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Original Article

Pelvicalcyeal System Morphology and Variations among Sudanese Subjects

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ABSTRACT

Background: The Pelvicalcyeal system of the kidney is a common site for congenital anomalies and variations. Understanding the three-dimensional orientation of renal calyces and their relationship to the frontal plane is critical for endourological procedures and the interpretation of imaging studies. This study aims to measure the upper, middle, and lower infundibular lengths and widths, as well as the infundibulo-pelvic angle (IFPA), classify the renal pelvis and collecting system, and explore the relationships between the lower infundibulum parameters (IFPA, Length of Lower Infundibulum (LIL), and Width of Lower Infundibulum (LIW)) and other parameters such as the type of collecting system, type of renal pelvis, laterality, and data source. Additionally, the study seeks to identify Pelvicalcyeal congenital anomalies and the presence of staghorn stones.

Patients and Methods: Samples for this study were from two sources: cadaveric kidney dissection, using rulers and metered tape for pelvic type identification, congenital anomalies, and staghorn stone assessment, as well as CT scan urography analyzed using the "Radi-ant Dicom" software tool.

Results: The results indicate that the longest infundibulum was the upper one, with the lower infundibulum being the widest. The IFPA measured greater than 90 degrees in 65% of the samples. The most frequent classifications identified were Type A1 and tricalyceal pelvicalyceal systems, along with the brachy type pelvis. Congenital anomalies were observed in 11% of cases, and staghorn stones were present in 5%. Notably, the IFPA was more acute in the left kidneys, widest in Simpson's Type A11, tricalyceal systems, and in brachy (short) pelvises. While these findings were statistically non-significant, significant differences were noted in cadaveric samples compared to CT findings. The lower infundibulum was longer in right kidneys (non-significant) and wider in left kidneys (non-significant).

Conclusion: The anatomy of the pelvicalyceal system in the Sudanese population aligns with global norms, while variability exists even among individuals within the same population.

Keywords: Kidneys; Pelvicalyceal System; Anatomy; Variations; Sudanese.

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INTRODUCTION

1.1 Gross Anatomy:

The pelvicalyceal system of the kidney is one of the common sites in the body to exhibit congenital anomalies and variations. It is typical to find, even within the same individual, morphological differences between the right and left sides. Although the system is usually identical within the same individual, it is rarely similar when compared to other individuals; thus, it can be considered akin to a fingerprint [(1)].

The three-dimensional orientation of the renal calyces and their relation to the frontal plane is of paramount importance in endourology procedures and in the interpretation of intravenous urograms (IVU) and computed tomography urograms (CTU). According to observations, the calyces may lie either anteriorly or posteriorly. According to Brodel's model, the anterior calyces are directed more medially than the posterior calyces. In contrast, the Hudson model identifies this as the exact reverse mirror image of the actual system [(2)].

Kaye and Reinke studied the in vivo CT model of the calyceal system and concluded that the right kidney is more likely to follow the Brodel model, while the left kidney tends to follow the Hudson model. This information is highly relevant when considering the site of insertion of the nephroscope during percutaneous nephrolithotomy (PCNL) [(2)].

1.1.1 Renal Pelvis:

The renal pelvis can be divided according to its shape and position. Regarding its classification based on shape, it can be categorized as long or brachy type, and according to its position, it can be classified as intrarenal, extrarenal, or borderline. Another system divides the pelvicalyceal system into multicalyceal, tricalyceal, bicalyceal, or unclassified [(3)].

The collecting system of the kidney consists of:

1.1.2 Minor Calyx:

During the embryological period, minor calyces develop in the anterior and posterior parts of the upper, middle, and lower poles, which later unite. They are classified into simple (draining directly) or complex types (joining each other before draining) based on their mode of drainage into the major calyces [(4)].

1.1.3 Major Calyx

There are usually two major calyces, but there may be three in number. During the embryological period, due to the posterior rotation of the kidney, the former lateral and medial calyces become anterior and posterior respectively. According to the orientation of the major calyces (upper, middle, and lower), the kidneys can be divided into two types:

1. Brodel type – dominant in the right-sided kidneys.

2. Hudson type – dominant in the left-sided kidneys [(4)].

1.1.4 The Infundibulum:

Typically, there are upper and lower infundibulae draining the upper and lower major calyces; occasionally, there may also be a middle (hilar) infundibulum for a middle calyx. Both the length, width, and angle of the lower infundibulum to the pelvis play a significant role in stone clearance by extracorporeal shock wave lithotripsy (ESWL) [(4)].

1.1.5 Pelvis:

The renal pelvis has been classified using various systems, including:

1. Position: intrarenal or extrarenal.
2. Length: brachy-pelvis or long pelvis.
3. Pattern of drainage of the minor/major calyces [(4)].

It can also be classified into:

1. Tricalyceal.
2. Bicalyceal.
3. Multicalyceal.
4. Unclassified [(4)].

A meta-analysis of multiple studies evaluating the variations in pelvicalyceal anatomy divided the system into two main groups:

1. A1/A11, which represents more than 60%, indicating mainly two calyces draining to the pelvis.

2. B1/B11 constitutes about 33%, representing a midzone area of drainage independent of the upper and lower zones [(5)].

Stones are most likely to form in the lower calyx of the renal collecting system due to its narrower and longer structure. This characteristic also affects the rate of stone clearance by ESWL or PCNL in this region [(6)].

The pathophysiology of renal stone disease is multifactorial, encompassing dietary factors, urine stagnation, urinary tract infections, and the internal anatomy of the pelvicalyceal system, which plays a major role, as evidenced by numerous studies. In one study utilizing CTU, it was found that the anatomy of the pelvicalyceal system differs between stone-forming and non-stone-forming kidneys [(7)].

In another study involving patients with pelvicalyceal stones, it was noted that in stone-forming kidneys, compared to the non-stone-forming kidneys, the infundibuloureteric pelvic angle (IFPA) was found to be more acute in the stone-forming kidneys, indicating a relationship between the internal configuration of the pelvicalyceal system and the pathophysiology of stones [(8)].

Several studies have suggested using parameters such as the internal anatomy of the pelvicalyceal system, in addition to stone size and location, as these factors are crucial when determining the type of intervention for stone disease, for example, choosing PCNL versus ESWL [9].

A study was conducted to compare three-dimensional CT scans to conventional transverse CT scans and intraoperative findings. The conclusion was that the 3D CT scan has high sensitivity and specificity in assessing both the vascular and pelvicalyceal systems [10].

Due to the severe shortage of data regarding the pelvicalyceal system in the Sudanese population, this study aims to explore the anatomy and variations of the calyceal system and renal pelvis, which will benefit both urologists and radiologists managing urological conditions.

MATERIALS AND METHODS

2.1 Design:

Comparative observational analytical cross-sectional study.

2.2 Time of the Study:

The study was conducted from September 2020 to February 2021.

2.3 Setting:

Population:

1. Cadaveric dissected kidneys.
2. CT scan urography.

2.4 Inclusion Criteria:

The cadavers were male or female adults, properly dissected, and relatively new. For the CT scan urography, male or female adult patients with contrast used and good quality images were included.

2.5 Exclusion Criteria:

Old, macerated cadavers in which the anatomy was not clear; patients with a history of major kidney surgery or pyeloplasty; patients with DJ stents, PTNT, or urological pathology obscuring the collecting system anatomy were excluded.

2.6 Parameters Studied:

1. Length and width of the upper, middle, and lower infundibula.
2. The infundibulo-pelvic angle (IFPA) was measured using Sampaio's method.
3. The type of the collecting system.
4. The type of renal pelvis.
5. The presence of staghorn stones or congenital anomalies.

2.7 Sample Size:

A total of 50 cadaveric kidneys and 50 CT urography images were selected using a convenience sampling approach.

2.8 Statistical Analysis:

1. The mean and standard deviation of the length and width of the upper, middle, and lower infundibula were calculated.

2. The percentage of each subtype of collecting system and renal pelvis was identified.

3. Differences between the right and left kidneys regarding the various measures were identified and interpreted using an unpaired sample T-test.

4. The correlation between the lower infundibulum parameters (IFPA, LIL, and LIW) and other parameters (type of collecting system/type of renal pelvis/laterality and data source) was identified and tested either using unpaired sample T-tests or ANOVA, with p-values calculated.

5. The percentage of staghorn stones and congenital anomalies was also calculated.

2.10 Procedure:

1. Following formal dissection techniques, each kidney was first isolated, classified as right or left, and then transected in the coronal plane, starting from the renal hilum. The entering neurovascular structures were completely removed to visualize the whole collecting system. Different morphological measurements of the pelvicalyceal system of the kidney were measured using a ruler and measuring tape, including the infundibulo-pelvic angle, as well as identification of the pelvi-calyceal system and pelvic types. Lastly, the presence of congenital anomalies and staghorn stones was assessed.

2. The same measurements were conducted on the CT scan urography. This time, a radiological software program, "Radiant DICOM," was used, which transforms and cuts the images in different anatomical planes, including the three-dimensional.

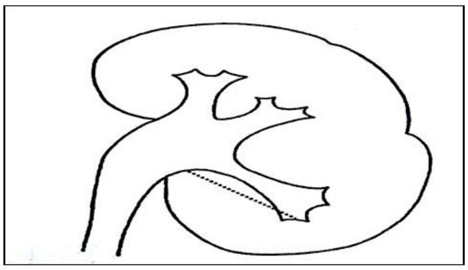


Figure (1): Infundibular length (mm), measured as the distance between the most distal point of the calyx and the midpoint of the lower lip of the renal pelvis [4]

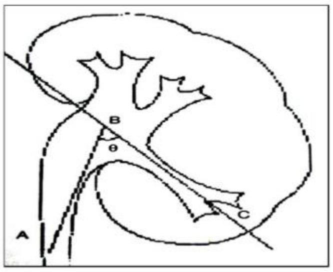


Figure (2): AB- Ureteropelvic Axis, BC - Lower pole infundibular Axis Θ- Infundibulo pelvic angle [(4)]

RESULTS

Firstly, the laterality of kidneys and the sources of the data identified and percentages calculated (Graphs 1 and 2).

3.1-The infundibular measurements:

The length and width of each infundibulum was measured and expressed in mm, and the mean and standard deviation was calculated **(Table 1, and Figure 3).**

3.1.1-infundibulum length:

The infundibulum length was measured from the most distal point of the major calyx, to the midpoint of the upper lip of the renal pelvis.In the current study, the upper infundibulum was the longest, (12.6-40.7 mm, mean value of 23.07 ±4.9 mm), middle infundibulum was (9.7-35.10 mm, mean value of 19.32 ± 5.3 mm), and the lower infundibulum was the shortest, (8.27-30.7 mm, mean value of 16.5±4.2 mm).The LIL was longer in the RT sided kidneys, (mean 17.07±4.74 mm), to (16.09±3.86 mm) in the LT. However unpaired T- test, was not significant statistically, p-value= 0.255 **(Table 1, Figure 3).**

3.1.4- infundibulum width:

The infundibulum width was measured at the narrowest point .In the current study, the upper infundibulum was (1.7-13.10 mm, mean value of 5.6± 2.3 mm), middle infundibulum was the narrowest (1.5-13.5 mm, mean 5.2 ± 2.1 mm), and, the lower infundibulum was the widest (1.3-13.30 mm, mean 6.89 ± 2.66 mm).The LIW was wider in the LT sided kidneys (mean 7.03±2.68 mm) in the LT side, to (6.72±2.66 mm) in the RT. Again the unpaired T- test was not significant statistically, p-value= 0.561 **(Table 1, Figure 3).**

3.2-The infundibulopelvic angle:

The (IFPA) was measured as the angle between the ureteropelvic axis and lower pole infundibular axis. The ureteropelvic axis was formed by connecting two points, one at the center of renal pelvis and the other point in the ureter opposite the lower pole. In the current study , it was (160 to 45.9 , mean 95.8 ± 21.4 degrees).The IFPA, is the most important single factor, in determining the success rate of stone clearance after (ESWL), with a cut value of (90 degrees) , so comparisons had been made to illustrate the differences between the RT and LT sides , different types of the renal pelvis , collecting system ,and source of data , to show if there is a significant variations (Table 1).

The IFPA was wider in the RT sided kidneys, (mean 98.6±22.5 degrees), to (93.6±20.4 degrees) in the LT, unpaired T- test was not significant statically, p-value= 0.258. Also ANOVA -test to compare the mean of the IFPA of different types of renal collecting system, Ningthoujam classification ,(Bicalyceal 94.78 ± 24.18 VS Tricalyceal 96.04± 20.42 VS Unclassified 99.10±15.97), p-value= 0.882, of types of renal collecting system, Sampaio classification, (A1 94.18± 22.71 VS A11 104.04±29.62 VS B1 92.46±13.26 VS B11 95.52±11.42, unclassified 99.10±15.97), p-value= 0.545, and for types of renal pelvis, according to length, (Long 90.72± 23.28 VS Brachy 98.21± 20.71 VS Absent 99.10±15.97) (p-value= 0.251). All were not significant statistically. Again to compare the mean of the IFPA types of renal pelvis, according to position, Intra-renal (99.08± 24.42) vs Extra-renal (91.51± 17.59) vs borderline(91.32±18.95), absent (99.10±15.97) was not significant statically (p-value= 0.251).The cadaveric samples has the widest IFPA (104.4 ± 21.2) degrees, to the (87.1± 18.02) degrees in the CTU samples. T- Test, the difference was statistically significant, p-value< 0.001. With a cut point of (90 degrees), the IFPA in the present study in most of the specimens was >90 degrees, with overall percent of (65%), with only (45 %) <90 degrees, that was similar to that of Sampaio FJB study (65 VS 74%) **(Table 1, Figure 4)**

3.3-Classification of renal collecting system:

3.3.1-According to Sampaio classification:

The most frequent collecting system type was type A1 (52%), followed by type B1 (18%), then (type A11 and type B11), the least frequent was the (unclassified) **(Table 2, Figure 5, Graph 3).**

3.3.2-According to NINGTHOUJAM DD *et al.*:

The tricalyceal variant, was the most common (57%), the bicalyceal system was about only half of that number, with the unclassified type was the least **(Table 2, Figure 2, Figure 6, Graph 4).**

3.4-Number of major calyces:

Taking into account that, the tricalyceal variant, was the most common type pelvicalyceal system, most of the kidneys contain three major calyces (57%), and few only two.

3.5-The number of minor calyces:

Following dissection, the number of minor calyces in each zone (upper zone, middle zone and lower zone) was calculated separately and added up to get this value, a mean + S.D value of (6.4 + 1.6), the total number of minor calyces being the minimum of (4) and the maximum of (9).

3.6-Classification of renal pelvis:

3.6.1-According to the length: In the present study the cut length of (20 mm), was used as a value to categorize the renal pelvis as (long or short –brachy). The short –brachy type was the most common type (60%), the long (33%), absent in about 7 kidneys, so that the major calyces, draining directly into the upper ureter **(Table 2, Figure 7, Graph 5)**

3.6.2-According to the position in relation to the hilum: According to the position of the pelvis in relation to the renal hilum, the intra-renal pelvis, was the most common, representing about half of the total sample size, and the extra-renal type, was less than that, represented by one third of the sample size, and 13% (borderline) **(Table 2, Graph 6)**.

3.7-The presence of congenital anomalies and staghorn stones:

Congenital anomalies identified in the present study in the form of (tortuous ureters, PUJ obstruction, absent pelvis, aberrant renal artery) in (11%) of the samples. While Staghorn stones, usually reaches very large size (>2cm), was identified only in 5 kidneys (all are cadaveric) **(Table 2, Graph 7-8).**

Table (1): Infundibular and (IFPA) measurements

The parameter		n	Minimum (mm)	Maximum (mm)	Mean (mm)	SD. (mm)
Upper infundibular length		100	12.60	40.70	23.07	4.95
Middle infundibular length		66	9.72	35.10	19.32	5.32
Lower infundibular length		100	8.27	30.70	16.51	4.26
Lower infundibular length	Right	43	17.07	4.74		
	Left	57	16.09	3.86		
Upper infundibular width		100	1.75	13.10	5.68	2.39
Middle infundibular width		65	1.55	13.50	5.24	2.11
Lower infundibular width		100	1.31	13.30	6.89	2.66
Lower infundibular width	Right	43	6.72	2.66		
	Left	57	7.03	2.68		
Infundibuloureteropelvic angle(IFPA) in degrees(⁰)		100	45.90	160.00	95.79	21.43
Right		43	45.90	160.00	98.60	22.56
Left		57	45.90	160.00	93.68	20.48
Total		100	45.90	160.00	95.80	21.43

The measurements of all infundibular parameters (in mm) and (IFPA-in degrees) in both the cadaveric and CTU images.

Table 2: Types of Pelvicalyceal system, renal pelvis, Congenital anomalies and Staghorn stones

Variable	(n=100)	n	%	Cumulative Percent%
Type of collecting system – Sampaio classification	AI	52	52.0	52.0
	AII	15	15.0	67.0
	BI	18	18.0	85.0
	BII	8	8.0	93.0
	Unclassified	7	7.0	100.0
Type of collecting system – Ningthoujam classification	Bicalceal	36	36.0	36.0
	Tricalyceal	57	57.0	93.0
	Unclassified	7	7.0	100.0
Type of renal pelvis – according to length	Long	33	33.0	33.0
	Brachy	60	60.0	60.0
	Absent	7	7.0	7.0
Type of renal pelvis – according to position	Intra-renal	50	50.0	50.0
	Extra-renal	30	30.0	30.0
	Borderline	13	13.0	13.0
	Absent	7	7.0	7.0
Frequency of congenital anomalies	Present	11	11	11.0
	Not present	89	89.0	89.0
Frequency of staghorn stones	Present	5	5.0	5.0
	Not present	95	95.0	95.0

This table shows the sample distribution of the pelvicalyceal system according to Sampaio and Ningthoujam, the type of renal pelvis according to length and position, in addition to percentages of both congenital anomalies and staghorn stones.

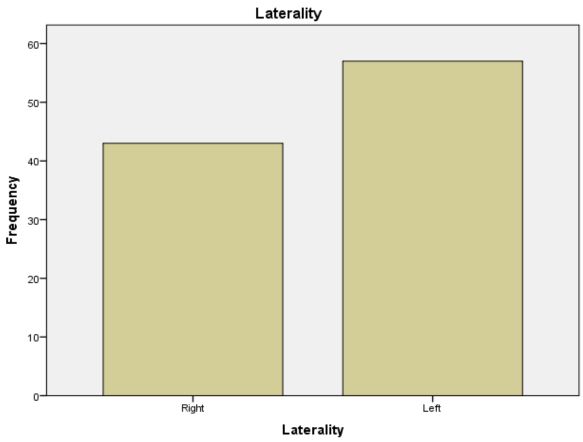
Figure (3): Multiple measurements to all infundibulae –CTU 3D image.

Figure (4): Infundibulopelvic-ureteric angles measured using Sampaio method, angle Formed by the central axis of the infundibulum and another axis connecting the central points of the ureter at the lower pole and ureteropelvic region-CTU image.

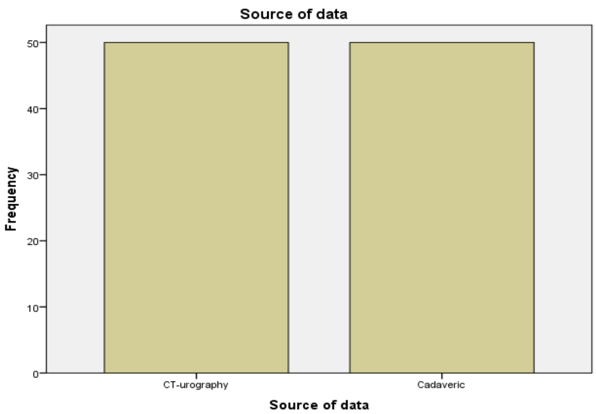
Figure (5): Classification of renal collecting system, using Sampaio and Ningthoujam methods-CTU 3D image: The right kidney-class: A11, Bicalyceal; the left kidney-class: A1, Bicalyceal

Figure (6): Upper-middle –and lower infundibulae, in a tricalyceal system-cadaveric photo.

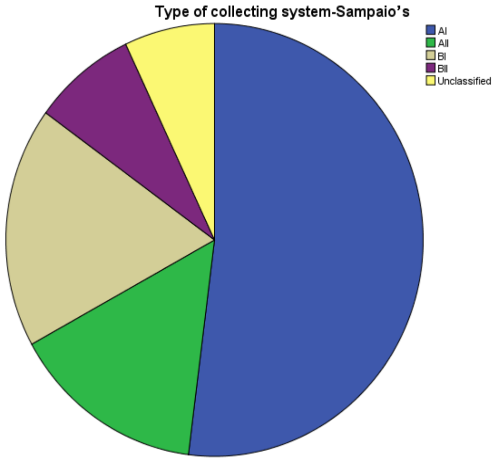
Figure (7): Classification of renal pelvis –according to the length (taking the 20 mm as a cut point) cadaveric photo.



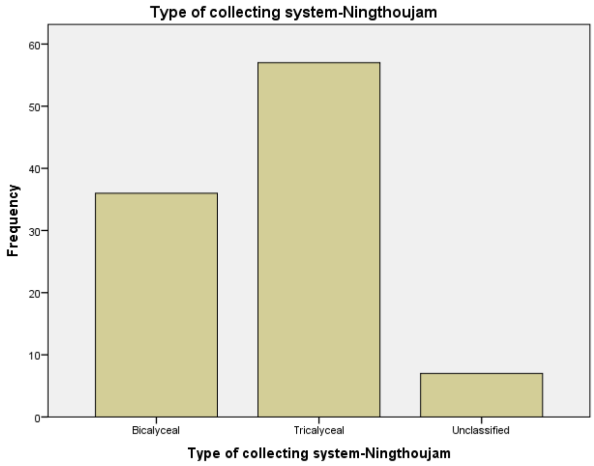
Graph (1): Laterality among the study sample



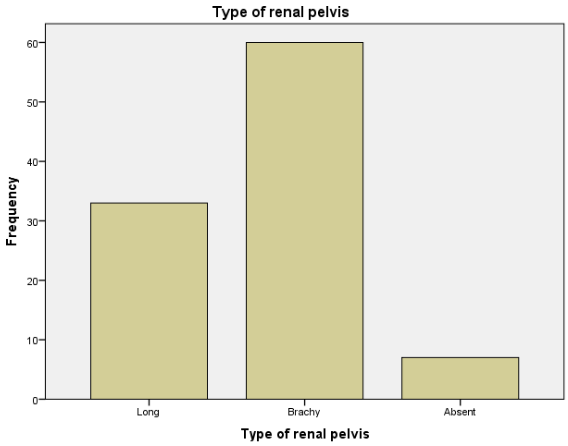
Graph (2): Source of data (cadaveric VS CTU)



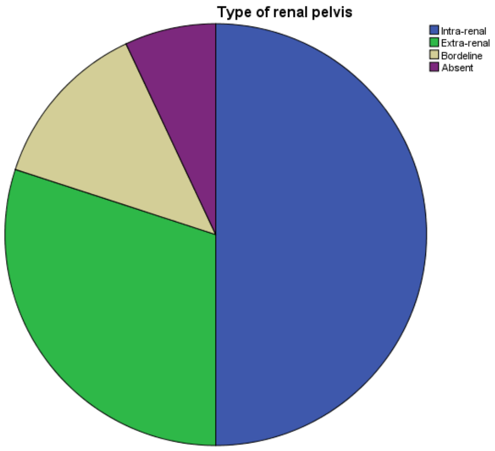
Graph (3): Type of collecting system-according to Ningthoujam



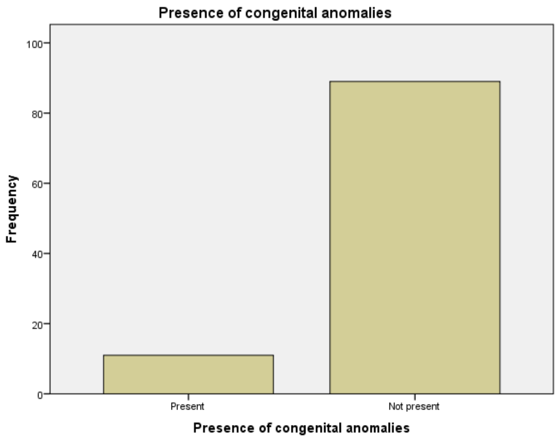
Graph (4): Type of collecting system-according to Sampaio Classification



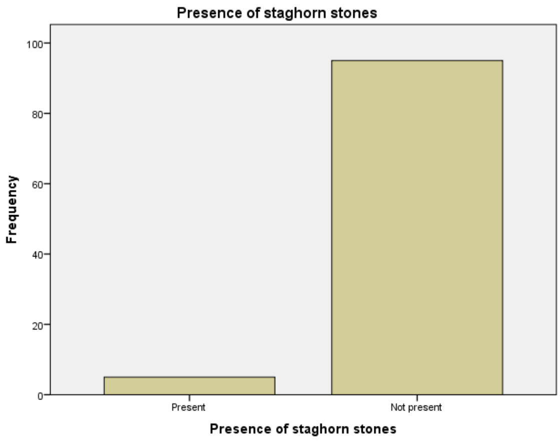
Graph (5): Type of renal pelvis-according to length



Graph (6): Type of renal pelvis-according to position



Graph (7): Presence of congenital anomalies



Graph (8): Presence of staghorn stones

DISCUSSION

The variations in the renal pelvis and collecting system can be compared to the fingerprints of individuals [11]. Not only are that, but even within the same person, the right and left sides identical only in about 37% of the time [5]. It has been observed that the lower calyces are the most frequent infundibulum in which stones form, necessitating subsequent interventions (44–24%). This phenomenon could be attributed to urine stagnation [11, 12].

In our study comparing the means of the three infundibula, the upper infundibulum was found to be the longest (mean 23.07± 4.9 mm), while the lower was the shortest (mean 16.5 ± 4.2 mm), which was almost the same as that observed in Tamil Nadu Dr. M.G.R. (17.5 ± 3.4 mm) [4], although it was longer in both Fabregas MA *et al.* (25.9 ± 2.7 mm) [12, 13].

A cutoff length of 20 mm is used during radiological evaluations to select suitable patients for extracorporeal shock wave lithotripsy (ESWL). In this study, the number of patients with infundibular lengths < 20 mm was higher than those with lengths > 20 mm (81% versus 19%), compared to the findings in Tamil Nadu Dr. M.G.R. (75% versus 25%) [4], which is similar to other studies (10.2–30.9 mm) [1]. According to Arzoz-Fabregas, longer length of the lower infundibulum (LIF) is associated with stone formation, as it is unlikely to be cleared by ESWL due to prolonged urine flow, leading to supersaturation and crystallization [12]. However, lower infundibular width (LIW) showed considerable variability (mean 6.89 ± 2.66 mm; range 1.31–13.30 mm) compared to (5.63 ± 2.2 mm) in Tamil Nadu Dr. M.G.R. (4) and (6.5 ± 8.2 mm) in Arzoz-Fabregas [12]. The critical value above which fragment clearance following ESWL becomes easier is > 4 mm; in the current study, the majority of the LIW measurements were > 4 mm (89% vs 11%) compared to Tamil Nadu Dr. M.G.R. (70% versus 30%) - cadaveric study [4] and Sampaio F.J.B. *et al.* (60% versus 40%) - cadaveric study [14].

The mean of the minor infundibular width (MIW) was the narrowest (mean 5.2 ± 2.1 mm; range 1.5–13.5 mm) compared to (2–7.4 mm) in Pankaj R. Wadekar and S. D. Gangane's study [1] and (1–10 mm) in Kupeli Bora *et al.*'s study (15). On the other hand, the upper infundibular width (UIW) was (mean 5.6 ± 2.3 mm; range 1.7–13.10 mm) compared to (1.01 ± 1.10 mm; mean 3.01 mm) in **Kupeli Bora *et al*.** [15] and (4.66 mm; range 2.2 to 11.3 mm) in Pankaj R. Wadekar and S. D. Gangane's study [1].

In our current study, the infundibular pelvic angle (IFPA) ranged from 160 to 45.9 degrees, with a mean of 95.8 ± 21.4 degrees, which is comparable to Ozgur Tan *et al.* (96 ± 22.1 degrees) - IVU study [16] and (94.7 ± 11.7 degrees) in Tamil Nadu Dr. M.G.R. - cadaveric study (4), but different from Zomorrodi *et al.* (112.5 ± 10.78) in another IVU study [17]. Comparing the IFPA of the right and left sides, although there was an observable difference (p = 0.258), this aligns with Zomorrodi A *et al.*, where the left side was more acute (95.2 ± 28.4 degrees) versus the right side (98 ± 29.4 degrees) - IVU study [17]. The IFPA was > 90 degrees in 65% of the sample, which aligns with Sampaio FJB, where > 90 degrees was observed in 74% of cases [5] and in 67.4% of the Tamil Nadu Dr. M.G.R. study [4].

The comparison of IFPA among different types of renal collecting systems and renal pelvis was conducted using ANOVA, but no statistically significant differences were identified. Lastly, a T-test was used to compare the means of IFPA (cadaveric: 104.25 ± 21.25 versus CTU: 87.20 ± 18.03), yielding a p-value < 0.001, with the widest IFPA found in cadaveric samples. Although the difference is statistically significant, it could be attributed to differences between the populations of the cadaveric versus CTU samples and the gross changes affecting cadaveric bodies during preparation and dissection.

The most frequent collecting system type in our study was type A1 (52%), followed by type B1 (18%). Type A11 was observed in 15% of the sample, while type B11 was found in 8%. The least frequent classification was unclassified (7%). These percentages are similar to those reported by Sampaio FJB (A1 45%, B1 21%, A11 17%, B11 16%) [5]. When using the Ningthoujam method, we noted two clear differences compared to Ningthoujam DD *et al.*'s study: in our current study, the tricalyceal type was notably more common than in the Ningthoujam study (57% to 17%), while the bicalyceal type was (36% to 21%), and the unclassified type was reported twice as frequently in our findings compared to the Ningthoujam study [4]. Studies conducted in Nepal reported tricalyceal types at 63.8% and bicalyceal types at 33.3%, compared to North Americans (tricalyceal 31.2%, bicalyceal 65.6%). These differences were statistically significant (p = 0.02), which could be attributed to population differences.

Regarding the total number of major calyces, nearly all studies report a tricalyceal or bicalyceal system (Fine and Keen, Ningthoujam *et al*., Miller *et al*. and Wadekar *et al.* [4, 6, 18, 19], except for studies in India (Kusum Gandhi study), where the observed total was (2–4) instead of (2–3) [6]. The total number of minor calyces had a mean ± standard deviation of (6.4 ± 1.6), with a minimum of 4 and a maximum of 9, correlating with other studies, such as Ningthoujam *et al.* [6–12], Wadekar and Gangane [5–11], and Kusum Gandhi [1, 4–11].

With a cutoff length of 20 mm, the short-brachy type pelvis accounted for 60%, the long type for 33%, and there were no absent kidneys [7]. The intra-renal pelvis was observed in 50% of cases, while the extra-renal type appeared in 30%, with 13% classified as borderline and absent in 7%. These findings are comparable to Anjana's study, which showed intra-renal pelvis in 79%, extra-renal in 5%, and absent pelvis in 3%. The literature reports the percentage of extra-renal pelvis cases to be 10% [20].

According to Sampaio and Argago's study, the anatomical factors affecting both the formation and clearance of lower infundibular stones include IFPA (> 90 degrees), LIF diameter (> 4 mm), and a calyceal system (> 3 infundibula) [14]. In our study, when comparing the right and left sides regarding these parameters, no statistically significant differences were identified, which does not explain why stone disease typically affects one side more than the other.

In the current study, 11% of the samples reported congenital anomalies of the pelvicalyceal system (such as absent, rudimentary, double/multiple pyelons (pelvis), intra-renal/extra-renal pelvis, congenital hydronephrosis, or diverticulum) [21]. In duplex renal systems, urine can move from one system to another, creating what is known as a "yo-yo effect," which could be associated with flank pain [22].

Staghorn stones, a special type of renal stone formed within the pelvis, were identified in only 5 kidneys (all were cadaveric). The most common site of stone formation is the lower infundibulum (24–44%), primarily due to prolonged urine stasis in that area [3, 12].

The limitations of this study include the fact that larger sample sizes yield more reliable results, and a meta-analysis involving a larger number of studies from diverse populations would be beneficial. Additionally, the only aspect of the minor calyces studied was their total number, while many other studies have evaluated the orientation and direction of minor calyces (anterior or posterior) as they drain into the major calyces, which can facilitate various endourological procedures. Future research could utilize spiral or three-dimensional CT scans, as well as techniques such as end casting of cadaveric samples.

In conclusion, the morphology of the pelvicalyceal system in the Sudanese population aligns with that of the global population. However, variability exists even within the same individual. Understanding the detailed anatomy of the Sudanese pelvicalyceal system is of paramount importance for radiologists and urologists conducting various modalities of invasive and non-invasive urological procedures (such as ureteroscopy, percutaneous nephrolithotomy (PCNL), percutaneous nephrostomy (PCN), and laparoscopic operations).

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