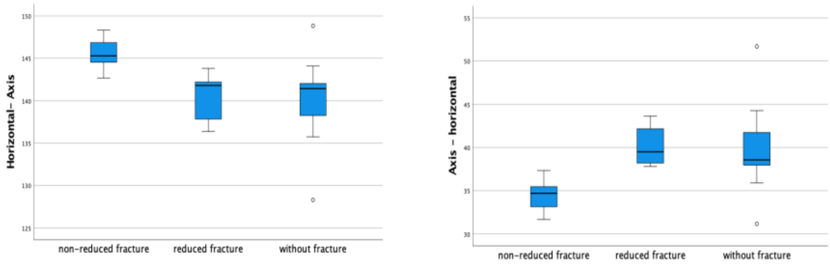


**Figure 2:** Angles comparison among non-reduced fractures (n=7) reduced fractures (n=5) and without fracture (n=13) cases on the left side.

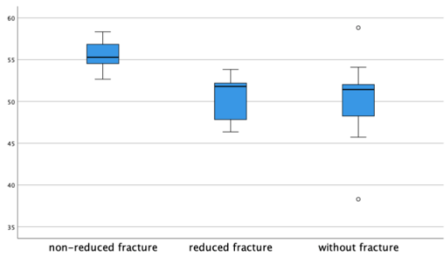


**Figure 3:** Iliopubic rami diameter comparison among non-reduced fractures (n=7) reduced fractures (n=5) and without fracture (n=13) cases on the left side.

**Table 1.** Median and interquartile range of measurements on both the left (n=25) and right (n=23) sides.

| | Left (n=25)<br>Median (Q1-Q3) | Right (n=23)<br>Median (Q1-Q3) |
|---|---|---|
| **IP rami diameter** | 8.00 (6.83-9.33) | 7.67 (6.67-9.67) |
| **Neurovascular obturator bundle** | | |
| PS- Cortical of the iliac wing | 129 (121-135) | 126 (121-136) |
| PS-Neurovascular obturator bundle | 39 (37-42) | 40 (36-44) |
| Neurovascular obturator bundle - Cortical of the iliac wing | 86 (82-95) | 87 (81-95) |
| Neurovascular obturator bundle - IP rami | 3 (2-4) | 3 (2-4) |
| **Acetabulum** | | |
| PS - Begining of acetabulum | 65 (58-72) | 67 (63-71) |
| Medial-Lateral limits acetabulum | 37 (33-40) | 36 (32-39) |
| Lateral limit of acetabulum - Cortical of the iliac wing | 23 (18-31) | 23 (19-31) |
| Acetabulum thickness sagittal | 9 (8-11) | 10 (8-11) |
| Acetabulum thickness coronal | 10 (8-11) | 10 (8-11) |
| **Angles** | | |
| Horizontal - Axis | 142 (139-145) | 141 (139-145) |
| Cephalo-caudal angle | 52 (49-55) | 51 (49-55) |
| Axis - Horizontal | 38 (35-41) | 39 (35-42) |
| **External Iliac Vessels** | | |
| PS – EIV | 67 (63-73) | 67 (63-71) |
| PS – EIA | 80 (73-86) | 78 (74-82) |
| IP rami - EIV Horizontal | 6 (4-8) | 5 (5-8) |
| IP rami - EIA Horizontal | 11 (9-13) | 11 (9-15) |
| IP rami -EIV Sagittal | 5 (4-8) | 5 (4-8) |
| IP rami -EIA Sagittal | 11 (9-14) | 11 (9-15) |
| PS - Lateral limit of Iliac vessels | 88 (82-97) | 86 (82-94) |
| Joint transverse dimensions | 21 (19-22) | 21 (18-24) |
| Joint transverse dimensions of the vessels - Horizontal | 22 (19-23) | 21 (19-23) |

**Table 2.** Median and interquartile range of variables in male (n=17) and female (n=8) cases on the left side.

| | Male (n=17) Median (Q1-Q3) | Female (n=8) Median (Q1-Q3) | p |
|---|---|---|---|
| **IP rami diameter** | 8.67 (8.00-9.67) | 6.83 (5.17-7.53) | **0.011** |
| **Neurovascular obturator bundle** | | | |
| PS- Cortical of the iliac wing | 129 (120-135) | 127 (123-135) | 0.793 |
| PS-Neurovascular obturator bundle | 39 (38-41) | 42 (34-45) | 0.381 |
| Neurovascular obturator bundle - Cortical of the iliac wing | 86 (82-95) | 89 (78-95) | 0.560 |
| Neurovascular obturator bundle - IP rami | 3 (2-4) | 3 (2-4) | 0.976 |
| **Acetabulum** | | | |
| PS - Begining of acetabulum | 63 (56-72) | 67 (60-72) | 0.560 |
| Medial-Lateral limits acetabulum | 38 (34-40) | 36 (32-39) | 0.308 |
| Lateral limit of acetabulum - Cortical of the iliac wing | 22 (19-31) | 25 (17-31) | 0.838 |
| Acetabulum thickness sagittal | 11 (9-11) | 8 (8-9) | **0.004** |
| Acetabulum thickness coronal | 11 (9-12) | 8 (8-10) | **0.009** |
| **Angles** | | | |
| Horizontal - Axis | 142º (138-144) | 143º (141-145) | 0.641 |
| Cephalo-caudal angle | 52º (48-54) | 53º (51-55) | 0.641 |
| Axis - Horizontal | 39º (36-42) | 38º (35-39) | 0.503 |
| **External Iliac Vessels** | | | |
| PS – EIV | 66 (63-71) | 73 (63-79) | 0.162 |
| PS – EIA | 78 (74-81) | 85 (71-90) | 0.503 |
| IP rami - EIV Horizontal | 7 (4-9) | 3 (1-7) | **0.032** |
| IP rami - EIA Horizontal | 11 (10-13) | 10 (7-14) | 0.319 |
| IP rami -EIV Sagittal | 7 (4-8) | 3 (1-6) | **0.013** |
| IP rami -EIA Sagittal | 11 (10-14) | 10 (7-14) | 0.291 |
| PS - Lateral limit of Iliac vessels | 88 (82-92) | 94 (80-98) | 0.560 |
| Joint transverse dimensions | 21 (19-22) | 20 (17-22) | 0.241 |
| Joint transverse dimensions of the vessels - Horizontal | 22 (19-24) | 21 (18-22) | 0.334 |

**Table 3.** Median and interquartile range of variables in male (n=16) and female (n=7) cases on the right side.

| | Male (n=16) Median (Q1-Q3) | Female (n=7) Median (Q1-Q3) | p |
|---|---|---|---|
| **IP rami diameter** | 8.67 (7.33-9.77) | 6.67 (6.00-9.33) | 0.056 |
| **Neurovascular obturator bundle** | | | |
| PS- Cortical of the iliac wing | 127 (124-138) | 120 (117-126) | **0.049** |
| PS-Neurovascular obturator bundle | 40 (37-43) | 42 (35-44) | 0.973 |
| Neurovascular obturator bundle - Cortical of the iliac wing | 88 (85-97) | 84 (76-90) | 0.061 |
| Neurovascular obturator bundle - IP rami | 3 (2-4) | 3 (2-3) | 0.146 |
| **Acetabulum** | | | |
| PS - Begining of acetabulum | 67 (63-71) | 70 (65-70) | 0.815 |
| Medial-Lateral limits acetabulum | 36 (32-40) | 34 (31-39) | 0.403 |
| Lateral limit of acetabulum - Cortical of the iliac wing | 27 (19-34) | 21 (16-24) | 0.109 |
| Acetabulum thickness sagittal | 11 (9-12) | 8 (7-9) | **0.018** |
| Acetabulum thickness coronal | 11 (9-12) | 8 (7-9) | **0.024** |
| **Angles** | | | |
| Horizontal - Axis | 141º (139-145) | 140º (137-148) | 0.815 |
| Cephalo-caudal angle | 52º (48-54) | 53º (51-55) | 0.815 |
| Axis - Horizontal | 39º (35-41) | 40º (31-43) | 0.738 |
| **External Iliac Vessels** | | | |
| PS – EIV | 66 (64-73) | 67 (81-71) | 0.947 |
| PS – EIA | 78 (74-84) | 78 (75-82) | 0.947 |
| IP rami - EIV Horizontal | 6 (5-9) | 5 (3-6) | **0.171** |
| IP rami - EIA Horizontal | 12 (9-17) | 10 (7-13) | 0.202 |
| IP rami -EIV Sagittal | 6 (4-9) | 5 (4-6) | **0.237** |
| IP rami -EIA Sagittal | 12 (9-16) | 10 (7-13) | 0.180 |
| PS - Lateral limit of Iliac vessels | 86 (83-95) | 86 (82-91) | 0.841 |
| Joint transverse dimensions | 20 (18-24) | 21 (17-24) | 0.920 |
| Joint transverse dimensions of the vessels - Horizontal | 21 (19-24) | 20 (17-23) | 0.402 |

**Table 4.** Median and interquartile range of variables in non-reduced fractures (n=7) reduced fractures (n=5) and without fracture (n=13) cases on the left side.

| | **Non-reduced fracture** Median (Q1-Q3) | **Reduced fracture** Median (Q1-Q3) | **Without fracture** Median (Q1-Q3) | **p** |
|---|---|---|---|---|
| **IP rami diameter** | 8.00 (7.00-8.33) | 9.33 (7.10-9.83) | 8.00 (6.33-10.65) | 0.590 |
| **Neurovascular obturator bundle** | | | | |
| PS- Cortical of the iliac wing | 129 (120-137) | 135 (125-137) | 123 (121-130) | 0.365 |
| PS-Neurovascular obturator bundle | 39 (36-44) | 40 (38-41) | 39 (34-44) | 0.985 |
| Neurovascular obturator bundle - Cortical of the iliac wing | 92 (80-99) | 94 (87-96) | 84 (81-94) | 0.477 |
| Neurovascular obturator bundle - IP rami | 3 (3-4) | 3 (2-6) | 2 (2-3) | 0.070 |
| **Acetabulum** | | | | |
| PS - Begining of acetabulum | 65 (55-72) | 71 (56-73) | 63 (61-71) | 0.872 |
| Medial-Lateral limits acetabulum | 38 (33-39) | 39 (34-43) | 36 (32-29) | 0.787 |
| Lateral limit of acetabulum - Cortical of the iliac wing | 24 (18-36) | 30 (21-32) | 22 (18-29) | 0.568 |
| Acetabulum thickness sagittal | 9 (8-10) | 11 (10-12) | 9 (8-11) | 0.251 |
| Acetabulum thickness coronal | 9 (8-11) | 11 (10-12) | 10 (9-11) | 0.237 |
| **Angles** | | | | |
| Horizontal - Axis | 145º (144-148) | 142º (137-143) | 141º (138 -143) | **0.006** |
| Cephalo-caudal angle | 55º (54-58) | 52º (47-53) | 51º (48-53) | **0.006** |
| Axis - Horizontal | 35º (32-36) | 40º (38-43) | 39º (37-42) | **0.004** |
| **External Iliac Vessels** | | | | |
| PS – EIV | 72 (64-80) | 67 (66-78) | 65 (60-70) | 0.171 |
| PS – EIA | 85 (72-90) | 81 (78-92) | 75 (72-82) | 0.134 |
| IP rami - EIV Horizontal | 7 (4-8) | 8 (3-10) | 4 (3-8) | 0.584 |
| IP rami - EIA Horizontal | 9 (8-15) | 11 (10-16) | 11 (9-13) | 0.523 |
| IP rami -EIV Sagittal | 7(4-7) | 7 (2-10) | 4 (3-8) | 0.786 |
| IP rami -EIA Sagittal | 9 (8-15) | 13 (10-17) | 11 (9-14) | 0.577 |
| PS - Lateral limit of Iliac vessels | 98 (82-98) | 89 (88-104) | 85 (81-91) | 0.143 |
| Joint transverse dimensions | 21 (18-22) | 22 (20-27) | 21 (18-22) | 0.518 |
| Joint transverse dimensions of the vessels - Horizontal | 22 (19-24) | 22 (20-26) | 20 (18-23) | 0.777 |

**Table 5.** Median and interquartile range of variables in non-reduced fractures (n=5) reduced fractures (n=6) and without fracture (n=12) cases on the right side.

| | **Non-reduced fracture** Median (Q1-Q3) | **Reduced fracture** Median (Q1-Q3) | **Without fracture** Median (Q1-Q3) | **p** |
|---|---|---|---|---|
| **IP rami diameter** | 7.67 (6.93-10.23) | 7.50 (6.24-9.42) | 8.87 (6.83-9.67) | 0.738 |
| **Neurovascular obturator bundle** | | | | |
| PS- Cortical of the iliac wing | 126 (114-150) | 126 (120-129) | 126 (122-137) | 0.794 |
| PS-Neurovascular obturator bundle | 44 (38-46) | 42 (38-44) | 37 (36-42) | 0.180 |
| Neurovascular obturator bundle - Cortical of the iliac wing | 80 (74-108) | 84 (80-87) | 90 (86-95) | 0.167 |
| Neurovascular obturator bundle - IP rami | 3 (2-4) | 3 (2-3) | 3 (2-4) | 0.624 |
| **Acetabulum** | | | | |
| PS - Begining of acetabulum | 70 (59-72) | 67 (60-70) | 67 (65-71) | 0.717 |
| Medial-Lateral limits acetabulum | 34 (33-38) | 39 (35-40) | 35 (31-39) | 0.266 |
| Lateral limit of acetabulum - Cortical of the iliac wing | 23 (16-46) | 21 (16-26) | 26 (21-31) | 0.429 |
| Acetabulum thickness sagittal | 10 (8-10) | 10 (9-10) | 10 (7-12) | 0.916 |
| Acetabulum thickness coronal | 10 (8-14) | 10 (8-10) | 10 (7-12) | 0.830 |
| **Angles** | | | | |
| Horizontal - Axis | 141º (138-146) | 141º (139-150) | 140º (138-145) | 0.639 |
| Cephalo-caudal angle | 51º (48-55) | 51º (49-60) | 50º (48-55) | 0.639 |
| Axis - Horizontal | 39º (34-42) | 39º (30-40) | 40º (35-42) | 0.660 |
| **External Iliac Vessels** | | | | |
| PS – EIV | 67 (66-78) | 67 (61-72) | 65 (62-74) | 0.426 |
| PS – EIA | 80 (75-90) | 79 (73-82) | 78 (73-85) | 0.735 |
| IP rami - EIV Horizontal | 5 (4-9) | 5 (4-9) | 6 (4-9) | 0.984 |
| IP rami - EIA Horizontal | 12 (9-16) | 13 (10-18) | 10 (8-15) | 0.587 |
| IP rami -EIV Sagittal | 5 (4-8) | 5 (4-8) | 6 (3-8) | 0.993 |
| IP rami -EIA Sagittal | 12 (9-16) | 12 (10-17) | 10 (8-14) | 0.698 |
| PS - Lateral limit of Iliac vessels | 90 (84-103) | 87 (80-91) | 85 (82-94) | 0.602 |
| Joint transverse dimensions | 19 (17-26) | 19 (17-26) | 22 (19-23) | 0.883 |
| Joint transverse dimensions of the vessels - Horizontal | 19 (17-26) | 21 (17-25) | 21 (20-23) | 0.940 |

**Appendix**

- Reporting guidelines (STROBE);

- Clinical Orthopaedics and Related Research submission guidelines;

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

| | Item No | Recommendation | Page No |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | Page 1.<br>"A retrospective cross-sectional analysis" |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 1 and 2.<br>"**Patients/Methods**<br>A retrospective cross-sectional analysis was conducted on 29 patients (25 on the left and 23 on the right totalizing 48 IP rami), using high-resolution computed tomography (CT) scans, being only possible to compare the left and right values in 19 cases, having not found significant differences between the left and right sides in any variable.<br>Morphometric parameters were recorded, including rami shape, diameters, and their relationship with neurovascular structures. Patients were 18 years or older, of Caucasian descent, with adequate CT imaging. Cases with severe fractures, metabolic bone disorders, or tumors were excluded. Statistical analysis assessed variations based on sex, laterality, and fracture status. The reliability of measurements was ensured through intraclass correlation coefficients (ICC), and comparative analyses were conducted using nonparametric tests.<br><br>**Results**<br>(1) The most common rami shapes were triangular and trapezoidal, with circular and quadrangular shapes occurring less frequently. (2) The median narrowest diameter is significantly larger in males (8.67 mm) than in females (6.83 mm) (p=0.011) on the left side, which influences screw selection. (3) The obturator neurovascular bundle is located at a median distance of 3 mm from the IP rami on both the left (p=0.976) and right sides (p=0.146), highlighting the risk of neurovascular injury during fixation. The external iliac vein (EIV) is positioned approximately 5 mm from the rami, while the external iliac artery (EIA) is located at a median distance of 11 mm. Significant sex-based differences in the proximity of the external iliac vein to the IP rami on the left side were observed (p=0.032). " |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Page 4 and 5.<br><br>"Pelvic ring fractures represent between 0.3% and 6% of all fractures, but are much more common in polytrauma patients and frequently involve the IP rami, which are among the most commonly affected structures when such fractures occur … Traditionally, open reduction and internal fixation (ORIF) has been employed… this complexity prompted a shift towards safer methods, leading to the development of the intramedullary approach… irrespective of technological aid, a thorough |

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| | | | understanding of anatomy is critical to ensure procedural safety, enabling surgeons to perform the fixation accurately even when advanced navigation tools are unavailable.” |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Page 5.<br>“This study, therefore, aims primarily to delineate and analyze the local neurovascular anatomy, specifically examining distances relevant to the external iliac vessels and obturator neurovascular bundle when performing percutaneous screw fixation for IP rami fractures. Additionally, it intends to outline the local surgical anatomy to assist in selecting the most appropriate implants for fracture fixation and to contribute to developing safe passageway guidelines for percutaneous rami fixation.” |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | Page 7.<br>“This study design was a cross-sectional retrospective analysis in which we aimed to describe the morphology and anatomy of the superior pubic ramus, contributing to determining a possible security hallway for percutaneous retrograde fixation” |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Page 8.<br>“To fulfill our objectives, we began randomly collecting data from 50 consecutive CTs (100 superior pubic rami) from patients with suspected pelvic fractures evaluated at the emergency department of a Level 1 Trauma Center from 2007 until 2023” |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants | Page 7.<br>“The inclusion criteria were: (1) 18 years old or older, (2) Caucasian race, (3) adequate computer topographies (CTs) in dorsal decubitus without fracture or with reduced fracture without displacement, and (4) clear visualization of obturator neurovascular bundle and external iliac vessels. CTs with prosthetic material were also included if they fulfilled the previous criteria and had clear bone limits.<br><br>The exclusion criteria were: (1) major fractures with complete distortion of pelvic girdle anatomy, (2) CTs without fracture reduction or highly comminuted fractures, (3) metabolic bone diseases, or (4) primary or secondary tumoral bone diseases.” |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic | Page 8 until 10.<br>“After collecting patient demographic data, we collected … The values of the linear measurements are expressed in millimeters (mm)” |

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| | | criteria, if applicable | |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Page 8.<br>"We used Sectra Uniview ® for our measurements. For bone-related aspects, we used the frequency "Bone". We confirmed the vessels' limits in each case in the "Abdominal /Mediastinum" frequency. When all crucial points were marked, we switched to the "Bone" frequency to collect our data. In addition, to increase data measurement quality, we simultaneously used coronal, horizontal, and sagittal views with a localizer tool, allowing us to see each point simultaneously in those plans so that we were certain about the position of our markings." |
| Bias | 9 | Describe any efforts to address potential sources of bias | Page 10.<br>"Each measurement was independently taken three times by two different observers and the median was considered. In the event of a discrepancy, a third researcher (MJA/ARP) was consulted for resolution." |
| Study size | 10 | Explain how the study size was arrived at | Page 8.<br>"To fulfill our objectives, we used a convenience sample. We began randomly collecting data from 50 consecutive CTs (100 superior pubic rami) …. However, 52 of them didn't fulfill the inclusion criteria (3) and were comprised in excluding criteria (1) and (2). Excluding criteria (3) and (4) didn't exclude a single rami." |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Page 10.<br>"Regarding Statistical analysis, we assessed the reliability among the three measurements with the intraclass correlation coefficient (ICC). Each measurement was described using the median of the mean values and Inter-Quartil Range (Q1-Q3)." |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | Page 10.<br>"Regarding Statistical analysis, we assessed the reliability among the three measurements with the intraclass correlation coefficient (ICC). Each measurement was described using the median of the mean values and Inter-Quartil Range (Q1-Q3) … Cases with reduced fractures, with non-reduced fractures, and without fractures were evaluated for both the left and right sides and compared using the Kuskal-Wallis test and Mann-Whitney pairwise tests with Bonferroni adjustment. A significance level of 5% was considered." |
| | | (*b*) Describe any methods used to examine subgroups and interactions | The methods used to describe the sex, left and right sides and analysis between reduced fractures, non-reduced fractures, and without fractures are the same indicated in the previous section (12(a). |

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| | | (*c*) Explain how missing data were addressed | Not applicable – every patient had all data that we proposed to collect. |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy | Not applicable – we use a convenience sample. |
| | | (*e*) Describe any sensitivity analyses | Not applicable – no sensitivity analysis was performed. |
| **Results** | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Page 11.<br>“a total of 29 cases were analyzed with a median age of 50 years (range: 18–90 years), of which 65% were male. Of these cases, 25 had measurements recorded on the left side, with the following distribution of rami shape: triangular in 32%, circular in 12%, quadrangular in 32%, and trapezoidal in 24%. Additionally, 23 cases had measurements recorded on the right side, with ramus shapes distributed as follows: triangular in 30%, circular in 35%, quadrangular in 5%, and trapezoidal in 30%.” |
| | | (b) Give reasons for non-participation at each stage | Page 11.<br>“As we explained before, from the initial sample, due to an absence of fulfillment of inclusion criteria or inclusion in the excluding criteria” |
| | | (c) Consider use of a flow diagram | Not applicable – the process of excluding patients, as it was simple, clear and objectively described and in this section |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Page 11.<br>“A total of 29 cases were analyzed with a median age of 50 years (range: 18–90 years), of which 65% were male. Of these cases, 25 had measurements recorded on the left side, with the following distribution of rami shape: triangular in 32%, circular in 12%, quadrangular in 32%, and trapezoidal in 24%. Additionally, 23 cases had measurements recorded on the right side, with ramus shapes distributed as follows: triangular in 30%, circular in 35%, quadrangular in 5%, and trapezoidal in 30%.” |
| | | (b) Indicate number of participants with missing data for each variable of interest | Not applicable - every patient had all data that we proposed to collect. |

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| Outcome data | 15* | Report numbers of outcome events or summary measures | Not applicable – we do not define outcomes. |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Not applicable - we do not have confounders. |
| | | (*b*) Report category boundaries when continuous variables were categorized | Not applicable - we do not have categoric variables. |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Not applicable - we do not have estimates of relative risk for a meaningful time period. |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Not applicable – no sensitive analysis was done. |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Page 19.<br><br>“Nowadays, for most cases of IP rami fixation, it is recommended to use 6.5 mm screws in males and 4.5 mm screws in female patients, considering a 1-2 mm margin from the cortical bone. However, due to individual anatomical variations, this should be viewed as a general proposal, evidencing the need for customized surgical strategies. The acetabular wall thickness in the Caucasian population, according to our study and Ochs et all. [17], averages |

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| | | | approximately 8-8.5 mm in females and 11-11.5 mm in males, which is crucial for ensuring safe periacetabular fixation in Nakatani type II and III fractures, while less relevant for type I fractures. From a practical perspective, the neurovascular obturator bundle is located at a median distance of 3 mm from the IP rami on both sides and sexes, with as little as 2 mm observed in some cases. This minimal separation underscores the need for extreme caution during screw or drill placement to avoid compromising these critical structures. The bundle passes closest to the medial portion of the IP rami, a region where cortical penetration must be strictly avoided. Similarly, the EIV lies approximately 5 mm from the IP rami, and the EIA is positioned at a median distance of 11 mm, both requiring careful consideration during surgical interventions. Fractures in this region, particularly if displaced, demand heightened vigilance due to the increased risk of life-threatening bleeding or functional impairments. Furthermore, achieving proper fracture reduction is essential for restoring the original cephalo-caudal angle.” |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Page 14.<br>“Our study presented several limitations, including a small sample size and the presence of fractures within the study group, which may have affected the generalizability of our findings. Additionally, there was a non-uniform distribution of sex among participants, potentially introducing bias. The study employed virtual trajectories of the screw rather than dedicated software, which may have impacted the precision of trajectory analysis. Another limitation was the absence of CT reconstruction, which could have provided more detailed anatomical insights. Furthermore, we did not measure the distances of the constrictions of the IP rami and the acetabulum from the PS, an important parameter for surgical planning. Finally, our measurements were limited to cephalo-caudal angles only, potentially restricting the comprehensiveness of our angular analysis.” |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Page 14 to 20<br>“Regarding the IP rami, we found no significant difference between the left and right sides… Regarding these parameters related to the neurovascular structures, additional research with larger sample sizes is essential to further elucidate the neurovascular relationships in this region.” |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Page 14.<br>“Our study presented several limitations, including a small sample size and the presence of fractures within the study group, which may have affected the generalizability of our |

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| | | | findings. Additionally, there was a non-uniform distribution of sex among participants, potentially introducing bias.” |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | “The authors received no financial support for the research of this article.” |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

# Clinical Orthopaedics and Related Research®

## Information For Authors


## Author Instructions by Article Type


## *CORR*® Clinical Research Article Submissions

**Clinical research manuscripts use patients to explore treatment, diagnosis, prognosis, or economic-decision analyses.**

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- All text must be double-spaced and 12-point Times New Roman font.
- Title page, Main Text, and all Tables must be provided as Word .doc/x files.
- Please use the equation editor or MathType for equations.
- Please do not use field functions.

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## Title Page

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A Title Page must be uploaded as a **separate** document from the blinded Manuscript, and include all of the following information:

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- Name, final degree(s), affiliation and e-mail address for all authors (**Note: list of authors must match the order stated on Title Page, and all email addresses must match those entered into the Editorial Manager at time of submission**)
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## Abstract

An Abstract structured with the sections outlined below must be included in the Manuscript and precede the Introduction section of the main text.

- *Background*

  1-2 sentences on what is known about the topic, followed by a sentence describing the deficiency in the literature that makes this study interesting and original.

- *Questions/purposes*

  2-4 explicit, testable questions or research purposes oriented around specific endpoints. These are meant to focus the reader on the messages you think are most important.

- *Patients/Methods*

  A brief description of your experimental methods, including study groups, comparisons made, etc.

- *Results*

  Provide 1 sentence answers to each of your questions. Each answer should refer back to its question, and where appropriate, each answer should provide an estimate of effect size (i.e. odds ratio, hazard ratio, or other metrics as needed) and the relevant statistical results in parentheses (please include exact p values unless < 0.001, in which case you may write p < 0.001).

- *Conclusion*

  Briefly explain the relevance of your findings and propose future research directions, if appropriate. Do not merely restate your results.

***Level of Evidence***

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## Main Text

The main text must be structured with the sections as outlined below.

#### Introduction

- *Background*

  1-2 paragraphs of background citing relevant literature describing what is known about the topic.

- *Rationale*

  Restate the questions/purposes, which you provided in the Abstract.

#### Patients/Methods

This section should contain information on the following sub-sections:

- *Study design and setting*
- *Participants*

- *Randomization (if applicable)*
- *Description of experiment, treatment, or surgery*
- *Aftercare/follow-up routine (if applicable)*
- *Variables, outcome measures, data sources, and bias*
- *Statistical analysis/study size*
- *Demographics/description of study population (if applicable)*
- *Accounting for all patients/study subjects (if applicable)*

**Results**

Use your research questions as subheadings under this section. Please answer each question with one paragraph of results.

**Discussion**

This section should contain information on the following sub-sections:

- *Limitations*
- *A paragraph for each question noted under "Questions/Purposes"*
- *Conclusion (1 paragraph)*

**References**

**To simplify the formatting process of your citations and references, we recommend authors use EndNoteand search for the *Clinical Orthopaedics and Related Research®* style and apply it to their manuscript before submitting.**

In-text citations:

Citations in the text should be identified by numbers contained within brackets, and not in superscript.

Examples:

"Negotiation research spans many disciplines [3]."

"Carrier systems include inorganic material synthetic polymer [10, 14, 18], natural polymers [14, 25, 33], and bone allograft [2, 16]."

"This effect has been widely studied [1-3, 7]."

List of References:

- The list of References should immediately follow the Discussion section of the Manuscript.
- The list of References must be in numerical sequence and alphabetized by the first author's last name (A-Z). All authors **up to 6** may be included; **if more than 6 authors, include the first 3 followed by "et al."**.
- If two references share identical authorship, the older publication date should be listed first.
- Use only official **PubMed journal abbreviations** and italicize those names. If the journal is not indexed in PubMed, then please include the full journal title in italics.
- Submission of references implies the authors have read the entire article and not merely the Abstract.
- The list of references should only include works cited that have been published or accepted for publication in full form.
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- Abstracts or preprints may not be used as citations.
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- Do not use footnotes or endnotes as a substitute for a reference list.

Examples:

Journal article

Kaplan FS, August CS, Dalinka MK. Bone densitometry observations of osteopetrosis in response to bone marrow transplantation. *Clin Orthop Relat Res*. 1993;294:79-84.

Chapter

Glick JM. Arthroscopic ankle arthrodesis. In: Guhl JF, Parisien JS, Boynton MD, eds. *Foot and Ankle Arthroscopy*. 3rd ed. Springer; 2004:163-174.

Book

Watkins RG. *Surgical Approaches to the Spine*. 2nd ed. Springer; 2003.

Website

Health Care Financing Administration. 2004 statistics. Available at: http://www.hcfa.gov/stats/stathili.htm. Accessed July 29, 2005.

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## Figures and Tables

- Figures and Tables must directly relate to a distinct point in the text; please avoid redundant illustrations.
- Figures and Tables must be numbered in Arabic numerals (e.g. 1, 2, 3, etc.) and cited in the Main Text in numerical order.
- All Figures and Tables must be **uploaded separately as individual files** (e.g. if there are 5 Figures, 5 separate figure files must be uploaded with the submission).

**Figures must be provided in JPEG, TIFF, or PNG format.**

**Tables and Flowcharts must be in editable Word .doc/x format.**

- For all previously published Figures and Tables included with a submission, authors are required to provide written permission from the copyright owner(s) for both the print and the online format. We do not refund any costs related to acquiring permissions**.** Any material received without permissions will be assumed to originate from the authors.

**Figures:**

- All interior Figure labels (i.e. A, B, C, D, etc.) should be added to the lower left-hand corner of the corresponding images.
- Arrows or lettering denoting particular features should be large enough to be seen when the photograph is reduced in size.
- Magnification, internal scale markers, and stains must be included when appropriate.
- Color may be used to make points not readily illustrated with black and white (e.g. surgical photographs, histologic sections, or complex graphics). However, the Journal will decide which images are to be printed in color. If you want to ensure color printing, please complete the color form upon article acceptance.
- To adhere to HIPAA regulations, no information should allow a patient to be identified. All faces and patient identifying marks must be masked/censored.

IMPORTANT: If absolutely essential to illustrate a key point, photographs of recognizable persons must be accompanied by signed consent from the subject or legal guardian.

**Figure Legends:**

- Figure Legends must be removed from the Figures and **provided separately** in a section following the List of References in the Manuscript.
- Legends must be written in grammatically complete sentences.
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- Identify previously published material by giving the original source in the form of a reference citation at the end of the figure description.

**Tables:**

- Provide a brief heading describing the table content. Tables do not have legends.
- All columns in a Table must have a heading, including the first column.
  - **For a horizontal table: 10-12 columns and 35-40 rows are maximum (including title and spacing).**
  - **For a vertical table: 6-8 columns and 50-60 rows are maximum (including title and spacing).**
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**Examples of acceptable ESM include**:

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- All supplementary material must be in standard file formats (PNG, JPG, PDF, TIFF, XLS, .doc/x, etc.).
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