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# A study of the incidence of the corona mortis within a South African patient sample using computerized tomographic angiography

Jade Naicker [a,*], Zithulele Nkosinathi Tshabalala [b], Jacques Janse van Rensburg [c], Andries Masenge [d], Obakeng Modisane [a], Steven Matshidza [e], Nkhensani Mogale [a]

[a] Department of Anatomy, Faculty of Health Sciences, School of Medicine, University of Pretoria, Gauteng, 9 Bophela Road, South Africa

[b] Department of Human Anatomy, Faculty of Health Sciences, School of Medicine, Nelson Mandela University,Eastern Cape,Old Uitenhage Road, South Africa

[c] Department of Diagnostic Radiology, Faculty of Health Sciences, School of Medicine, University of Free State, Free State, 3 Budget Avenue, South Africa

[d] Department of Statistics, Faculty of Natural and Agricultural Sciences, University of Pretoria, Gauteng, Lynwood Road and Roper Street, South Africa

[e] Department of Orthopaedics, Faculty of Health Sciences, School of Medicine, University of Free State, Free State, 3 Budget Avenue, South Africa

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ABSTRACT

*Introduction:* Retropubic hematomas are a common development in cases of pelvic ring trauma and post- operative repair of fractures to the anterior column of the pelvis. Early detection and diagnosis of such events using computed tomography angiography (CTA) are critical for successful intervention and patient recovery, especially when bleeding is a result of injury to the corona mortis (CM). The CM is the communication between the obturator vessels and the external iliac vessels typically via an accessory obturator vessel. This communication of vessels is identified as a major hindrance in anterior approaches to the pelvis.

*Materials and Methods:* This study investigated the incidence of CM and mapped out safe zones for the anastomosis in a South African sample using 73 adult angiograms from the Department of Diagnostic Radiology, Universitas Academic Hospital. After careful observation of the iliac system, the incidence of CM was documented. The distance from the CM to clinically relevant bony landmarks were recorded to formulate safe zones.

*Results:* The incidence of CM was observed in 33.1 % of the sample, with 20 % being venous and 13.1 % being arterial anastomoses. Statistically significant differences between the sexes were noted for safe zones between all landmarks except for the pubic tubercle ($p \geq 0.26$). The safe zone between the CM and the pubic tubercle were documented as 46.88 mm and the average diameter for all anastomotic vessels was noted as 2.83 mm (Range: 1.75 - 4.61 mm).

*Conclusion:* The inconsistencies presented in angiogram studies compared to cadaver studies suggest that angiograms should be limited to a diagnostic and therapeutic role of identifying the CM or injury thereof in the retropubic region. However, measurements concerning safe zones should rather be extracted from cadaveric studies.

## Introduction

Modalities of biomedical visualization such as computed tomography angiography (CTA) scanning can be effective in identifying the vascular anomaly that is the corona mortis (CM). These modalities provide surgeons with useful detection and diagnostic measures in order to administer effective and minimally invasive procedures [1]. CM or the ‘crown of death’ is a term that describes the anomalous communication between the obturator vessels and external iliac vessels or its inferior epigastric branch [2]. The anastomoses are completed by an accessory obturator vessel, a variant branch of the external iliac vessels, or its branches, that cross over the superior pubic ramus [2,3]. The CM is a variable anastomosis that rests posterior to the superior pubic ramus, within the retropubic space.

The clinical threat of the CM is significant and includes the inadvertent severing of its constituent vessels during anterior orthopedic approaches to the pelvis, leading to vascular spasm and retraction as well as pronounced hemorrhaging if not detected [4]. This reaction is

* Corresponding author. Dr Savage Road, Prinshof 349-Jr, Pretoria, 0084 Basic Medical Sciences building, Room 3-17, Prinshof Medical Campus, University of Pretoria, South Africa

*E-mail addresses:* Naicker.Jade@up.ac.za (J. Naicker), Zithulele.Tshabalala@mandela.ac.za (Z.N. Tshabalala), Jansevrj@ufs.ac.za (J.J. van Rensburg), Andries.Masenge@up.ac.za (A. Masenge), obakengc.modisane@gmail.com (O. Modisane), MatshidzaS@ufs.ac.za (S. Matshidza), Nkhensani.Mogale@up.ac.za (N. Mogale).

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not only an eminent threat associated with the CM but may also pose some difficulty during its visualization using computed tomography (CT) imaging [5]. Retropubic hematomas and fractures cause regional distortion in CT imaging, making the identification and diagnosis of the CM difficult [5]. However, angiography is still seen as the ideal tool for identifying the CM [6]. Additionally, angiography can aid in the repair of severed CM vessels via embolization, providing direct and prompt therapy to hemorrhaging vessels that may otherwise lead to hematomas [7]. It is evident that continued research needs to be done on the use of angiogram and CTA to further understand the CM, especially to evaluate its clinical significance.

Previous cadaver studies have widely reported on the prominent presence of venous anastomoses [1,4,8–13]. Investigations on the sensitivity of angiographic tools in identifying venous cases as well as retropubic hemorrhaging are needed considering the high incidence of venous anastomoses. The site of CM is said to range from the superior iliac crest to the pubic symphysis. As a result of this locality, the CM can inadvertently be severed when accessing the pelvis during anterior approaches, particularly using the Modified Stoppa approach. Therefore, investigating the incidence of CM and formulating appropriate safe zones where the CM is least likely to occur using relative landmarks will assist clinicians in avoiding the threat of CM injury, while promoting ideal recovery and patient health.

Although the incidence of CM has been more extensively studied using mainly cadaveric samples, CT angiogram studies serve to provide a more clinically centered investigation of the CM anomaly [13]. CT angiography can be utilized as a diagnostic tool, aiding the identification of the CM or retropubic hematomas as a result of injury [5]. However, there have been many inconsistencies between cadaveric and patient CT studies as reported in a review article by Papagrigorakis et al. [14]. The comparison between cadaveric and CT studies showed a lack of agreement between the samples, presenting a decreased incidence of CM in CT and patient studies. The minimal accounts of bleeding and morbidity as a result of severing these anomalous vessels and reasons for these inconsistencies are yet to be identified [14]. Therefore, it is necessary to investigate the CM using imaging by identifying and relating it to fixed landmarks to conceptualize the CM intraoperatively, which can in turn broaden the discussion of its clinical implications.

## Materials and methods

### Materials

A total of 73 ($n = 73$) pelvic angiograms of 49 male and 24 female patients, with an intact pelvis (145 hemi-pelves) of ages ranging between 18 to 85 years (mean age: 59, SD ± 14.6) were retrospectively observed. The angiograms were obtained from the Department of Diagnostic Radiology, Universitas Academic Hospital. Ethical clearance was obtained from the University of Pretoria, Faculty of Health Sciences Research Ethics Committee (Ethical clearance number: 259/2020) as well the University of Free State, Health Sciences Research Ethics committee (Ethical clearance number: UFS-HSD2020/15,557/2601) and the Free State Health Research Committee (Clearance number: FS_202,011_007). Research was conducted in accordance with the South African National Health Act 61 of 2003.

Angiograms of patients who presented with pathology or trauma that affected the visualization of the pelvic blood supply were not included. Angiograms displaying poor contrast and patients who were not in the correct supine orientation and presented with a tilted pelvis, were also excluded from the study.

### Methods

Seventy-three CT angiograms depicting the pelvic anatomy of patients, using the Discovery 750 HD 64-slice CT scanner, were analyzed from the patient database. These patients had been admitted to the Universitas Academic Hospital between 2020 and 2021. The raw images were viewed and analyzed using the ImageJ display program. Scans with clear visualization of pelvic blood supply were assessed by identifying the obturator vessels branching from or draining into the anterior division of the internal iliac vessels. Focus was placed on the medial aspect of the superior pubic ramus and any vessel which crossed the landmark was further investigated and identified. Any anastomoses between the obturator vessels and the external iliac vessels or any of its branches were classified as the CM and the incidence was recorded.

Any variations in the origin of the obturator artery or the drainage of the obturator vein as well as variations of any anastomosing component of the CM were documented. Measurements were simulated to scale on the angiograms using the Image J program. These included the distance from the CM to the:

- Midpoint of the superior pubic symphysis (SPS) (Fig. 1a)
- Midpoint of the posterior pubic symphysis (PPS) (Fig. 1b)
- The most anterior point of the pubic tubercle (PT) (Fig. 1c)
- The most anterior part of the anterior inferior iliac spine (AIIS) (Fig. 1d)

The specific CT slices depicting these exact landmarks were noted and stacked together in ImageJ along with the CT slice clearly depicting the CM anastomosis. A line was drawn from the fixed point of the CM using the line tool on ImageJ to the four above-mentioned landmarks. The length of the line and the diameter of the anastomotic vessels were then measured using the measure tool on ImageJ (Fig. 1e, 1f).

Comparison of the measurements between left and right sides and sexes was done using paired and unpaired *t*-tests, respectively. Interobserver and intraobserver reliability testing was done using 10 % of the sample and analysed using interclass correlation.

## Results

The current angiogram study exhibited a 33.1 % ($n = 48/145$) incidence of CM amongst the sample of 145 CT scanned hemi-pelves. The respective incidences of CM are documented in Table 1. The incidence of CM was reported as 33.3 % ($n = 16/48$) among the 24 females and 32.7 % ($n = 32/48$) among the 49 males.

Variations in the drainage of the obturator vein was observed, as 0.7 % ($n = 1/145$) of veins drained into the external iliac vein (Fig. 2). This vessel was classified as an aberrant obturator vein and crossed the superior pubic ramus similarly to the accessory obturator vein.

An anastomosis between the obturator vein and accessory obturator vein occurred in 29 % ($n = 42/145$) of cases, creating a venous CM. During these anastomoses, the accessory obturator vein, classified as an additional obturator vessel, was observed draining into the external iliac vein or its tributaries, specifically the inferior epigastric vein. Results show that in 83.3 % ($n = 35/42$) of cases, the accessory obturator veins drained into the external iliac vein and into the inferior epigastric vein in 16.7 % ($n = 7/42$) of cases. In 31 % ($n = 13/42$) of cases, the accessory obturator vein was seen not participating in an anastomosis with the obturator vein and was therefore not classified as CM. However, this vessel still maintained its course over the pelvic brim before draining into the external iliac system (Fig. 3).

Arterial CM consisted of an anastomosis between the accessory obturator artery and the obturator artery. This was observed in 13.1 % ($n = 19/145$) of cases. Accessory obturator arteries were observed as originating from either the inferior epigastric artery or the external iliac artery in incidences of 40.9 % ($n = 9/22$) and 59.1 % ($n = 13/22$), respectively (Fig. 4). Accessory obturator arteries were also classified as additional obturator vessels that originate from the external iliac system. These arteries coursed over the pelvic brim and on the medial aspect of the superior pubic ramus before entering the obturator canal.

The obturator artery also exhibited variations in its origin as 4.8 % ($n = 7/145$) of the obturator arteries originated from the external iliac

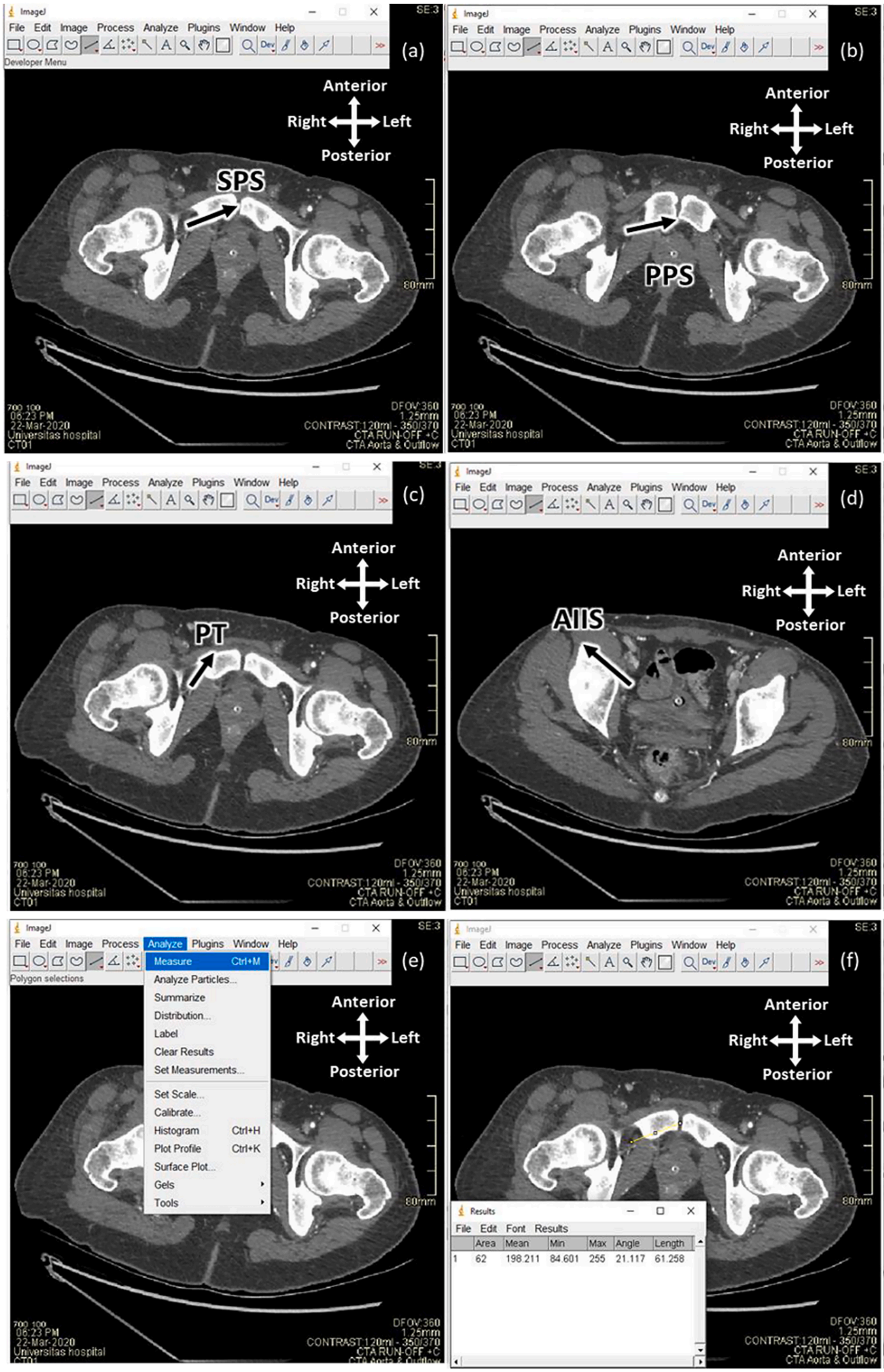


**Fig. 1.** Measurements taken between the corona mortis (CM) and the various bony landmarks. ***Key: (a)*** *Distance between the CM and the midpoint of the superior pubic symphysis (SPS),* ***(b)*** *Distance between the CM and the midpoint of the posterior pubic symphysis (PPS),* ***(c)*** *Distance between the CM and the most anterior point of the pubic tubercle (PT),* ***(d)*** *Distance between the CM and the most anterior point of the anterior inferior iliac spine (AIIS). These lines were then measured as seen using Image J software* ***(e)****, thereafter the program produced output as seen in image* ***(f)****, with the length measurement being captured.*

**Table 1**
The incidence of corona mortis on the left and right sides, including bilateral cases for all corona mortis cases as well as all venous and arterial cases. (***Key: CM:*** *Corona mortis)*.

| Incidence (%) | Left side | Right side | Bilateral | Overall |
|---|---|---|---|---|
| **CM (n)** | 39.6 (19) | 60.4 (29) | 45.8 (22) | 33.1 (48) |
| **Venous CM (n)** | 48.3 (14) | 51.7 (15) | 17.2 (5) | 20.0 (29) |
| **Arterial CM (n)** | 26.3 (5) | 73.7 (14) | 10.5 (2) | 13.1 (19) |

artery and 4.1 % ($n = 6/145$) originated from the inferior epigastric artery. Therefore, these vessels were classified as aberrant obturator arteries (Fig. 5).

The overall average and two-standard deviation of the diameter of the anastomotic vessels was reported as 2.83 ± 1.38 mm (Range: 1.75 - 4.61 mm). While 5 cases presented with a diameter more than 4 mm. All distances between the CM and the four bony landmarks exhibited no statistically significant difference between the left and right sides with p-values of 0.70 and higher. Comparisons of the distances between the CM

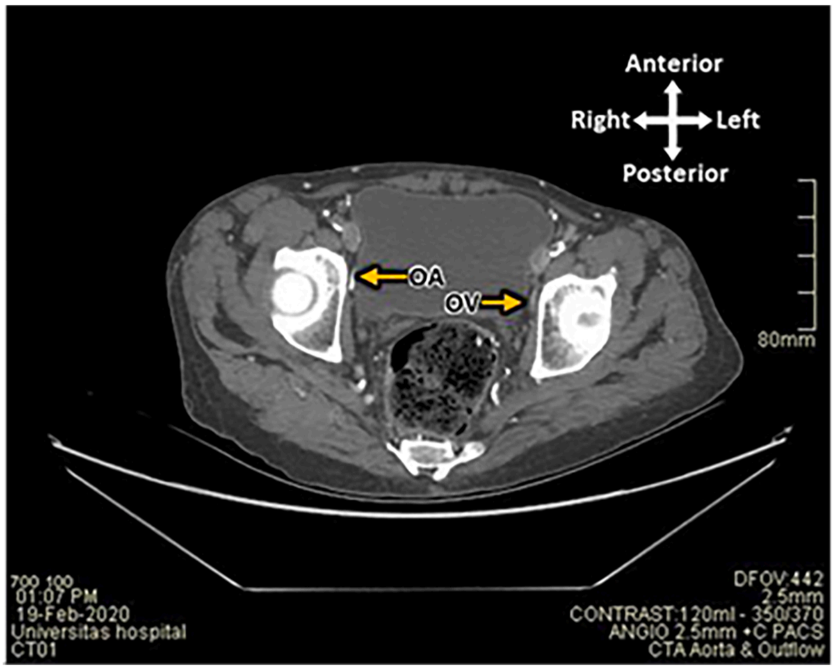


**Fig. 2.** Angiogram depicting an aberrant obturator artery (OA) and obturator vein (OV) originating from the external iliac artery and draining into the external iliac vein respectively. ***Key: OA:*** *Obturator artery,* ***OV:*** *Obturator vein.*

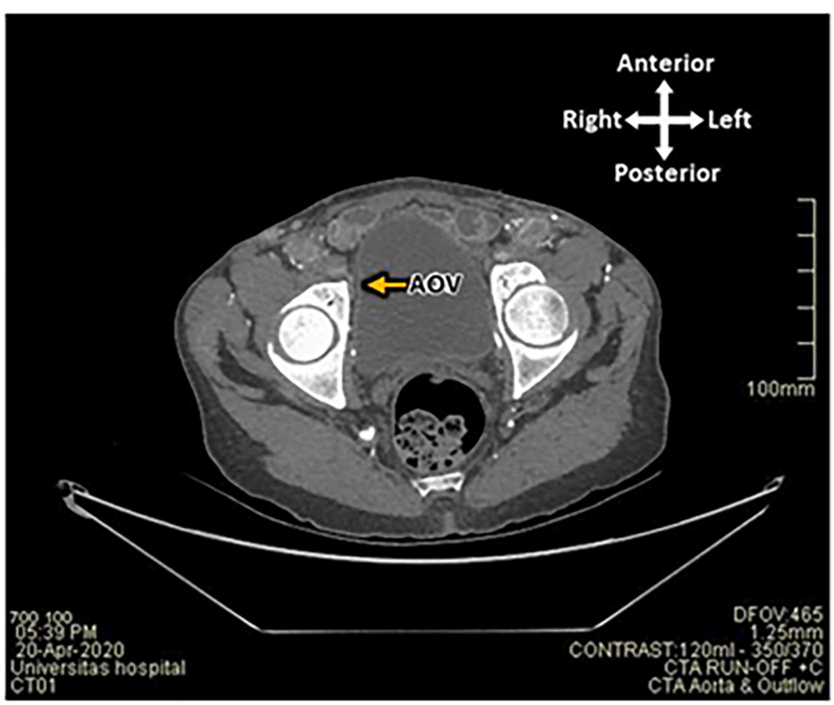


**Fig. 3.** The accessory obturator vein (AOV) draining into the external iliac vein. ***Key: AOV:*** *Accessory obturator vein.*

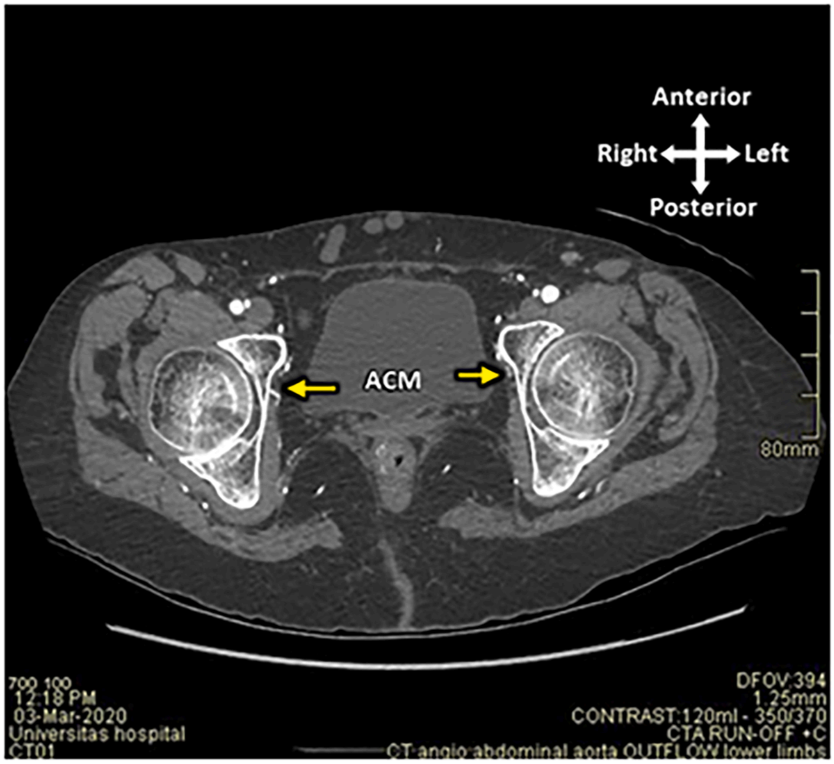


**Fig. 4.** A bilateral arterial corona mortis (ACM) on the left and right sides consisting of two accessory obturator arteries, originating from the external iliac artery, which formed an anastomosis with two obturator arteries. ***Key: ACM:*** *Arterial corona mortis.*

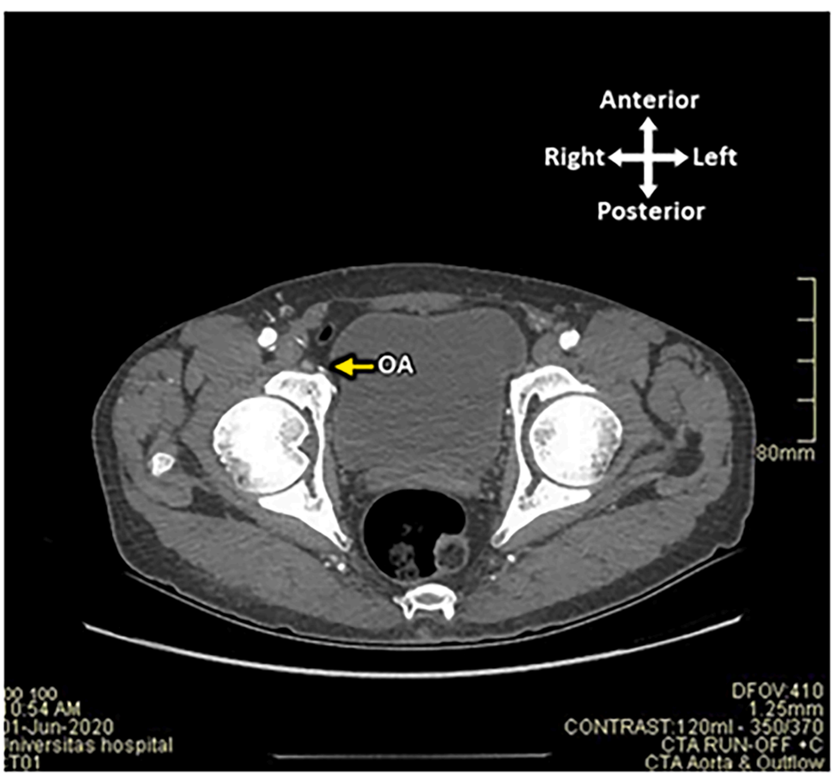


**Fig. 5.** The aberrant obturator artery (OA) which originates from the external iliac artery. ***Key: OA:*** *Obturator artery.*

and the SPS and PPS revealed that a statistically significant difference ($p = 0.01$) existed between male and females. While both distances between the CM and the PT and AIIS noted that no statistically significant difference ($p = 0.26$) existed between males and females. Therefore, it can be concluded that a statistically significant difference exists between males and females for safe zones from the CM to the superior and posterior midpoints of the PS which is presented in Table 2 below.

An excellent correlation co-efficient ranging between 0.95 – 0.99 was calculated for comparison between the inter and intra-observer and the original data as well as between inter- and intra-observer, meaning the intra-observer reliability is highly consistent with the original data and one can conclude the accuracy of results and repeatability of the methods.

## Discussion

The current study reported an incidence of 33.1 % ($n$ = 48/145) of CM cases amongst the 145 angiographic pelvic sides. This incidence correlates with multiple CT imaging studies that have identified the anomaly [15–18]. In a study investigating 100 hemi-pelves using angiographic CT scans, Steinberg et al. noted an incidence of 33 % ($n$ = 66/200) CM with a total of 15 bilateral cases in their sample, exhibiting close correlation with the current study's findings [17]. Table 3 summarizes the findings of previous angiographic studies that present similar results regarding the incidence of CM.

The current CT angiogram study observed 20 % ($n$ = 29/145) of venous CM cases. Higher cases of venous CM are not commonly reported in angiogram studies, with most studies exclusively investigating arterial CM as seen in Table 4 [5,15,17,18]. The lack of reporting of the incidence of venous CM does limit comparison with cadaveric studies as many report a predominant incidence of venous anastomoses [4,8,9,11,19].

A possible explanation for the higher incidence of arterial CM cases and lower observations of venous CM cases in angiogram studies could be the limited visualization of vasculature in CT imaging. Contrast of anatomical structures differ between arterial and venous vessels depending on the injection of contrast medium, and the reliance on anatomical relations to differentiate arteries from veins due to their similarities in densities [20]. The current study sample exhibited a lack of contrast of venous structures, making observations more ambiguous when identifying cases of CM which may explain the decreased incidence of CM cases compared to cadaver studies. Another explanation for the discrepancy in the incidence of CM between studies is the inconsistency regarding the description of a CM. The current study categorized the CM as a connection between the external and internal iliac systems, whereas some studies include aberrant vessels that course over the superior pubic ramus [5,16,18,21].

In the current study, an incidence of 7.59 % ($n$ = 13/145) of obturator arteries was observed to have originated from the external iliac artery or its inferior epigastric branch and were categorized as aberrant obturator arteries. A incidence of 0.69 % ($n$ = 1/145) of aberrant obturator veins was observed draining into the external iliac vein. Animaging study by Han *et al.* reported an incidence of 3.03 % ($n$ = 20/660) of obturator arteries originating from the inferior epigastric artery and 1.81 % ($n$ = 12/660) of aberrant obturator veins draining into the external iliac vein [21]. Additionaly, a study by Smith *et al.* reported a incidence of 29 % ($n$ = 29/100) of aberrant obturator arteries cases originating from the inferior epigastric artery [5]. While a study by Dueñas–Garcia *et al.* reported a incidence of 27.9 % ($n$ = 24/87) of aberrant obturator arteries [16]. These reports prove that higher incidences of arterial anomalies were presented in past literature compared to the current study which may be due to discrepancies in sample sizes between studies.

The overall mean distances documented in the current study between the anastomoses and the landmarks SPS and PPS, were 62.44 mm and 55.08 mm, respectively. These distances were consistent with the average distances between the venous and arterial CM and the midpoint of the PS documented by Han *et al.* and Steinberg *et al.* (Table 5) [17,21]. This may suggest that the PS can be a reliable landmark to utilize for the localization of the CM during anterior approaches to the pelvis.

The distance of the CM in relation to the PT and AIIS was not utilized in previous angiographic investigations of the CM. Therefore, these landmarks cannot be thoroughly discussed; however, the application of these safe zones may be more efficient as no statistically significant difference between the sexes was noted. The significant differences between male and female dimensions are largely due to the pelvis being a sexually dimorphic bone, affecting the morphometric values between bony landmarks [23]. Statistically significant differences in the mean distances between the CM and PS in males and females were noted in

**Table 2**
The mean distances between the CM anastomosis and the various bony landmarks (SPS, PPS, PT, and AIIS) for males and females. ***(Key: CM:** Corona mortis, **SPS:** Superior pubic symphysis, **PPS:** Posterior pubic symphysis, **PT:** Pubic tubercle, **AIIS:** Anterior inferior iliac spine, **CI:** Confidence interval, **M:** Male, **F:** Female.).*

| Variables | Sex | Mean (mm) | Range (mm) | Two-standard deviation | 95 % CI (mm) |
|---|---|---|---|---|---|
| **CM - SPS** | M | 60.21 | 46.34–73.75 | 17.48 | 57.06–63.36 |
| | F | 67.18 | 57.11–88.17 | 16.84 | 62.69–71.67 |
| **CM – PPS** | M | 52.48 | 39.36–66.08 | 16.04 | 49.58–55.37 |
| | F | 60.57 | 51.34–76.31 | 15.90 | 56.33–64.81 |
| **CM - PT** | M & F | 49.07 | 36.91–67.55 | 15.08 | 46.88–51.26 |
| **CM - AIIS** | M & F | 58.25 | 45.17–77.03 | 17.10 | 55.76–60.73 |

**Table 3**
Incidences of arterial corona mortis in angiogram studies. ***(Key: CM:** Corona Mortis.).*

| Author (Year) | % CM (n) |
|---|---|
| Karakurt et al. (2002) [15] | 28.5 (28/98) |
| Dueñas – Garcia et al. (2017) [16] | 27.9 (24/86) |
| Perandini et al. (2018) [18] | 30 (90/300) |
| **Current study (2024)** | **33.1 (48/145)** |

**Table 4**
Incidences of arterial corona mortis in angiogram studies. ***(Key: CM:** Corona Mortis.).*

| Author (Year) | % arterial CM (n) |
|---|---|
| Karakurt et al. (2002) | 28.5 (28/98) |
| Smith et al. (2009) | 29 (29/100) |
| Steinberg et al. (2017) | 33 (66/200) |
| Perandini et al. (2018) | 30 (90/300) |
| **Current study (2024)** | **13.1 (19/145)** |

**Table 5**
Average distance between the CM vessels and the PS. ***(Key: CM:** Corona mortis, **Avg:** Average, **PS:** Pubic symphysis, **R:** Range, **SPS:** Superior pubic symphysis, **PPS:** Posterior pubic symphysis).*

| Author (Year) | Avg. distance between arterial CM and PS (mm) | Avg. distance between venous CM and PS (mm) |
|---|---|---|
| Karakurt et al. (2002) [15] | 31.8 (males)/ 36.2 (females) | – |
| Smith et al. (2009) [5] | 56 (R: 41–72) | – |
| Han et al. (2017) [21] | 66.87 (R: 41–119) | 59.60 (R: 43–82) |
| Steinberg et al. (2017) [17] | 55.2 (left)/ 57.2 (right) | – |
| Perandini et al. (2018) [18] | 50 | – |
| Daodi et al. (2019) [22] | 57 (R: 48–71) | 57 (R: 48–71) |
| **Current study (2024)** | **SPS: 65.5 (R: 46.3–88.2) PPS: 55.8 (R: 39.4–76.3)** | **SPS: 61.7 (R: 47.7–76.1) PPS: 54.6 (R: 40.6–68.6)** |

studies by Karakurt *et al.* and Steinberg *et al.* ($p < 0.05$) [15,17]. Steinberg *et al.* reported a larger mean of 62.2 mm for females and 55.85 mm for males and Karakurt *et al.* concluded a mean distance of 36.2 mm for females versus 31.8 mm for males [15,17]. These measurements are consistent with the results of the current study which exhibited a discrepancy in the distances between sexes, with females presenting a larger average distance between the CM and PS.

The current study also reported 5 cases where the diameter of the anastomosing vessel exceeded 4 mm whereas a significantly smaller diameter of 2.6 mm and less was reported in previous literature [5,17,18,21,24]. A larger diameter may enhance the threat of hemorrhage associated with the CM. Additionally, Smith et al. discussed the difficulty of diagnosing the CM during retropubic hematomas when the diameter is greatly diminished, causing decreased detectability [5]. Similarly, CM vessels with a smaller diameter may cause some difficulty in identifying the anomaly.

The vascular spasm and retraction of the CM may pose complications in its visualization via imaging tools such as CTA as a higher incidence of CM is identified in patients with no pelvic trauma [25]. Imaging tools have proven to be useful in identifying and conceptualizing the CM intraoperatively and expanding its clinical significance, with angiography considered the ideal tool for this [6]. In the event of retropubic hematomas caused by injury to the CM or aberrant vessels, angiograms may assist in a therapeutic role by targeting the site and origin of bleeding either pre- or post-operatively and preventing the threat of injury via diagnosis [7,26,27]. Continued research regarding the use of angiograms and CT scans must be implemented for further understanding and awareness of CM, especially within clinical settings.

A review study by Boutefnouchet et al. described the incoherencies in the incidences and location of the CM between cadaveric and clinical studies and reported a higher incidence of CM amongst the cadaveric studies [27]. A comparative review study by Papagrigorakis et al. (2018) suggested the same discrepancy by noting a incidence of 14 % - 33 % CM among clinical studies [17,21] compared to the 19 % - 65 % incidence in cadaveric studies [4,12]. This exhibits large inconsistencies between the samples.

Since the study utilized linear, unidimensional measurements between landmarks on a CT slice, the measurement does not accommodate for the spatial relation of structures that lie anterior or posterior to each other. Other factors such as slice thickness of CT scans may affect the exactness of measurements simulated on CT imaging which may explain the incongruities between the distances in cadaver and clinical study [28]. However, angiographic validation would be a powerful diagnostic tool in CM cases [29]. The high incidence of CM cases and variations emphasizes the clinical significance of the CM and the importance of establishing a clinical understanding of the anatomy and incidence of the anomaly to ensure safe orthopedic treatments.

## Conclusion

We can conclude that the incidence of the CM within the South African angiogram sample resulted in 33.1 % ($n = 48/145$). The inconsistencies presented between angiogram and cadaver studies suggest that angiograms should be limited to a diagnostic and therapeutic role of identifying the CM or injury within or pertaining to the retropubic region provided the specificity of the vessels is thorough. Further clinical studies are necessary to evaluate the implications of the anatomy and variations of the CM.

## Limitations

The majority of patients presented with a case of cardiovascular disease which may effect the vasculature. The contrast of venous structures was low making the identification of venous CM difficult. Linear, unidimensional measurements were utilized without the option of 3D reconstruction of scans which would have enhanced the accuracy of dimensions measured.

## CRediT authorship contribution statement

**Jade Naicker:** Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Zithulele Nkosinathi Tshabalala:** Supervision, Writing – review & editing. **Jacques Janse van Rensburg:** Data curation, Visualization. **Andries Masenge:** Formal analysis. **Obakeng Modisane:** Writing – review & editing. **Steven Matshidza:** Conceptualization, Data curation, Investigation, Supervision, Validation. **Nkhensani Mogale:** Investigation, Methodology, Supervision, Validation, Writing – review & editing.

## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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