Variations In the Pelvicalyceal Pattern in Human Kidneys

A Dissertation submitted To

The Tamil Nadu Dr. M.G.R. Medical University

In partial fulfilment of the requirements

for the award of the degree of

M.D. (Branch V) Anatomy

April 2013

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CERTIFICATE

This is to certify that this dissertation entitled **"Variations in the Pelvicalyceal pattern In Human Kidneys"** is the bonafide record of work done by Dr.T.S.R.Anjana under my guidance and supervision in the Department of Anatomy during the period of her postgraduate study for M.D. (Branch V) Anatomy from 2010 to 2012.

The Dean,
Thanjavur medical college,
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CONTENTS

Introduction

VARIATIONS IN THE PELVICALYCEAL PATTERN IN HUMAN KIDNEYS

Abstract :

Introduction: The advent of more conservative methods of treatment for renal pathologies has necessitated a precise knowledge of renal pelvicalyceal system.

Aims and objectives :

1. To study the anatomical variations in the pelvicalyceal pattern in human kidneys.
2. To analyse the various dimensions of lower pole infundibulum of kidneys.
3. To compare and correlate the dimensions with clinically significant parameters.

Materials and methods :

Human kidneys belonging to both sexes were collected from dissection cadavers in the department of anatomy, Thanjavur Medical College and autopsied bodies in the department of Forensic Medicine, Thanjavur Medical College. Various patterns of the pelvicalyceal system along with morphometric dimensions of the infundibulum which leads from the major calyces to the renal pelvis were studied. The result was then correlated with clinically significant parameters.

Results :

The renal pelvis was intrarenal in position in majority(79%) of specimens and the type AI was more common when classified according to Sampaio's classification. An interesting variation of extrarenal calyces with absent pelvis was observed in one specimen in the present study.The lower pole calyceal distribution was 2.41± 0.81. The common pattern of drainage of lower pole minor calyces was simple pattern(51%). The lower pole infundibular length had a mean±S.D value of 17.5 ± 3.4 mm. The infundibular width had a mean value of 5.63±2.2 mm. The mean value of length by width ratio was 3.6±1.5. The mean value of infundibular height was 12.5±3.93 mm. The mean infundibulo pelvic angle was 94.7±11.61 degrees.

Conclusion :

The varying patterns of the collecting system of the kidney must be taken into consideration while examining a radiological report of a patient with pathologies involving the kidneys. This is because for many pathologies, the treatment procedure involves approaching the area involved through the calyces. The difference in pelvicalyceal patterns and variations in different parameters help urologists and radiologists in choosing the right mode of treatment for the patients. This is not only helpful in reducing post procedural complications but also in minimising the economical burden upon the patients.

Keywords : kidneys - pelvicalyceal pattern - infundibulum.

INTRODUCTION :

The kidneys lie retroperitoneally in the paravertebral gutter of the posterior abdominal wall. On coronal section, each kidney is said to have an outer cortex and an inner medulla. Extensions of the cortex centrally as columns of Bertini separate the medulla into pyramids and the apical portion of pyramids protruding into the minor calyces are called papilla [(1)]. The minor calyces unite with their neighbours to form two or possibly three large chambers, the major calyces. The major calyces drain into the infundibula[(2)]. The renal pelvis is normally formed from the junction of infundibula.

The minor calyces, the major calyces, the infundibulae and the renal pelvis are collectively called as the intrarenal collecting system [(3)]. Variations in the collecting system are numerous. Variations in the gross anatomy of the renal collecting system are probably as numerous as that of fingerprints of individuals [(4)]. The symmetry of the collecting system in a single individual on both the sides is only around 37% [(5)].

The position of the renal pelvis varies considerably in being either extrarenal or intrarenal. Sometimes the renal pelvis can occupy an intermediate position between these two positions and it is termed as the borderline pelvis. Various anomalies involving the different parts of the collecting system include variation in number, size and position or form. Variation in number includes unipapillary kidney and polycalycosis [(6)]. Variation in size may vary from being a microcalyx or a megacalyx. Examples for anomalies in position or form include aberrant or ectopic papilla and pyelocalyceal diverticulum. Not only do the number and position of the different parts of the collecting system vary between the individuals, but also the parts can either be absent or extremely elongated[4]. Based on length, the renal pelvis can be classified into two types as long and short (brachy) type of pelvis.

Apart from variations in the gross patterns, morphometric evaluation of features of lower pole collecting system spatial anatomy is also studied in detail. The lower pole collecting system anatomy plays a crucial role in predicting the end result of treatment procedures. The different parameters under study include infundibular length, infundibular height, infundibular width and infundibulopelvic angle. These parameters are a great aid in assisting urologists and radiologists to do various procedures.

The knowledge of detailed calyceal anatomy is essential for urologic procedures like percutaneous nephrolithotomy, percutaneous nephrostomy, flexible ureterorenoscopy, endopyelotomy and retrograde intrarenal surgery. It is also essential for indicating and predicting the outcome of Extracorporeal Shock Wave Lithotripsy for treating lower pole nephrolithiasis [7]. The fragment clearance following this procedure is mainly dependent on an ideal infundibulopelvic angle .

The anatomical variations as well as the complexity of the lower pole drainage system affected by infundibular length, width and infundibulopelvic angle would indicate the likely effectiveness of each of the treatment method chosen [8]. These variations will certainly pose difficulty in introduction and manipulation of nephroscopes. It is helpful for better understanding and interpretation of standard intravenous urography studies, planning a modality of treatment and predict the outcome of various procedures. It is also useful for minimising intra- and post procedural complications.

Inspite of these numerous practical implications of variations in the pelvicalyceal anatomy for urologists and radiologists, only few studies have detailed the morphology of different patterns. Hence this study has been done to analyse and reemphasize the importance of adequate knowledge regarding the various patterns and also to evaluate certain morphologic parameters for comparison with clinically significant values.

Aims and Objectives

AIMS AND OBJECTIVES:

1. To study the anatomical variations in the pelvicalyceal pattern in human kidneys.
2. To analyse the various dimensions of lower pole infundibulum of kidneys.
3. To compare and correlate the dimensions with clinically significant parameters.

Review of literature

REVIEW OF LITERATURE:

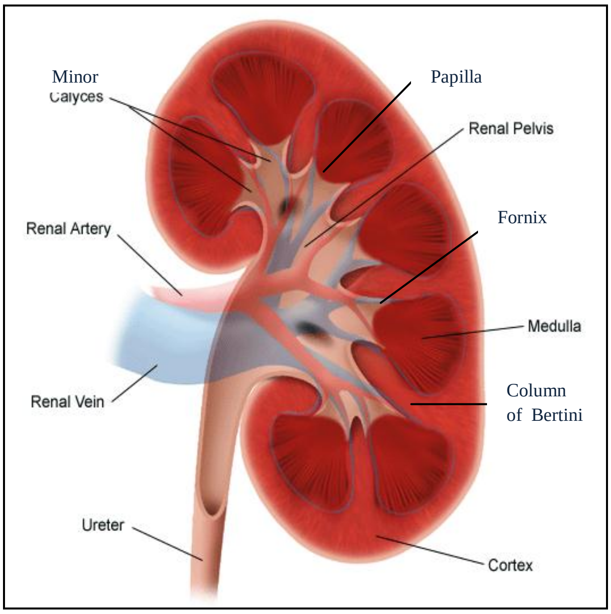
SYNOPSIS:

1. NORMAL ANATOMY
   - Papilla
   - Minor calyces
   - Major calyces
   - Infundibulum
   - Renal pelvis
2. RELATIONSHIP BETWEEN THE INTRARENAL ARTERIES AND THE KIDNEY COLLECTING SYSTEM.
3. RELATIONSHIP BETWEEN THE RENAL VENOUS SYSTEM AND THE KIDNEY COLLECTING SYSTEM.
4. EMBRYOLOGY
5. MOLECULAR REGULATION OF DEVELOPMENT.
6. BRIEF VIEW OF HISTOLOGY
7. CONGENITAL ANOMALIES
   - Anomalies in number
   - Anomalies in position or form
   - Anomalies in size
8. CLINICAL SIGNIFICANCE

1. NORMAL ANATOMY :

The kidneys are reddish, bean shaped organs located on either side of the vertebral column in the retroperitoneal region of posterior abdominal wall. They extend from T_{12} (twelfth thoracic vertebra) to L_3 (third lumbar vertebra) level, but the right kidney is positioned at a slightly lower level (9). The lateral border of the kidney is convex and as we proceed centrally the renal sinus is present. Here the vascular structures and the collecting system coalesce before entering or exiting the kidney. These structures are covered by yellow sinus fat and this marks an easily recognized landmark during renal procedures (10)

Fig 1: Coronal section of left kidney



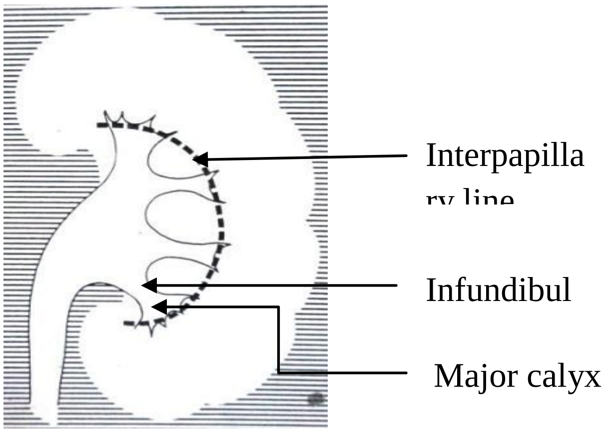
Along the medial border of each kidney there is the presence of a linear fissure oriented vertically called the renal porta or hilum (11). The renal arteries and nerves enter through the renal hilum, while the renal veins, lymphatics and the renal pelvis continuing as the ureter exit through it. In the anteroposterior direction the arrangement of the structures in majority of specimens is the vein – artery – pelvis complex[12, 13, 14,15].

On coronal section, two parts are clearly visible in the renal parenchyma. The outer part is the renal cortex and the inner part is the renal medulla. The medulla consists of numerous, discrete conical shaped areas which look noticeably striated in appearance and are darker than the surrounding cortex. These structures constitute the renal pyramids. The apex of the pyramids is called the papilla [6]. The extensions of the renal cortex between the renal pyramids are the renal columns of Bertini. The cortex contains nephrons which act as the functional unit of the kidney. The glomerulus and the convoluted tubules of nephrons which are responsible for the filtration of urine are located within the cortex. The striated appearance of the medullary pyramids is due to the presence of loops of Henle and collecting tubule part of the nephron. These parts function as the beginning of the collecting system [16].

PAPILLA:

The apex of the renal pyramid which intrudes into the minor calyx is called papilla. The papilla indents only the centre of a minor calyx . The surrounding sharp edged portion of the minor calyces is the renal fornix. This fornix acts as the point of entry of catheters for many of the renal procedures like stone removal using flexible nephroscopes. The interpapillary line connects the fornices of the calyces and all points on this line are equidistant from the lateral border of the kidney [6] .

Fig 2 : Interpapillary line connecting the fornices

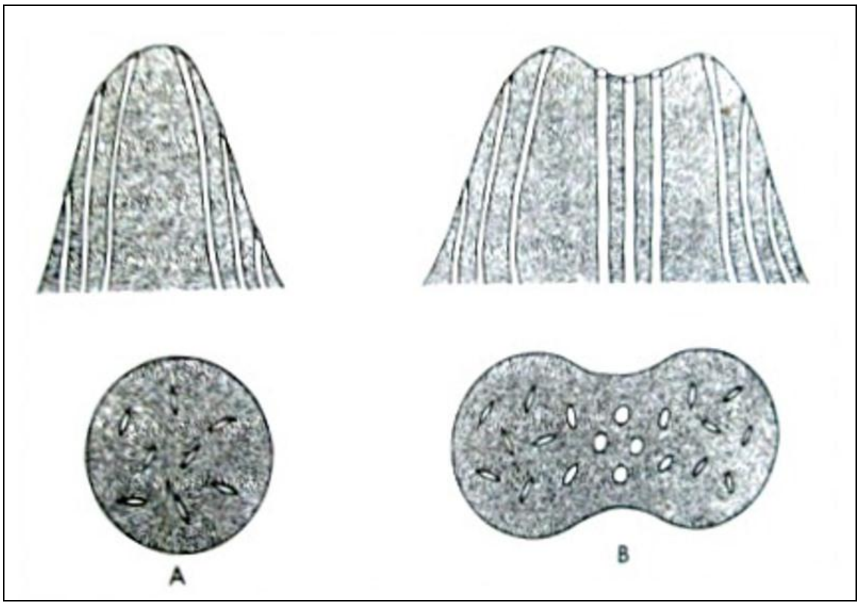


Each minor calyx surrounds either a single or groups of 2-3 papillae.

The renal papillae are considered to be the initial gross structure of the collecting system. On examination, there are usually seven to nine papilla per kidney. Sometimes they range from four to eighteen in a kidney(10). They consist of openings of the distal collecting ducts of Bellini.

The papilla are arranged in two longitudinal rows which are approximately 90degrees from one another. There is an anterior row that faces the lateral direction because of the orientation of the kidney and a posterior row which is directed posteriorly. The papilla can assume a simple or a compound structure in a fully developed kidney. The simple form of papilla is structured like a single inverted cone whose convex surface projects into the calyceal lumen. The compound papilla is with a complex shape consisting of flat, concave and cleft like profiles that protrudes into the calyceal lumen (17). The simple type of papilla has narrow slit like openings of the collecting ducts. When conditions of increased back pressure arise as in obstruction due to stones, there is closure of the collecting ducts in a simple papilla (10). This closure effectively prevents reflux of urine into the renal parenchyma. In the compound type, there are open, round orifices that permit intrarenal reflux of urine into the renal parenchyma.

Fig 3 : Shape of opening of orifices in simple and compound papilla



MINOR CALYX :

Sykes (1963) found that in the foetal kidney there were anterior and posterior divisions for the minor calyces. But they become fused in the upper and lower pole regions. His finding was, that such a fusion may persist in the middle part which is also called the hilar part. He also made a point that these minor calyces were arranged in pairs in the upper pole, middle zone and the lower polar regions. The upper pole had three pairs which faced cranially. In the middle zone, two pairs were seen facing laterally. The fusion between the divisions was gradual and it occurred maximally in the upper pole region. All these changes happened in the last trimester of pregnancy, thus attaining the pattern found in adult kidneys [(18)]. Some minor calyces have an anterior or posterior orientation relative to the frontal plane of the kidney.

Sabnis et al (1997) classified the minor calyces based on their mode of drainage into simple and complex pattern. When the minor calyces drain directly into the major calyx separately, it is classified as a simple pattern of drainage . Sometimes the minor calyces unite with each other before draining into the major calyx. Such a pattern belongs to complex type[19] .

MAJOR CALYCES :

The minor calyces unite with each other to form two or sometimes three larger chambers called as the major calyces [2]. According to Fine and keen (1966), there were two major calyces in a majority of cases and rarely there was a third major calyx [20]. They also noticed that sometimes there was no formation of major calyces. The major calyces are positioned at various angles with respect to the coronal (frontal) plane of the kidney [21]. During development, following the rotation of the posterior aspect of the kidney laterally, the major calyces which were laterally positioned became oriented anteriorly. Also the medially facing major calyces were directed posteriorly [2].

The major calyces in the upper and lower poles are directed at different angles with respect to the coronal plane. The rest of the calyces in the middle zone are oriented in two distinct rows, one in the anterior direction and the other in the posterior direction. Based on the angle and direction of orientation of the calyces, two types of kidneys were described by Brodel and Hodson. Brodel (1901) described that the posterior calyces were oriented at an angle of 20 degrees posterior to the frontal plane and the anterior calyces were seen projecting at an angle of 70 degrees in the anterior direction with respect to the frontal plane [22].

In Hodson (1972) type of kidney, it was exactly the mirror image of the Brodel type. Here the anterior calyces were seen projecting at an angle of 20 degrees with the frontal plane and the posterior calyces made an angle of 70 degrees with the frontal plane of the kidney [(23)].

Kaye and Reinke (1984) observed the calyceal position in the middle or hilar zone of the kidneys by computed tomographic imaging. According to their studies, the right sided kidneys predominantly belonged to the Brodel type whereas the left sided kidneys often resembled the Hodson type of kidney [(24)]. This distribution of Brodel type in right sided kidneys and Hodson type in left sided kidneys was confirmed by Sampaio et al (1988) in a study on 3-D pyelocalyceal casts [(25)].

INFUNDIBULUM:

The major calyces drain into the infundibulum. The renal pelvis is normally formed from the junction of the infundibula [(2)]. The renal pelvis is formed by the union of upper and lower infundibula. The presence of a third infundibula indicate the presence of a third major calyx in the middle or hilar region of the kidney [(2)]. The anatomical structure of the lower pole infundibulum plays a crucial role in the drainage of stone fragments following Extracorporeal Shock Wave Lithotripsy used as a mode of treatment for nephrolithiasis. The various morphometric parameters including infundibular length, width and the angle of the infundibulum with the ureteropelvic axis are important parameters that need to be considered before planning of any procedure for treating nephrolithiasis.

RENAL PELVIS :

The renal pelvis can be classified into various types depending on its shape, position with respect to renal sinus, length and the pattern of drainage of minor and major calyces. Then the relationship of the renal pelvis and the calyces with the renal vessels is also discussed.

Bruce et al (1967) observed the position of the pelvis as being intrarenal, extrarenal or borderline. The borderline pelvis is intermediate between the intrarenal and extrarenal positions. Very rarely, the pelvis cannot be demonstrated at all and the ureter is seen arising directly from the major calyces [(26)].

Didio (1970) found that the pelvis can be classified based on length as long type and brachy type. When the pelvis is small with the major calyces being long, it belongs to the brachy type. At the same time, when there are short major calyces ending in a large renal pelvis, it belongs to the long type of renal pelvis [(27)] .

Anson and McVay (1971) made an observation by combining the two features described by the previous authors. According to them, the extrarenal type of pelvis appears larger and the intrarenal pelvis which lies entirely within the renal sinus looks smaller [(28)].

Edwards et al (1975) also described the renal pelvis based on their position within or outside the renal sinus. They reinstated that the position of pelvis being of two types, intrarenal and extrarenal types [(29)].

The following are the different types of classification of renal pelvicalyceal system that can be used by endourologists and radiologists for basic clinical evaluation.

Graves (1986) made a different type of classification of the pelvicalyceal patterns. It consisted of four types depending on the shape of the renal pelvis along with prominences of the calyces [(30)].

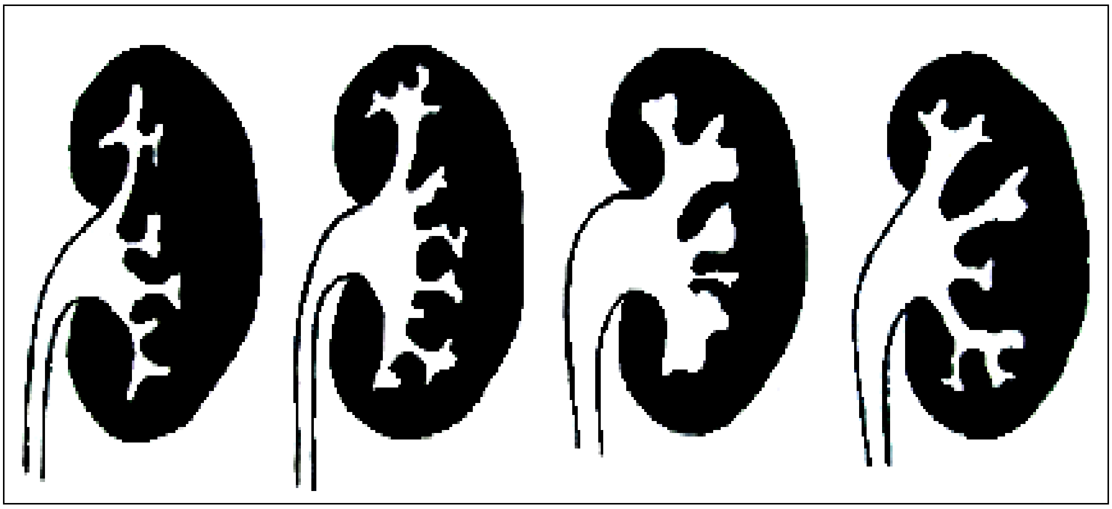
Type A – Classic 'Y' Shaped

Type B – Inverted 'T' Shaped

Type C – Balloon Shaped

Type D – Inverted Bagpipe Shaped.

Figure 4: Grave's classification of pelvicalyceal patterns



A (Classic Y shape) B (Inverted T shape) C (Balloon shape) D (Inverted bagpipe shape)

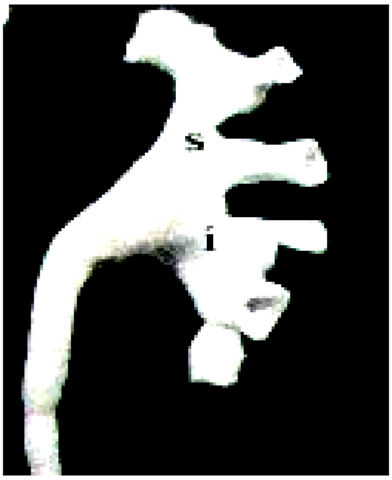
Sampaio and Lacerda (1988) gave a variety of dimension to the classification of the pelvicalyceal patterns based on their three dimensional study on polyester endocasts of the renal collecting system [(5)]. It is classified into two main groups depending on the drainage pattern seen in the upper and lower pole regions along with the middle zone. The two main divisions are group A and group B based on whether the drainage is dependent on two or three major calyces.

In group A, the kidney is drained by two groups of calyces. These two groups seem as if to arise as a main division of the renal pelvis from the upper and lower poles and the middle zone has a drainage system that is dependent on upper or lower group of calyces or sometimes both. There are two subtypes under this category. In type AI, the minor calyces drain into the upper or lower calyceal groups. Those minor calyces can sometimes drain into both the groups. In the second type AII, the middle zone drainage is by calyces that cross with each other. One of the cross draining calyces drains into the upper calyx and the other into the lower calyx. They made an interesting observation that in this type AII with cross draining calyces, the one that drained into the lower calyceal group was anterior in position in around 88% of casts. Also, these crossing calyces enclosed within them a space called interpelvic – calyceal space. This space is bounded medially by the renal pelvis and laterally by the crossing calyces.

In group B, the middle or the hilar zone is drained by a separate calyx and is independent of both the upper and lower calyceal groups. This group is in turn divided into two types. In type BI, there is a separate calyx draining the middle zone which is not connected to both the superior and inferior calyceal groups. In type BII, middle zone is drained by one to four minor calyces that end directly into the renal pelvis. The predominant type of pattern that was found during their study was A I type followed by type B I.

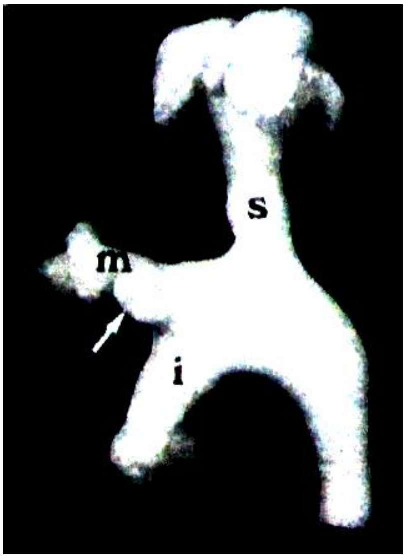
The endocasts of different types of pelvicalyceal patterns are clearly shown in the picture below. The orientation of minor calyces in anterior and posterior directions with respect to the frontal plane of the kidney can be easily made out as shown in the picture showing B I type. The presence of crossing calyces in the middle zone is a characteristic feature of type A II and it is seen in the picture below.

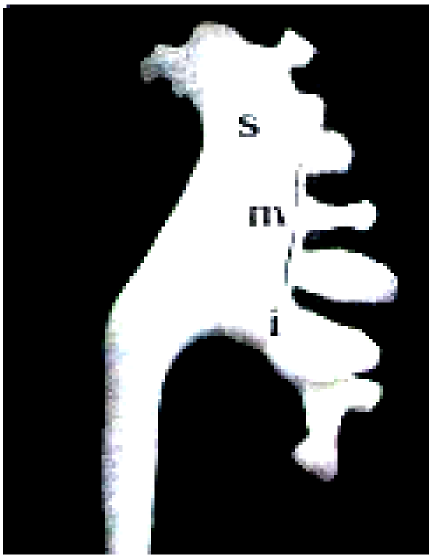
Figure 5: Sampaio's classification of pelvicalyceal patterns.



A I – Two major calyces from superior(s) and inferior(i) poles with middle zone drainage dependent on any one of them or both.

A II – Same as A I, but with crossing calyces in the middle zone. *-interpelvic calyceal space.





BI, there is a separate calyx draining the middle zone which is not connected to both the superior and inferior calyceal groups.(s-superior,m-middle,i-inferior.)

BII, middle zone is drained by one to four minor calyces that end directly into the renal pelvis.

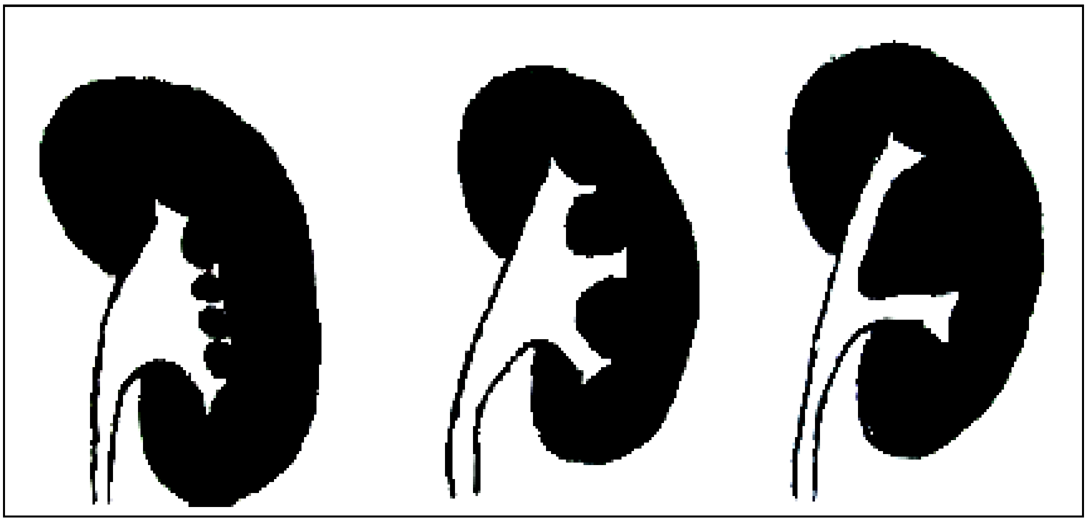
The pelvicalyceal pattern within a kidney shows variation not only between individuals, but also within an individual on both sides. The pelvicalyceal pattern between two kidneys of the same individual had only 37% symmetry. This analysis by Sampaio by studying the pattern in endocasts was confirmed by himself in a radiologic study in 1933 [31, 32].

Ningthoujam DD et al (2005) also analysed the pelvicalyceal patterns by dissection method and by studying intravenous urography pictures [4]. According to them, the renal pelvis is classified into three major groups based on the pattern of drainage, number and position of minor as well as major calyces. They are the multicalyceal or radiate type, triangular or tricalyceal type and the bicalyceal or Y shaped types.

The multicalyceal or radiate type constituted 30 % of all the kidney specimens dissected and studied by them. There appears that the minor calyces open in a radiating manner into the major calyces or directly into the renal pelvis. In such type of drainage, the renal pelvis appears larger. It is found that the renal tissues surrounding the minor calyces are difficult to separate. The infundibulum appear shorter in this type or sometimes it is not demonstrable clearly.

The triangular or tricalyceal types was observed in 40% of specimens studied. It is the commonest type according to this study. There is the presence of three major calyceal groups in upper, middle and lower regions. These calyces are formed by the fusion of corresponding minor calyces that finally drain into it. The size of the renal pelvis is moderate in this type. The position of the middle zone calyx is variable, sometimes close to the upper zone calyx or at times to the lower zone calyx. In 8 – 10 % of this type, the infundibulum from the upper pole calyx appears long and thin when compared to the short infundibulum of the middle and lower pole calyx.

Figure 6: Pelvicalyceal patterns – As proposed by Ningthoujam DD et al



Multicalyceal or radiate type — Tricalyceal type — Bicalyceal type

The Y Shaped or bicalyceal type constituted 20% of specimens. The pelvis is formed by the union of two major calyces – one from the upper pole and the other from the lower pole. The infundibulum of these two calyces are long and the pelvis barely contains any space. The two calyces appear to be of same length in some of the specimens. Two types of this Y shaped pelvis are encountered. The symmetrical or classic Y shaped pelvis is with two symmetrical upper and lower pole major calyces. Each calyx has the drainage of four to five minor calyces. The minor calyces draining the middle zone are found to open into either the upper pole or lower pole major calyces. The asymmetrical type had one infundibula which is longer and more dominant than the other. The lower pole minor calyx may drain into the upper pole major calyx and vice versa.

The remaining 10% of specimens could not be categorized into any of these types and they are grouped under unclassified type. There were the presence of a middle zone major calyx continuing as the renal pelvis or draining directly into the ureter and there can be an absent major calyx .The middle zone minor calyces may show extreme cross drainage going to the opposite polar regions. Some specimens presented with extrarenal calyces.

Apart from minor calyces draining into the major calyx from the lateral aspect, there can be an anterior and posterior orientation of minor calyces. These are more marked in the middle zone. These minor calyces can be named as apical, apicoanterior, apicoposterior, anterior and posterior according to their positions. The number of these anterior and posterior minor calyces is also variable. They may appear to drain into the major calyces perpendicular to the frontal plane. The posterior calyces appear medial to the anterior calyces in ultrasound studies and intravenous urography studies.

In intravenous urography study, the following structures are identified. The minor calyces, major calyces, length of the infundibula and shape of the renal pelvis. Although the pattern can be studied using intravenous urography study, the depth of the branching pattern is clearly studied in dissection specimens. The exact number of minor calyces and the crossing calyces are clearly made out following dissection. Apart from the pattern of drainage of lower pole minor calyces, the number of minor calyces in the lower pole also has an impact in stone formation. The number was more in patients with stone formation than in normal persons.

According to Ningthoujam DD et al, the different types of pelvicalyceal patterns described by them corresponding to the Graves’ and Sampaio’s classification is as follows. There is a considerable overlapping between the groups and it is clearly evident in the table given below. The multiradiate type is almost the same as group B II described in Sampaio's classification and the bicalyceal type is the same as group A I of Sampaio's classification.

Table 1: Correlation between the three classifications of pelvicalyceal patterns

<table>
<tr><td>SAMPAIO'S</td><td>Type A-I</td><td colspan="2">Type A-II</td><td colspan="2">Type B-I</td><td>Type B-II</td></tr>
<tr><td>NINGTHOUJAM DD et al</td><td colspan="2">Bicalyceal or Y shaped</td><td colspan="2">Tricalyceal or triangular</td><td colspan="2">Multicalyceal or radiate</td></tr>
<tr><td>GRAVES</td><td>Classic Y,
Type A</td><td colspan="2">InvertedT,
Type B</td><td colspan="2">Balloon,
Type C</td><td>Bagpipes,
Type D</td></tr>
</table>

The pattern with crossing calyces as described by Sampaio is grouped under unclassified type in Ningthoujam DD et al classification.

2. RELATIONSHIP BETWEEN THE INTRARENAL ARTERIES AND THE KIDNEY COLLECTING SYSTEM :

Sampaio and Aragao (1990) studied the anatomical relationship between the intrarenal arteries and the collecting system in 82 three dimensional casts[(33)]. The calyces in the upper pole are surrounded by arteries which arise from two main divisions.

In majority of individuals one branch is from the anterior division of the renal artery and the other branch is from the posterior division of the renal artery. In the middle or hilar zone, the artery to this region crosses anterior to the renal pelvis in around 65% of casts studied. The lower pole calyces are surrounded by branches from the inferior segmental branch of the anterior division in majority of cases. The renal pelvis is related posteriorly to the posterior segmental artery. These relationship between the arterial branches and the renal calyces are to be considered before planning of the percutaneous procedures.

The percutaneous interventions guided through the calyces include percutaneous nephrolithotomy for stone removal and nephrostomy done for drainage of abscess. The endourological procedures involving removal of stones by open methods also require thorough idea of this relationship. The knowledge of relationship between vessels and the pelvicalyceal system is also essential in interpreting the intravenous urography studies. The renal artery that crosses anterior to the renal pelvis can sometimes compress upon the renal pelvis and this compression can produce an indentation in radiological studies. Although the relationship between the renal arteries and the collecting system is greatly varied among individuals, their knowledge is essential especially before performing percutaneous procedures.

Figure 7: Relationship between intrarenal arteries and the kidney collecting system

The arrow indicates an artery passing anterior to the renal pelvis in an endocast.

3. RELATIONSHIP BETWEEN THE RENAL VENOUS SYSTEM AND THE KIDNEY COLLECTING SYSTEM :

Sampaio and Aragao (1990) observed the relationship between the intrarenal venous system and the collecting system in 52 three dimensional polyester resin corrosion endocasts[34]. It was found that the venous channels surround the calyceal infundibula like a collar and there is the presence of numerous arch like channels connecting the anterior and the posterior venous channels. These connecting branches are seen to be intimately related to the calyces.

Figure 8: Relationship between renal venous system and the kidney collecting system

The arrows indicate vessels surrounding the infundibulum in an endocast.

In 40% of endocasts, a large inferior tributary of the renal vein is seen in relation to the anterior part of the ureteropelvic junction. In 69% of casts, a posterior or retropelvic vein is seen and the same vein can sometimes be found at the junction of the upper calyx and the renal pelvis. Because of the presence of such a tributary of the renal vein in the posterior relationship of renal pelvis, direct approach to the renal pelvis is quiet dangerous. In such cases, the renal pelvis can be accessed via the transparenchymal approach that passes through the fornices and then the calyces[35]. Although the veins are arranged all around the calyces, they are worth attention because of back bleeding that arises as a complication following any damage.

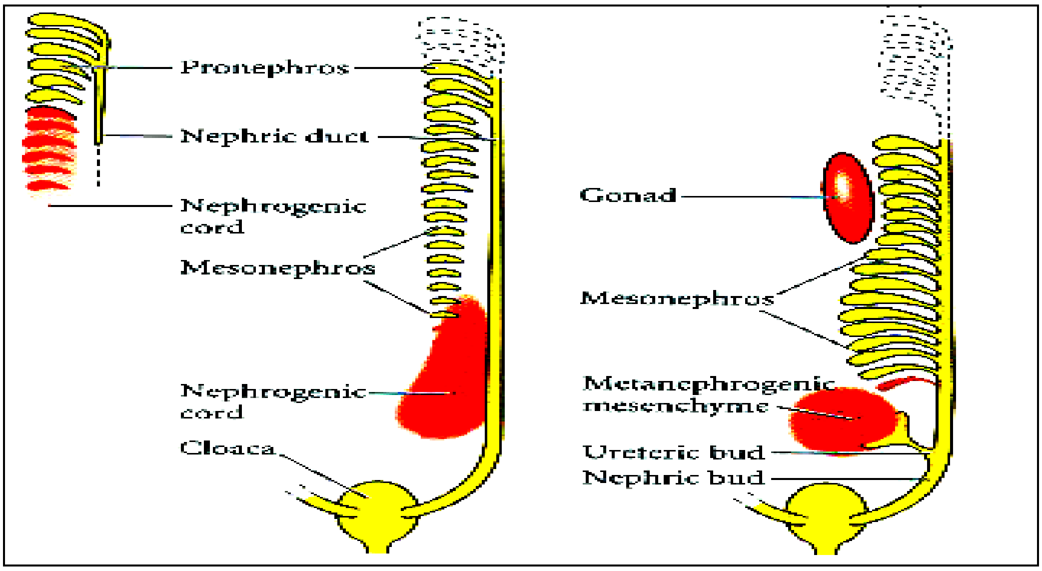
4. EMBRYOLOGY:

The human kidney is said to be made up of specialized cells which work in an organized manner to maintain internal homeostasis of the body including acid base balance, electrolytes and various other components [36]. The human urogenital system is developed from the intermediate mesoderm. The excretory and the collecting parts of the kidney are derived from two sources, the metanephric blastema and the ureteric bud respectively. The formation of excretory part of the kidney consists of three stages of development. The pronephros stage, the mesonephros stage and the metanephric stage which actually gives rise to the permanent metanephric kidney[37].

At the end of the third week of development, there occurs a condensation of cells in the cervical region called the pronephros. In a 10- somite stage embryo, between the second and sixth somites this condensation occurs. The tubules arising from the pronephros and these cell groups start regressing even before the caudal structures are formed. The only importance of these structures is the development of a rare cystic structure which may arise as a vestige [17]. In this stage, the intermediate mesoderm is divided into a medial part, the mesonephric duct and a broad lateral part called the nephrogenic cord.

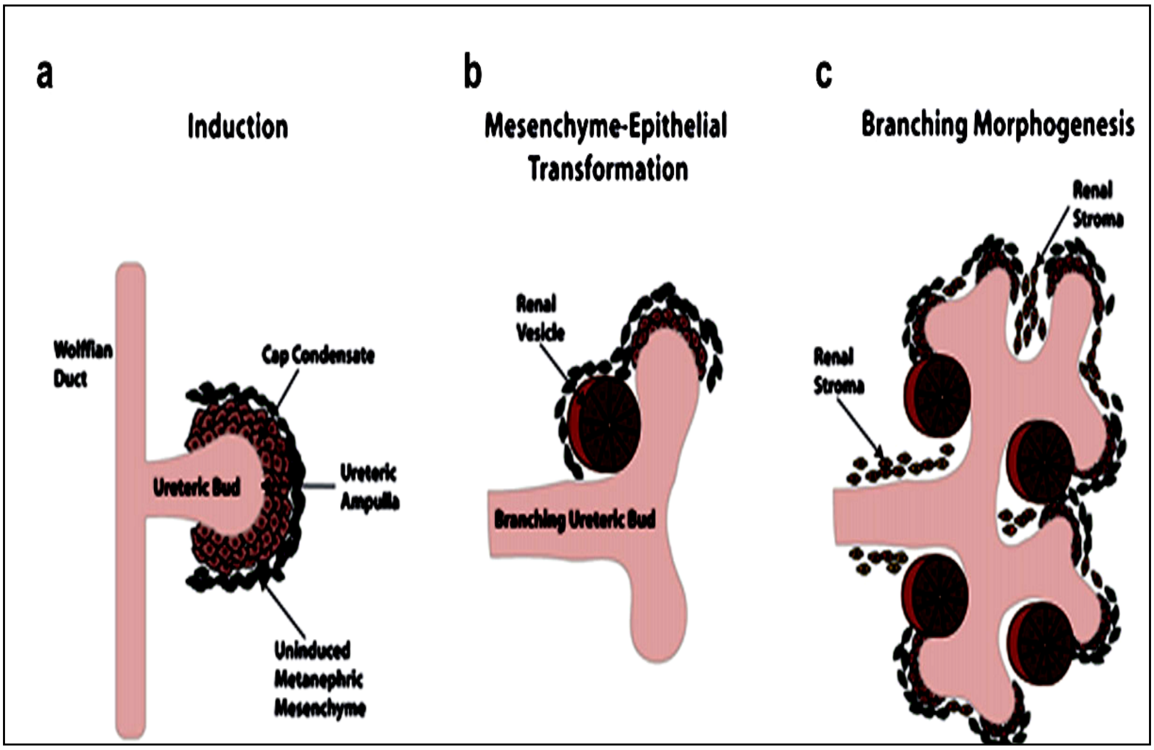
After the third week of gestation, the pronephros completely involutes and it is replaced by the mesonephros. This occurs in a 20-somite stage embryo between the 9th and 13th somites. It is in the upper thoracic to upper lumbar (L3) segments. During regression of the pronephric tubules, the mesonephric tubules first appear. These tubules drain into the mesonephric or Wolffian duct. These tubules and the cranial portion of the duct start regressing and by the end of eighth week of gestation, most of it have disappeared. However in males, a few caudal tubules and the mesonephric duct remain and take part in the formation of genital system. Although these two stages do not take part in the formation of the adult kidney they are necessary for the formation of an outgrowth from the caudal part of the mesonephric duct, the ureteric bud. This occurs close to the opening of the mesonephric duct into the cloaca.

Figure 9: Successive stages of development of kidney and ureter



The ureteric bud diverticulum develops at the level of 28th somite around fifth week of gestation. The ureteric bud is surrounded by a tissue that is derived from the lower part of the nephrogenic cord. This is the metanephric blastema. The ureteric bud induces the metanephric blastemal tissue to develop into nephrons at around seven weeks of gestation. Thus it is concluded that the metanephric blastemal tissue does not develop into nephrons unless induced by the ureteric bud. The two basic processes that underlie the development of kidney hereafter include nephrogenesis and branching morphogenesis. The process by which the glomerulus along with the tubules (except the collecting tubules) are formed is called the nephrogenesis. The other process by which the collecting ducts, calyces, renal pelvis and the ureter are formed is included under a process called branching morphogenesis[36].

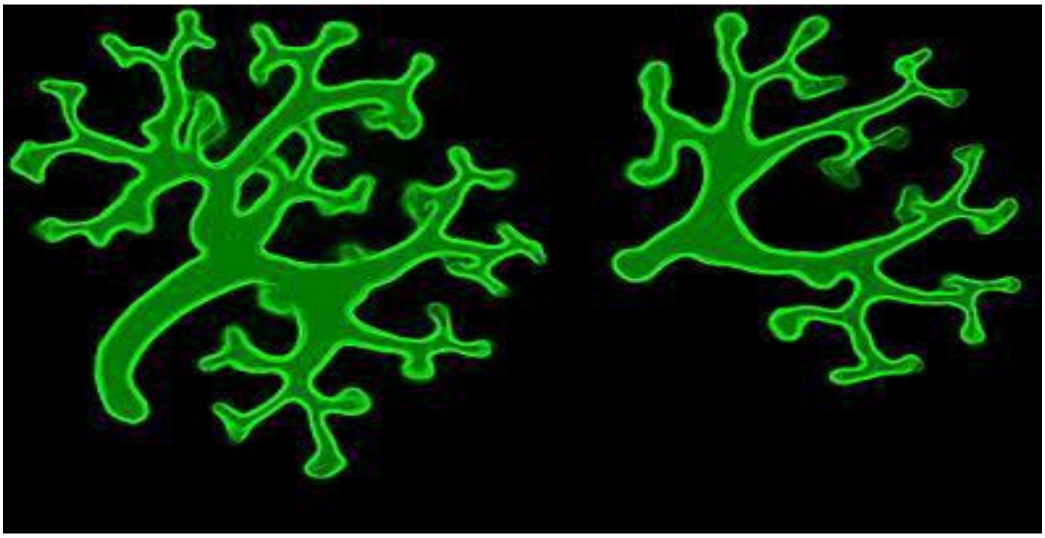
Figure 10: Branching morphogenesis in the development of kidney



The ureteral bud growth is considered to consist of two components, elongation and division [17]. When the ureteral bud elongates, the dilated tip of the ureteral bud called the ampulla containing specialized cells interacts with the metanephric blastema. Then the ureteral bud moves in a cephalad direction from the original sacral situation along with the metanephric blastema. Also as soon as the ureteric bud invades the metanephric blastema, branching of the ureteric bud is initiated. Potter [38] in 1972 described the ureteric bud as having four main functions including progression in an anterior direction, division, initiation of nephrogenesis and establishing communication between the collecting ducts developed from the ureteral bud and the nephrons derived from the metanephric blastema.

The ureteral bud divides in a dichotomous fashion with more such divisions occurring in the upper and lower pole regions than in the middle or hilar zone [3]. Thus in the adult kidney the parenchyma appears thicker in the polar regions and is said to contain increased number of nephrons. The divisions start appearing by 5th week of intrauterine life and continue till the fifth month of gestation. The divisions which occur in the end are usually seen in the periphery of the medulla. The total number of divisions may approximately be around 15 – 17 branching generations. Along with the branching pattern seen in the ureteral bud there is concomitant formation of nephrons from the metanephric blastema following interaction between it and the ureteral bud.

Figure 11: Generations of dichotomous branching - Invitro 3 D - culture of isolated ureteric buds in fluorescent microscopic imaging



The initial three to five generations that are formed from the ureteral bud dilate to form the renal pelvis. The following three to five generations again dilate to form the calyces and papillae. The last six to nine branching generations give rise to the collecting ducts. The infundibulum connecting the calyces and the renal pelvis are derived from the generations that branch after those forming the renal pelvis. The only difference is that these divisions forming the infundibulum do not dilate. Potter described that the renal papilla in many cases developed from the 11th generation of divisions of the ureteric bud. When the developing kidneys move in to attain their adult position, they undergo a 90degree rotation about the longitudinal axis. Thus the renal pelvis faces a medial direction.

The renal cortex constituting about 70% of total kidney volume at birth becomes arranged as a compact mass of tissue around the periphery at around 22 weeks of gestation (39). The renal medulla containing cone shaped structures called pyramids constitutes around 30% of total kidney volume at birth. The pyramids have a broad base towards the renal cortex and an apex facing the renal medulla. The apex of the pyramids where the collecting ducts open is called the renal papilla. A pyramid along with the cortex overlying it is called the primitive renal lobe.

At around fourth month of gestation, there are seven anterior and seven posterior discrete renal lobes. The process of renal lobe formation takes place at sites where the calyces are formed. The number of renal lobes formed thus depends on the number of pyramids which in turn is dependent on the number of calyces formed (3). During 28th week of gestation, the boundaries between the lobes start assimilating. If these boundaries persist even in adult life, it gives a grooved appearance to the kidney and the condition is termed as persistent fetal lobation. Also the calyces start fusing and the one to one relationship between the calyces and the papilla is not found in the adult kidneys. This process is more seen in the poles thus resulting in the formation of compound calyces, each draining two to four papilla. The cortical tissue seen in between the pyramids constitute the renal columns of Bertini. When such a column is thicker it gives a bulbous appearance and produces an indentation on the major calyx. It may simulate an intrarenal mass and such a hypertrophied column of Bertini is called a renal pseudotumour [(3)].

5 .MOLECULAR REGULATION OF DEVELOPMENT:

The growth of the ureteric bud and its interaction with the metanephric blastema is essential for development of the kidney. This is regulated by the release of Glial cell Derived Neurotrophic Factor (GDNF) from the metanephric blastema. After it is released, it binds to the surface of the ureteric bud through the Rearranged during Transfection (RET) factor. Paired box – 2(Pax – 2) gene that is expressed in the intermediate mesoderm directly initiates the transcription of Glial cell Derived Neurotrophic Factor [(36)]. Bone Morphogenetic Protein – 4 (BMP-4) has the ability to block the glial cell derived neurotrophic factor and modulate the outgrowth of the ureteric bud [(40)]. The formation of renal pelvis, calyces and geographical demarcation of the renal parenchyma into cortex and medulla is regulated by various factors including FGF-7, FGF-10, Bone Morphogenetic Protein(BMP), Glypican – 3 and P^{57} ^{KIP2} families.

6. BRIEF VIEW OF HISTOLOGY:

The proximal part of the urinary tract is said to be made up of three layers in its wall. From inner to outer it consists of mucosa, smooth muscle layer and an outer adventitial layer. The mucosal layer is lined by transitional epithelium in the calyces and the renal pelvis similar to the lining of ureter. The smooth muscle layer consists of two types of smooth muscle cells. One type of cell is similar to that which is seen in ureter and this can be traced above up to the level of minor calyces. The other cell type lines the inner aspect of the outer muscle layer and is observed to line the minor calyces. This is an atypical layer which does not extend beyond the pelviureteric junction. They also act as pacemaker cells which initiates ureteric peristalsis. They aid in coordinated peristalsis of the ureter [(2)]. The adventitial layer consists of loose connective tissue. The capsule lining the renal sinus is fused with the adventitial layer, so care should be taken during surgery in this plane.

CONGENITAL ANOMALIES:

Anomalies of different parts of the collecting system include variation in number, size and position or form.

(i) Anomalies in number:

a. Unipapillary kidney:

The kidneys in many mammals including dog, cat, sheep, rabbit, monkey and rat have only a single papilla. Such a unipapillary kidney can be found in humans rarely. The unipapillary kidney has a single papilla with or without a calyx. There is a single renal lobe. When present, it is found to be associated with other anomalies such as ipsilateral hypoplasia or contralateral agenesis of kidney.

The hypothesis behind the formation of unipapillary kidney suggests that when only one tubule following the first period of dichotomous division goes into a period of second dichotomous division, this condition will occur or it can be due to failure of branching in the 6-10th generations. The rest of the tubules end in a blind diverticulum which seem to arise from the renal pelvis or may become a blind ending ureter [6].

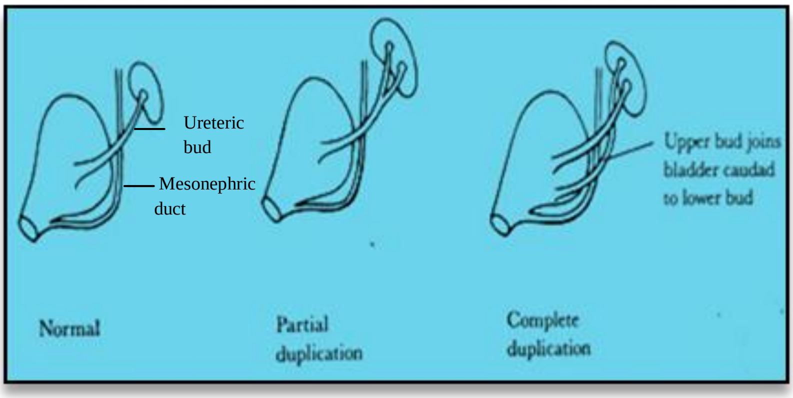
b. Polycalycosis :

In this condition, the number of minor calyces can be 40 or even more. Such a condition is normally seen in some mammals including cows and seals. But it is rarely seen in humans. Sometimes this condition is associated with megacalyces and may be seen in Rubinstein Taybi syndrome, an autosomal dominant syndrome following mutation in CREBBP(cyclic AMP Response Element Binding Protein) gene. Apart from these associations , it is usually free from complications [6].

c. Duplex collecting system:

When a kidney is drained by two pelvicalyceal systems, it is called a duplex kidney [6]. Such a duplication of the collecting system can either be partial or complete. Partial duplication is due to branching of the ureteric bud even before it establishes contact with metanephric blastema. This can extend anywhere from bladder to the renal pelvis. When the duplication is close to the renal pelvis it can result in bifid renal pelvis.

Fig 12: Duplex collecting system – embryology.



Complete duplication is as a result of formation of two separate ureteric buds from mesonephric duct. The two buds invaginate the metanephric blastema separately and result in formation of an upper and a lower intrarenal collecting system [3]. When the duplication is complete, it offers differential diagnosis for hydronephrosis during intravenous urographic studies. This is because the contrast material injected dilates the less well supported pelvicalyceal system that lies outside the renal sinus. The radiologist must be aware of such an anomaly before interpretation of radiological studies.

(ii) Anomalies in position or form :

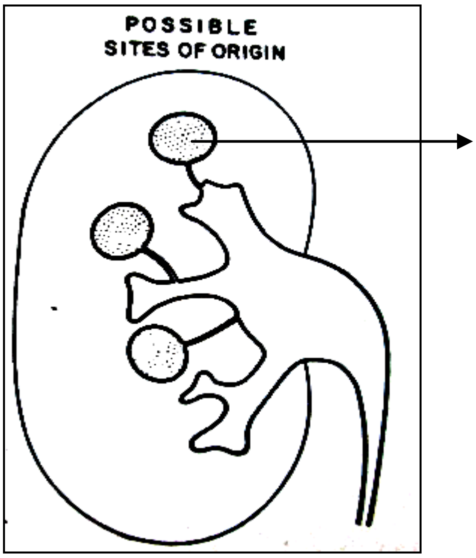
(a) Aberrant or ectopic papilla:

Most renal papillae are found to empty into a minor calyx normally. In the upper and lower pole regions, the complex type of minor calyces are common. In such areas papillae are seen to open side by side into a major calyx. An aberrant or ectopic papilla can virtually open into any part of the collecting system including the major calyx, infundibulum or the intrarenal part of renal pelvis. This may present as a filling defect and must be differentiated from a stone , tumor or other pathologic conditions. In retrograde pyelography or excretory urography, it looks like a round, smooth defect. The smooth border and fixed location in the collecting system helps in differentiating this condition from a stone or a tumor. In oblique views, its origin from the papilla can be traced out. The fornix surrounding it appears as a thin, opaque rim of contrast material surrounding the aberrant papilla. This is called the ‘halo sign’[6]. Although the anomaly is considered insignificant in terms of management, sometimes they help avoid unnecessary investigations causing physical and economical burden upon the patient.

b. Pyelocalyceal diverticulum :

A pyelocalyceal diverticulum is a cystic cavity within the renal parenchyma that communicates with the collecting system and is lined by transitional epithelium [41]. It can be of two types, one in which the cyst communicates with a minor calyx and the other type where it communicates with a major calyx or renal pelvis [42]. The one which connects with the minor calyx is commonly found in the upper pole. The diverticulum can be single or multiple, unilateral or bilateral.

Figure 13: Pyelocalyceal diverticulum.



The developmental basis of such a condition suggests that one of the tubules belonging to the last generation of divisions fails to dilate as it normally happens to form the infundibulum and persists as a diverticulum [6]. It is commonly seen in the upper pole because it is there in the upper pole, the number of tubule formation is the largest. This condition is usually an incidental finding in ultrasonography. But very rarely, the diverticulum can act as a nidus for infection following stasis of urine . In such conditions, it is ideal to remove the diverticulum by doing percutaneous procedures or rarely open removal.

c. Extrarenal calyces :

The presence of extrarenal calyces is a rare anomaly involving the collecting system and it was first described by Eisendrath in 1925[43]. In this condition the major calyces and the renal pelvis are extrarenal in position. The embryological reason behind the condition is not known exactly. The possible cause could be a disparity in growth between the metanephric tissue and the ureteric bud. There can be a rapid prolongation of the ureteral bud or a slow development of the metanephric blastema. When it is said that the ureteral bud develops rapidly, the calyceal system is well developed even before merging with the metanephric blastema. When there is a slow development of the metanephric blastema, its connection with the collecting system is delayed. The calyces remain unsupported and while doing procedures like retrograde pyelography, they become easily distended and it adds to the differential diagnosis of hydronephrosis. It is essential to be aware of this condition when operating on a kidney with features of distorted calyceal appearance on imaging studies done preoperatively. Thus any injury to the calyces can be prevented in operations on an otherwise normally functioning kidney .

(iii) Anomalies of size :

a) Microcalyx :

There are no clear morphometric dimensions as to say a calyx as a microcalyx. A microcalyx is a minor calyx that is tiny yet otherwise looking normal in all aspects. It consists of a fornix and the tubules draining into it normally [3]. In an intravenous urogram it can be easily mistaken for a pathology as it appears as a small projection of contrast material [6]. It is seen as a small cup with a small papilla projecting into it.

Thus the presence of a tiny papilla helps it differentiate from other conditions as the other conditions may not contain a papilla projecting into it.

(b) Megacalyx:

Megacalyces or Puigvert's disease [(44)] is a congenital anomaly in which the minor and the major calyces appear dilated and the renal pelvis is of normal caliber. The calyces are of over size without any blunting. The number of calyces in this condition is also increased. There is the presence of more than eighteen calyces in radiological studies and thus it is differentiated from hydronephrosis [(45)]. The important diagnostic criteria include dilated calyces, pelvis with normal caliber and absence of vesico ureteral reflux or obstruction. The possible reason for this condition could be underdevelopment of the medullary pyramids and subsequent lack of projection of papillae into the calyces. This makes the calyces appear dilated.

(c)Abortive calyx :

An abortive calyx is a minor calyx which does not present the characteristic cup shape in its tip. Instead it presents with a terminally blunt end and this abortive calyx when present appears broader than it is tall. The more commonly located position is at the base of the upper pole infundibulum. It can have a direct communication with the renal pelvis. When present, it is usually single [(3)].

(d) Anomalous calyx:

It is considered a minor variation seen in pelvicalyceal anatomy. The presence of a short calyx without a papilla is termed an anomalous calyx. The common location is in the middle zone between the upper and lower pole major calyces. A radiologist must be aware of such a variation as it may pose a diagnostic problem leading onto unnecessary investigative procedures to the patient [46].

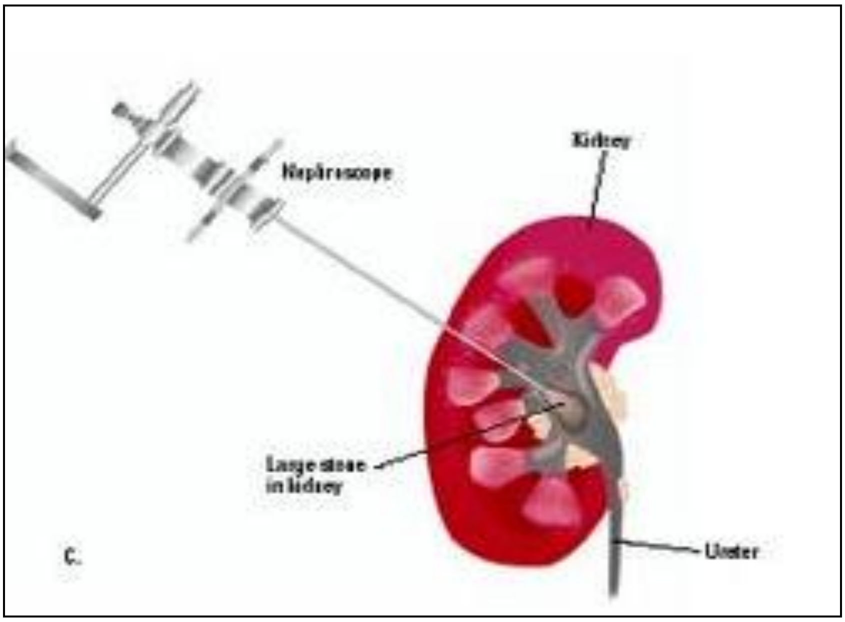
CLINICAL SIGNIFICANCE :

The knowledge of variations of pelvicalyceal patterns is essential to anatomists, endourologists and interventional radiologists. Since the patterns are amply varied in all the individuals and even in the same individual on both sides, it is difficult to differentiate normal from pathology. In the past, the treatment for nephrolithiasis and abscess in the kidney included open surgery in contrast to percutaneous procedures done recently. While performing percutaneous procedures, the site of entry into the required location has to be made with adequate knowledge of different patterns of the collecting system.

The various percutaneous procedures done for treating pathologies involving the kidney include percutaneous nephrostomy, antegrade pyelography, antegrade stent positioning, percutaneous nephrolithotomy and ureteric dilatation. All these procedures require positioning of a cannula or puncturing via percutaneous approach[47]. These are done under imaging guidance bearing in mind the different patterns of the pelvicalyceal system. The basic rule before gaining access into the pelvicalyceal system is that a direct puncture into the renal pelvis is dangerous because of risks of laceration and bleeding .

The ideal method is to reach the collecting system via a transparenchymal approach into a suitable calyx and then into the renal pelvis. The puncture is made as peripherally as possible because the vascular branches are smaller there and entry into the collecting system is made through the fornix. The approach through infundibulum is considered dangerous because of large vessels surrounding it[32]. When the renal function is poor, an initial puncture with a fine needle of contrast material allowing opacification of the collecting system is done as it allows selection of a suitable calyx for puncture.

Fig 14 : Percutaneous nephrolithotomy- puncture is made as peripherally as possible



Percutaneous nephrolithotomy is a minimally invasive procedure developed as an alternative to open surgery in treating renal calculi. It is considered a well standardized technique for treating calyceal stones. When the situation of the renal calculi is in the renal pelvis, the preferred approach is through a middle or lower pole calyx. They are associated with less vascular complications [48]. . For percutaneous nephrostomy procedure which is usually done to relieve obstruction caused by abscess or tumors, posterior calyces are preferred. When the same procedure is done for ureteric manipulations, the preferred site is through a middle calyx as access to the ureter is better and easier than through a lower pole calyx[49]. Based on clinical experience, it is found that access to the lower pole calyx is difficult [50]. But following assessment of lower pole calyceal anatomy using different morphometric parameters, other options like flexible ureterorenoscopy or Extracorporeal Shock Wave Lithotripsy (ESWL) can be utilized.

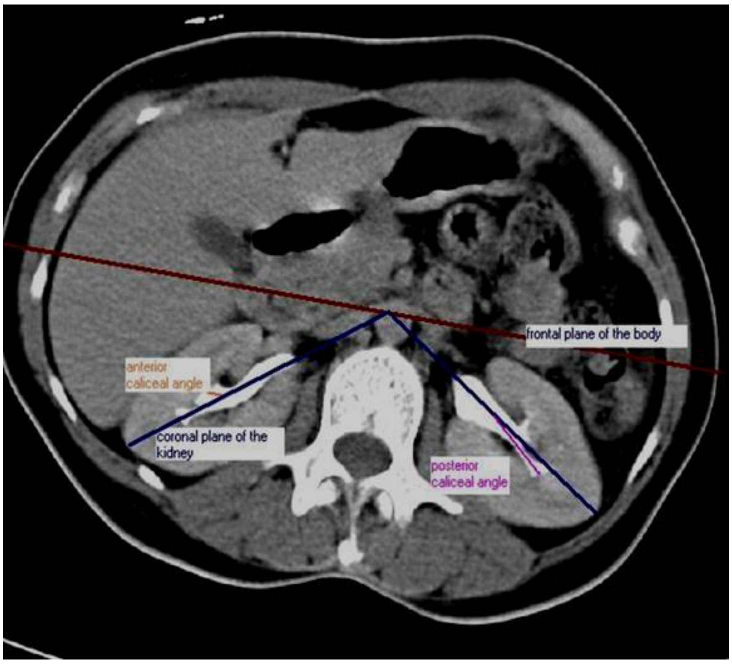
The various parameters of the lower pole calyceal infundibulum that are evaluated before any procedure include lower pole infundibular length, width, length by width ratio, height and infundibulopelvic angle. The role of percutaneous procedures for treating nephrolithiasis have taken a backseat with the advent of Extracorporeal Shock Wave Lithotripsy (ESWL). The only drawback of this procedure is retention of stone fragments following the procedure in patients with unfavourable lower pole anatomy. The poor fragment clearance must be considered with caution as it leads to urinary tract infection, repeated stone formation, obstruction and even hydronephrosis.

Apart from gravity dependent position of lower pole calyces, the various parameters of lower pole infundibulum as mentioned above play a role in fragment clearance following Extracorporeal Shock Wave Lithotripsy [51,52,53,54]. There is a shift of focus from studying only metabolic factors as a reason for stone formation to evaluating calyceal anatomy as a cause. This is because it is difficult to explain when it occurs in a single calyx in one side but not in the other kidney [55].

The varying patterns play an important role not only for interpretation of radiological data and performing percutaneous procedures, but also during open surgical procedures. The relationship between the calyces and the vessels is especially crucial when performing open procedures.

The other mode of treatment for nephrolithiasis includes flexible ureteorenoscopy. When the upper pole infundibulum is thin and long, introduction and manipulation of nephroscopes through the superior pole becomes difficult and it is vice versa when the infundibulum is short and broad [5]. Thus the knowledge of pelvicalyceal patterns and evaluation of various parameters of lower pole infundibulum helps in planning an ideal mode of treatment, predicting the outcome of a treatment procedure, understanding and interpretation of radiological studies like intravenous urography[8]. The experience with which the angles are measured also plays a role in correct evaluation[56]. The infundibulopelvic angle is a major contributor in stone formation especially of the lower pole calyx[57]. The patients with unfavorable lower pole pelvicalyceal anatomy can be suggested the proper mode of treatment that is suitable for them[58].

Fig 15: Computed Tomographic imaging to calculate the angle of orientation of major calyces



The angle of orientation is calculated with respect to the frontal plane of the kidney. The blue line in the picture indicates the frontal plane of the kidney while the red line passes through the frontal plane of the body.

The proper positioning of patients on table before performing various percutaneous procedures is also important due to the anterior and posterior orientation of the calyces. The exact angle of orientation can be calculated using computed tomography studies as proposed by Kaye and Reinke.

Materials and methods

MATERIALS AND METHODS:

Design :

Comparative study.

Time of the study :

The study was conducted from September 2010 to November 2012.

Setting :

Dissection laboratory of the Department of Anatomy, Thanjavur Medical college and autopsy room of the Department of Forensic Medicine, Thanjavur Medical College.

Inclusion criteria :

Kidney specimens from adult human cadavers aged more than 20 years of both sexes in the Department of Anatomy and from autopsied bodies in the Department of Forensic Medicine, Thanjavur Medical College during the period of September 2010 to May 2012 were included in the study.

Exclusion criteria :

Specimens from cadavers aged less than 20 years.

Parameters studied :

- ❖ Position of renal pelvis.
- ❖ Classification of pelvicalyceal patterns.
- ❖ Minor calyces
  - Number
  - Drainage pattern of lower pole calyces
  - Orientation of minor calyces

❖ Lower pole infundibulum

- Length
- Width
- Height
- Infundibulopelvic angle

Sample size :

100.

Statistical analysis :

Datas were entered in Microsoft Excel Spreadsheets. One way ANOVA with Tukey's post hoc test and Unpaired 't 'test was used for comparison between groups. This was done using GraphPad Instat version 3.01 for windows (Graphpad Software, San Diego, California, USA). $P < 0.05$ was considered statistically significant.

Figure 16 : Infundibular width(mm) is measured at the narrowest point in the lower pole infundibulum

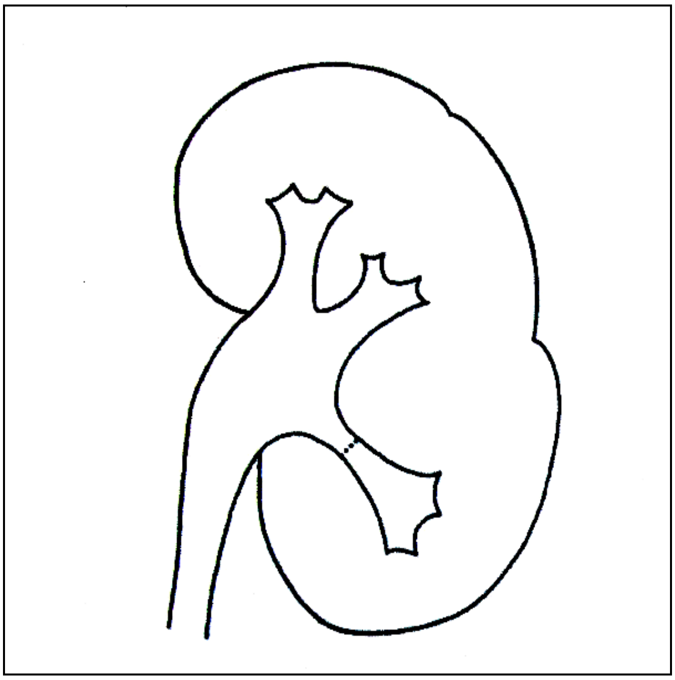


Figure 17: Infundibular height(mm),measured as the distance between horizontal line passing through the lowermost part of the lower Infundibulum and the highest point of the lower lip of the renal pelvis.

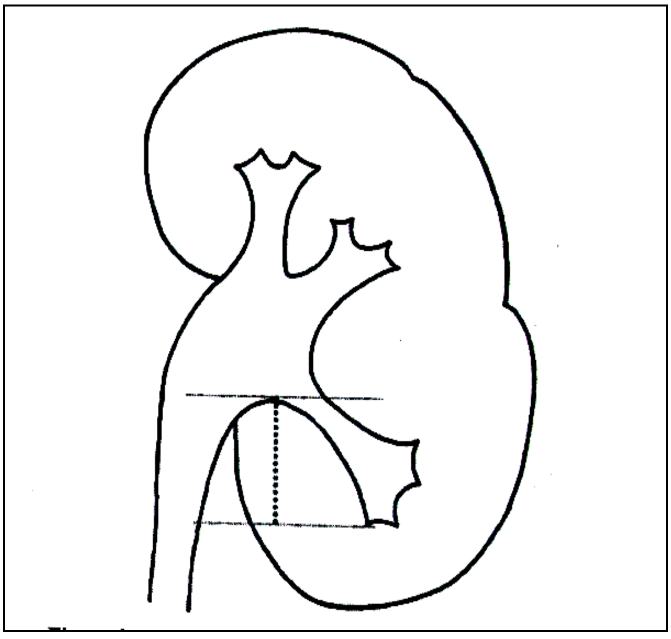


Fig18: Infundibular length(mm), measured as the distance between the most distal point of the calyx and the midpoint of the lower lip of the renal pelvis.

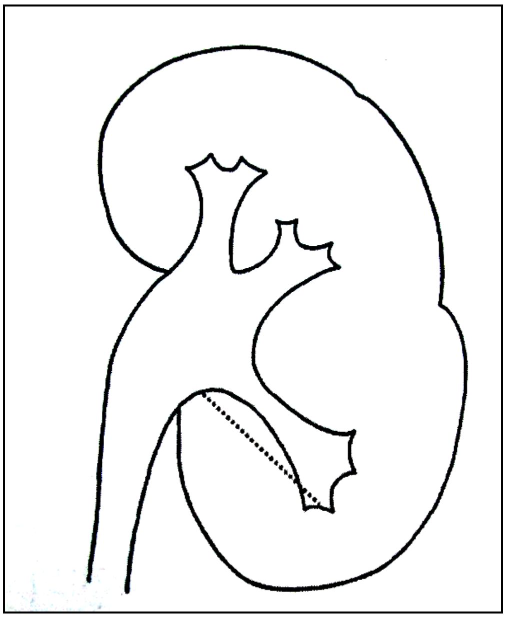
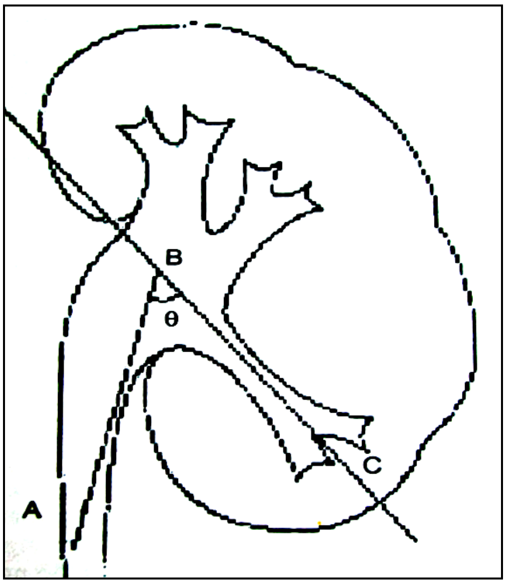


Figure 19: AB- Ureteropelvic Axis, BC - Lower pole infundibular Axis

θ -Infundibulo pelvic angle



The infundibulopelvic angle is measured as the angle between the ureteropelvic axis and lower pole infundibular axis[62]. The ureteropelvic axis is formed by connecting two points, one at the center of renal pelvis and the other point in the ureter opposite the lower pole.

Procedure :

The morphologically healthy, undamaged kidneys without previously known kidney disease were removed en bloc during routine dissection from cadavers in the Department of Anatomy, Thanjavur Medical College and at autopsy in the Department of Forensic Medicine, Thanjavur Medical College in the age group of 20-70 years, during the study period.

The specimen was removed from the cadaver by making an incision in the skin of the anterior abdominal wall extending from the xiphisternum to the level of pubic symphysis. Another incision was made horizantally at the level of xiphisternum and the skin with superficial fascia was reflected. The rectus abdominis muscle was divided and the peritoneum was cut open from xiphisternum to the pubic symphysis level [59]. After mobilizing the intestinal loops, the peritoneum and fat were cut just outside the lateral border of kidney [60] and they were cleared from the anterior surface . Then dissection was carried out behind, freeing the kidney from the anterior surface of psoas major muscle. The ureter is then identified below, lying medial to psoas major muscle and is cut midway between the renal pelvis and its entry into the bladder. The renal artery and the renal vein were divided just before their entry into the renal hilum.

The kidneys along with the ureter thus removed were washed thoroughly in running water and were serially numbered from 1 – 100. The specimens were preserved in a solution containing 10% formalin and thymol. During dissection, the anterior wall of the renal sinus was removed piecemeal. The removal was done starting from the renal hilum. The vessels entering the renal sinus are removed and the calyces are separated by making a clean coronal slice from the lateral margin through the sinus. After the specimens were dissected, they were studied for variations in pelvicalyceal patterns. The number, orientation and pattern of drainage of minor calyces were observed. The lower pole infundibulum was studied in detail and the following morphometric parameters including its length, width, height and angle with the ureteropelvic axis were recorded using rulers, divider and protractor. The values were expressed as mean ± S.D and the values were analysed for statistical significance between groups.

Luminal casting :

Fresh kidney specimens were washed thoroughly in running tap water. Then the blood from the renal vessels was removed by injecting spirit till a clear fluid comes out. The kidneys were then allowed to air dry by keeping them turned downwards. The general purpose silicone gel was introduced through the canula into the cut end of ureter. This was done with the help of a metallic gun designed for injecting the material (Fig. 20). The material is injected until complete resistance is felt and the canula was withdrawn slowly. The free end of the ureter was tightly secured with silk. The specimens were allowed to cure for 24 hours. Then the surrounding tissues were removed by dissection after subjecting them to physical method of boiling. The resultant casts indicate the pelvicalyceal patterns and the details of minor calyces clearly.

Fig 20 : General purpose silicone gel with gun.

Results

RESULTS

The pelvicalyceal pattern was studied in 100 cadaveric kidneys by dissection method. The following observations were made in relation to renal pelvis, minor calyces and the pelvicalyceal patterns and the results were tabulated.

RENAL PELVIS :

The position of renal pelvis varies in relation to the renal sinus . In the present study, they are categorized as belonging to four different types as intrarenal, extrarenal, borderline and absent. The intrarenal type completely lies within the renal sinus and the extrarenal pelvis lies entirely outside it. The borderline type lies partly inside and outside the renal sinus.

The following table illustrates the percentage of specimens belonging to different types of renal pelvis in the present study .

TABLE 2: POSITION OF RENAL PELVIS

S.No	Position of renal pelvis*	Number of specimens n = 100	Frequency (%)	Specimen no.
1.	Intrarenal	79	79	1,3,4,5,7,8….
2.	Extrarenal	5	5	6,18,20,44….
3.	Borderline	13	13	9,10,17,19….
4.	Absent	3	3	2,29,100.

*Position of renal pelvis was in relation to renal sinus. In case of absent pelvis, the major calyceal infundibulum was seen directly opening into the ureter with no demonstrable renal pelvis.

PELVICALYCEAL PATTERNS :

In the present study, the percentage of specimens based on grouping done according to Sampaio's classification is given below .

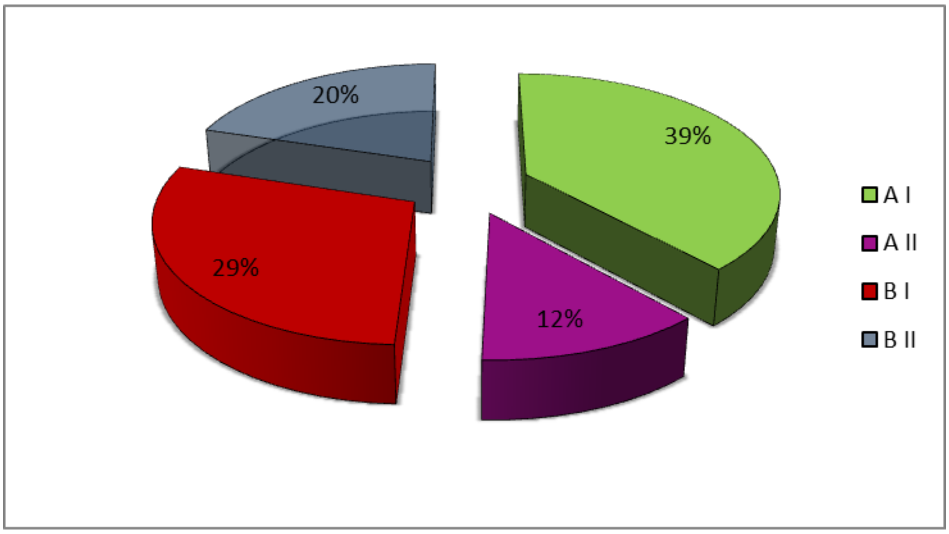
TABLE 3: FREQUENCY OF PELVICALYCEAL PATTERNS CLASSIFIED ACCORDING TO SAMPAIO'S CLASSIFICATION

S.No	Pelvicalyceal pattern*	Number of specimens	Frequency (%)	Specimen no.
1.	A I	38	38.4	2,7,8,10,11….
2.	A II	12	12.2	20,28,34,41….
3	B I	29	29.2	1,3,6,16,18…
4.	B II	20	20.2	5,9,12,13,14,….

*Based on Sampaio's classification. Group A – the kidney is drained by two groups of calyces from upper and lower poles, the middle zone drainage is dependent on them. A I – Two major calyces from superior and inferior poles with middle zone drainage dependent on any one of them or both. A II – Same as A I, but with crossing calyces in the middle zone. Group B - In group B, the middle or the hilar zone is drained by a separate calyx and is independent of either of the upper or lower calyceal groups. BI, there is a separate calyx draining the middle zone which is not connected to both the superior and inferior calyceal groups. In type BII, middle zone is drained by one to four minor calyces that end directly into the renal pelvis.

The total number of specimens does not add to 100 because one specimen did not belong to any of these categories. It presented with extrarenal calyces which drained directly into the ureter. Such a presence of extrarenal calyces was not categorized into any of these four types described by Sampaio. The following piechart represents the frequency of specimens classified according to Sampaio's classification.

FIGURE 21 : CLASSIFICATION OF PELVICALYCEAL PATTERN*



*Based on Sampaio's classification. A I – Two major calyces from superior and inferior poles with middle zone drainage dependent on any one of them or both. A II – Same as A I, but with crossing calyces in the middle zone. BI, there is a separate calyx draining the middle zone which is not connected to both the superior and inferior calyceal groups. In type BII, middle zone is drained by one to four minor calyces that end directly into the renal pelvis.

Ningthoujam DD et al proposed another method of classifying the pelvicalyceal pattern based on the pattern of drainage, number and position of minor as well as major calyces. The different groups include multicalyceal , tricalyceal and bicalyceal types. and those that donot belong to the above types is grouped as unclassified type. In the present study, all the specimens could be categorized into the above mentioned groups in contrast to Sampaio's classification . The specimen with extrarenal calyces and absent renal pelvis is categorized under unclassified type. The percentage of specimens belonging to each group in the present study is shown in the following table.

TABLE 4: CLASSIFICATION OF PELVICALYCEAL PATTERNS AS PROPOSED BY NINGTHOUJAM DD ET AL

S.No	Pelvi calyceal patterns*	Number of specimens n=100	Frequency (%)	Specimen no.
1.	Multicalyceal	23	23	5,9,13,14….
2.	Tricalyceal	27	27	1,3,6,16….
3.	Bicalyceal	35	35	2,7,8,9,10,…
4.	Unclassified	15	15	4,18,20,22….

*As proposed by Ningthoujam DD et al. In multicalyceal type, there is the upper and lower pole calyces . In the middle zone, the minor calyces appear to open directly into the renal pelvis between the two polar calyces. In tricalyceal type, there is the presence of three major calyceal groups in upper, middle and lower regions. In bicalyceal type, two major calyces – one from the upper pole and other from the lower pole are present. Each calyx has the drainage of four to five minor calyces. The unclassified type consists of cross draining calyces in the middle zone, absent major calyces or extrarenal calyces opening directly into ureter.

MINOR CALYCES :

The following observations were made in relation to minor calyces. The total number of minor calyces, lower pole minor calyceal distribution, orientation of minor calyces in the middle zone relative to frontal plane of the kidney (number of kidneys with anteriorly oriented and posteriorly oriented minor calyces) and pattern of drainage of lower pole minor calyces. Among all these factors that are taken into account, the lower pole calyceal distribution and the pattern of drainage of lower pole calyces play an important role in stone formation and in clinical evaluation of patients to choose optimal mode of treatment.

TABLE 5: TOTAL NUMBER OF MINOR CALYCES

S.No	Total number of minor calyces*	Number of specimens n=100	Frequency (%)	Specimen no.
1.	3	1	1	62
2.	4	1	1	60
3.	5	23	23	4,5,13,17,…
4.	6	28	28	6,10,11,12,….
5.	7	27	27	3,8,9,14,……
6.	8	15	15	1,2,7,20……
7.	9	4	4	25,46,68,83
8.	11	1	1	69.

* Following dissection, the number of minor calyces in each zone (upper zone, middle zone and lower zone) was calculated separately and then the total number of minor calyces were added up to get this value.

The total number of minor calyces had a mean $\pm$ S.D value of 6.46 $\pm$ 1.28. The total number of minor calyces being 3,4 and 11 are seen in only one specimen each in the present study.

LOWER POLE CALYCEAL DISTRIBUTION:

The calculation of number of minor calyces in the lower pole carries clinical significance .When the number of minor calyces is more than four the patients are more prone for fragment retention following Extracorporeal Shck Wave Lithotripsy.

TABLE 6: LOWER POLE CALYCEAL DISTRIBUTION

S.No	No. of Lower pole minor calyces*	Number of specimens n=100	Frequency (%)	Specimen no.
1.	1	10	10	3,12,13,30….
2.	2	48	48	4,5,6,14,16….
3.	3	34	34	1,2,7,8,10…..
4.	4	7	7	9,22,29,33….
5.	5	1	1	58

* It includes the minor calyces present in the lower zone. It does not include the minor calyces in the middle zone whose drainage is dependent on the lower pole major calyx.

In the present study, mean number of lower pole minor calyces was 2.41 with a standard deviation of 0.81. Majority of kidneys had two minor calyces in the lower pole according to the present study followed by three numbers. The number of minor calyces being five was seen in only one specimen.

ORIENTATION OF MINOR CALYCES :

In certain kidneys, the minor calyces draining the middle zone had an anterior or posterior orientation in relation to the frontal plane of the kidney. For certain procedures like percutaneous nephrolithotomy, the preferred route of entry is through the posteriorly oriented minor calyces. In the present study, the number of kidneys with the presence of anterior and posterior orientation were calculated and tabulated. Such an orientation of minor calyces cannot be made out clearly in intravenous urography studies. They are clearly made out in 3-D HCT studies.

TABLE 7: ORIENTATION OF MINOR CALYCES

S.No	Orientation of minor calyces*	Number of specimens	Frequency (%)	Specimen no.
1.	Anterior	36	36	2,4,5,10,…..
2.	Posterior	27	27	1,3,7,8,13….

* orientation of minor calyces was seen in relation to the frontal plane of the kidney.

In this study, the percentage of specimens with anteriorly oriented minor calyces were more when with the percentage of specimens with posteriorly oriented minor calyces.

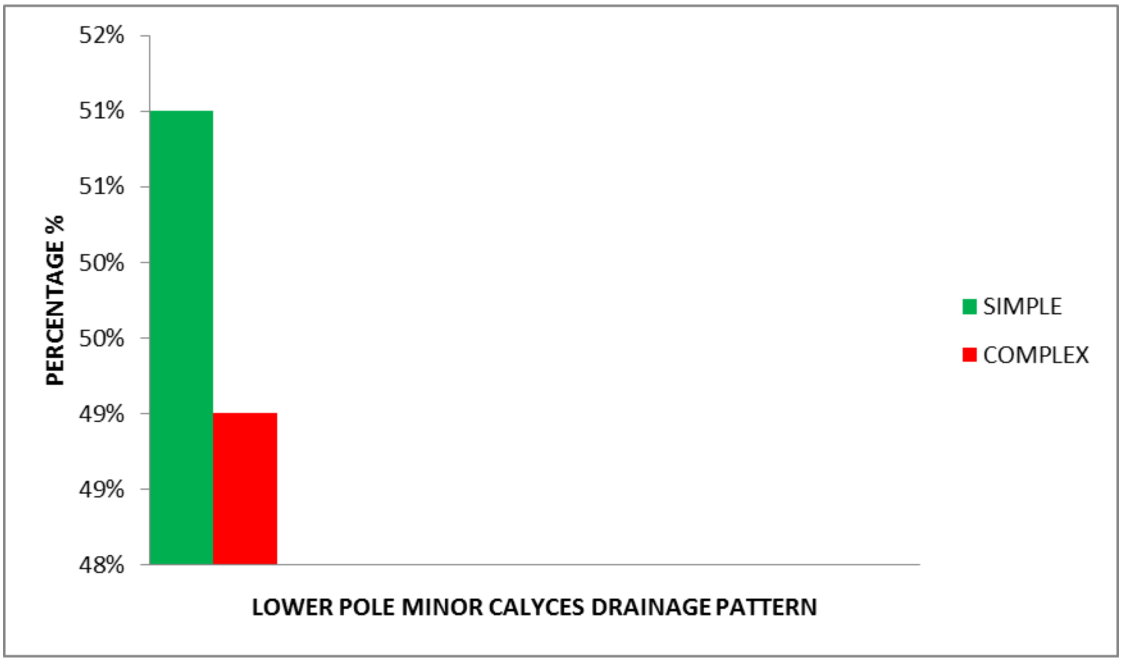
TABLE 8: PATTERN OF DRAINAGE OF LOWER POLE MINOR CALYCES

S.No	Pattern of drainage of minor calyces*	Number of specimens n=100	Frequency (%)	Specimen no.
1.	Simple	51	51	2,3,4,5,6,8,….
2.	Complex	49	49	1,7,11,15,….

* Pattern of drainage is studied for minor calyces in the lower pole. In simple pattern, the minor calyces open directly into the major calyces separately. In complex type, the minor calyces unite with each other before draining into the major calyces.

The percentage of specimens with simple and complex pattern of drainage of lower pole minor calyces is almost equal in the present study with a slightly increased percentage of simple pattern of drainage. The complex pattern of drainage facilitates stone fragment retention following Extracorporeal Shock Wave Lithotripsy used as a mode of treatment for nephrolithiasis. The following is a bar diagrammatic representation to show the percentage of specimens with simple and complex type of drainage pattern of minor calyces in the lower pole.

FIGURE 22: PATTERN OF DRAINAGE OF LOWER POLE MINOR CALYCES



In the present study, the simple type of drainage pattern for lower pole minor calyces is seen in 51% of kidneys and the complex type of drainage pattern is seen in 49% of kidneys.

LOWER POLE INFUNDIBULUM :

The various parameters of the lower pole infundibulum with relevant clinical significance include infundibular length, width, length by width ratio , height and infundibulopelvic angle. The above mentioned parameters were measured in the present study and the mean value and standard deviation were calculated.

In the present study, seven kidneys presented with a pelvicalyceal pattern wherein the minor calyces drained directly into the renal pelvis and another specimen with extrarenal calyx and absent pelvis. In such specimens, there is no demonstrable infundibulum and all the above measurements were made in remaining 92 kidneys out of the total 100 kidneys dissected and studied. The values are expressed as mean ± S.D .

TABLE 9 : LOWER POLE INFUNDIBULUM – VARIOUS PARAMETERS

S.no	Measurements of lower pole infundibulum*	Minimum	Maximum	Mean ± S.D
1.	Infundibular length (mm)	13	28	16.1 ± 6.03
2.	Infundibular width (mm)	3	10	5.63 ± 2.2
3.	L/W	1.4	7.7	3.6 ± 1.5
4.	Infundibular height (mm)	7	21	12.5 ± 3.93
5.	Infundibulopelvic angle (degrees)	65	120	94.7 ± 11.7

***** The lower pole infundibulum is the lowermost infundibulum that leads from the major calyx to the renal pelvis. Since the position of lower pole infundibulum is against gravity, the various parameters are considered before making a choice of Extracorporeal Shock Wave Lithotripsy or percutaneous nephrolithotomy for treating complex stones.

LOWER POLE INFUNDIBULAR LENGTH :

It is measured as the distance between the distal point of the lowermost calyx and the midpoint of the lower lip of the renal pelvis. In the present study the lower pole infundibular length had a range of 13 – 28 mm. The mean value was 16.1mm with a standard deviation of 6.03mm.

Mean ± S.D = 16.1 ± 6.03 mm.

Apart from measuring the range of infundibular length, the specimens were categorized as falling into two categories.

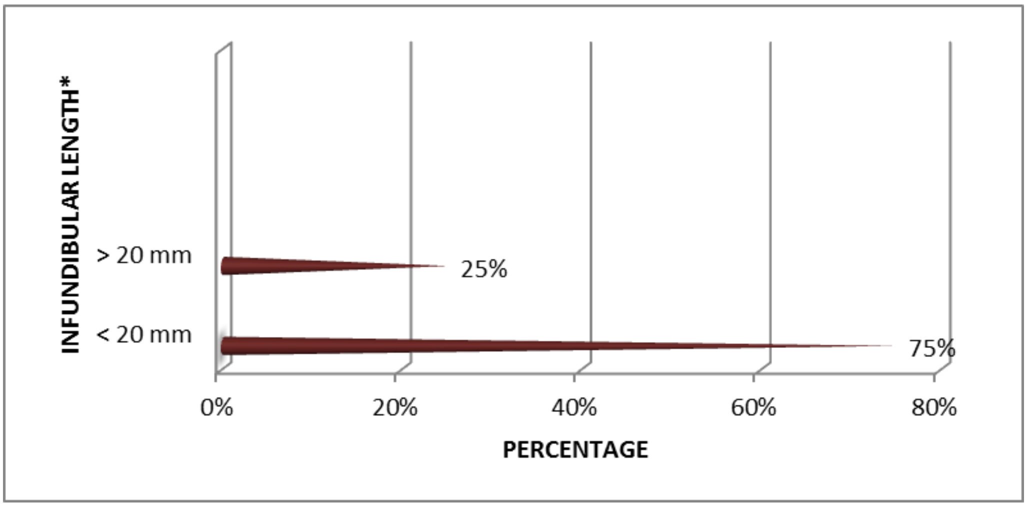
TABLE 10 : LOWER POLE INFUNDIBULAR LENGTH

S.No	Lower pole infundibular length(mm)*	Number of specimens	Frequency (%)	Specimen no.
1.	< 20	69	75	1,3,4,6,7,8,….
2.	$\geq$ 20	23	25	2,9,10,11,…..

* The infundibular length of 20mm is used as a cutoff point during radiological evaluation in choosing suitable patients for Extracorporeal Shock Wave Lithotripsy.

In the present study, the percentage of specimens with infundibular length less than 20mm is higher than the percentage of specimens with more than 20mm.

. FIGURE 23: LOWER POLE INFUNDIBULAR LENGTH



The above bar diagram represents the number of specimens falling into two categories based on the cutoff point of 20mm for infundibular length.

LOWER POLE INFUNDIBULAR WIDTH :

The lower pole infundibular width is measured at the narrowest point of the lower pole infundibulum.The value ranged from a minimum value of 3mm to a maximum value of 10mm in the present study. The mean value of the infundibular width was 5.63mm with a standard deviation of 2.2.

Mean $\pm$ S.D (mm) = 5.63$\pm$ 2.2

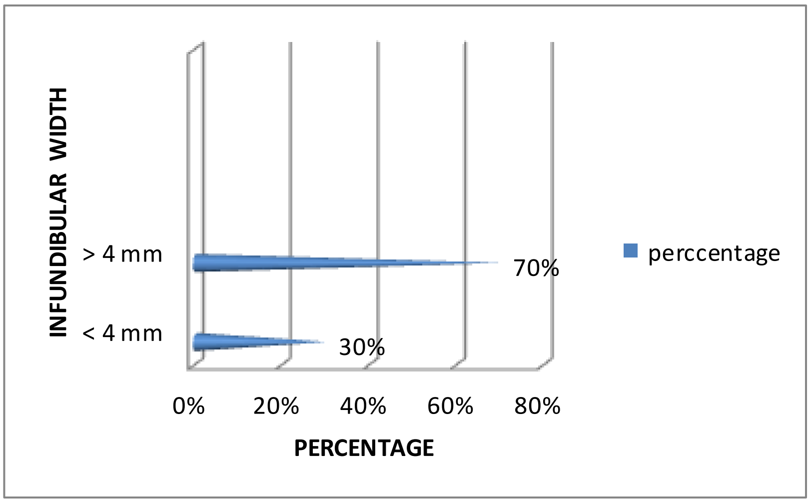
TABLE 11 : LOWER POLE INFUNDIBULAR WIDTH

S.No	**Lower pole infundibular width(mm)***	**Number of specimens**	**Frequency (%)**	**Specimen no.**
1.	< 4	28	30	3,10,12,21,….
2.	$\geq$ 4	64	70	1,2,4,7,8,9,…..

*The critical value above which the fragment clearance following Extracorporeal Shock Wave Lithotripsy becomes easier was 4mm for infundibular width.

The bar diagram shown here clearly illustrates the percentage of those specimens with infundibular width less than 4mm and those with more than 4 mm.

FIGURE 24 : LOWER POLE INFUNDIBULAR WIDTH



It is evident that the percentage of specimens with infundibular width more than 4mm outnumber the specimens with values less than 4mm in the present study.

LOWER POLE INFUNDIBULAR LENGTH BY WIDTH RATIO :

The lower pole infundibular length and width as individual determining factors are taken into account in preoperative radiological evaluation. The idea of considering these factors as a ratio also proved helpful. In the present study the minimum value of the lower pole infundibular length by width ratio was 1.4 and the maximum value as 7.7. The mean infundibular length by width ratio was 3.6 with a standard deviation of 1.5.

Mean ± S.D = 3.6 ± 1.5.

TABLE 12 : LOWER POLE INFUNDIBULAR LENGTH BY WIDTH RATIO

S.No	**L/W***	**Number of specimens**	**Frequency (%)**	**Specimen no.**
1.	≤ 3.5	61	66.3	1,2,4,7,9,….
2.	> 3.5	31	33.7	3,6,8,10,12,…..

*lower pole infundibular length by width ratio. As in the previous parameters, the critical value of this ratio beyond which fragment clearance is easier following Extracorporeal Shock Wave Lithotripsy was studied and the value was found to be 3.5 and the specimens are classified into two groups based on that value.

LOWER POLE INFUNDIBULAR HEIGHT:

The lower pole infundibular height is measured as the distance between the horizontal line passing through the distal point of the lowermost calyx and the horizontal line passing through the highest point on the lower lip of renal pelvis. In the present study, the infundibular height had a minimum value of 7 mm and a maximum value of 21 mm. The mean value was 12.5mm with a standard deviation of 3.93mm.

Mean $\pm$ S.D (mm) = 12.5 $\pm$ 3.93.

TABLE 13 : LOWER POLE INFUNDIBULAR HEIGHT

S.No	Lower pole infundibular height(mm)	Number of specimens	Frequency (%)	Specimen no.
1.	$\leq$ 15	62	67.4	1,3,6,8,12,14,15,….
2.	> 15	30	32.6	2,4,7,9,10,11,16,…..

When the infundibular height is more than 15mm, the fragment clearance becomes difficult following Extracorporeal Shock Wave Lithotripsy used as a treatment for nephrolithiasis.

LOWER POLE INFUNDIBULOPELVIC ANGLE :

The infundibulopelvic angle is measured as the angle between the axis passing through the lower most infundibulum and the ureteropelvic axis. The lower pole infundibulopelvic angle was considered by many authors as a single factor that can be taken into account for clinical evaluation. This is because in persons with acute infundibulopelvic angle , the passage of fragments following Extracorporeal Shock Wave Lithotripsy becomes difficult. Hence this angle was also measured in the present study. In the present study, the values are expressed as range along with mean and standard deviation. The mean and standard deviation values are determined for both sides separately.

The table clearly illustrates the above mentioned values for both sides.

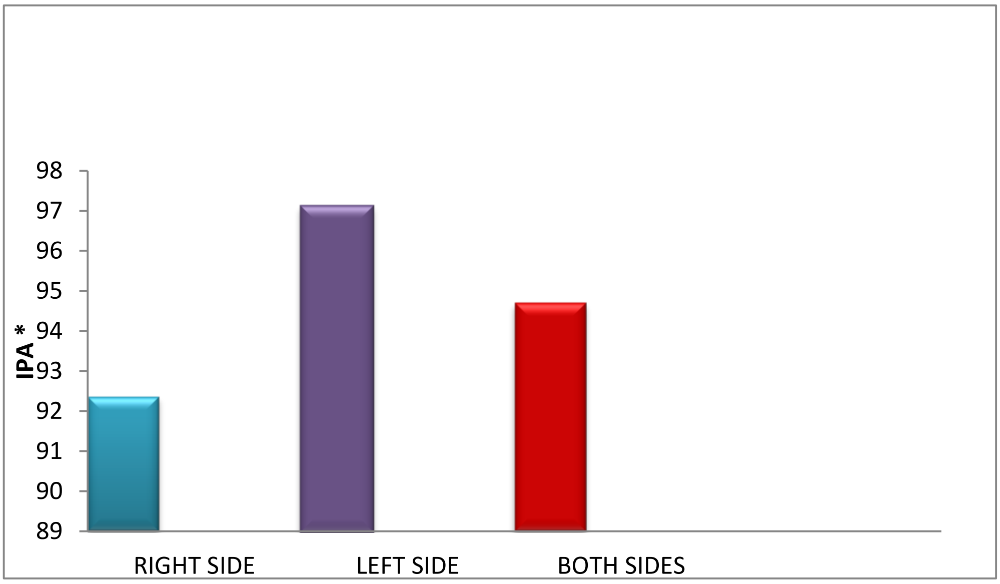
TABLE 14: INFUNDIBULOPELVIC ANGLE – COMPARISON BETWEEN TWO SIDES

S.No	SIDE OF THE KIDNEY	Lower pole infundibulopelvic angle (degrees)	Mean ± S.D
1.	Right	70-110	92.36 ±11.03
2.	Left	65-120	97.05±12.18
3.	Both sides	65-120	94.70±11.61

The lower pole infundibulopelvic angle is also an important determinant for fragment clearance following Extracorporeal Shock Wave Lithotripsy. The angle was measured as the angle between the axis passing through the lower most infundibulum and the ureteropelvic axis.

The bar diagram given below represents the comparison of mean infundibulopelvic angle on right and left sides.

FIGURE 25: INFUNDIBULOPELVIC ANGLE – COMPARISON OF BOTH SIDES



*mean infundibulopelvic angle expressed in degrees

TABLE 15 : INFUNDIBULO PELVIC ANGLE-FREQUENCY OF SPECIMENS WITH ANGLE $\leq$ 90 degrees AND > 90 degrees.

S.No	Lower pole infundibulopelvic angle (degrees)	Number of specimens	Frequency (%)	Specimen no.
1.	$\leq$ 90	30	32.6	2,4,7,8,9,12,14,….
2.	> 90	62	67.4	1,3,6,10,11,19,22,…..

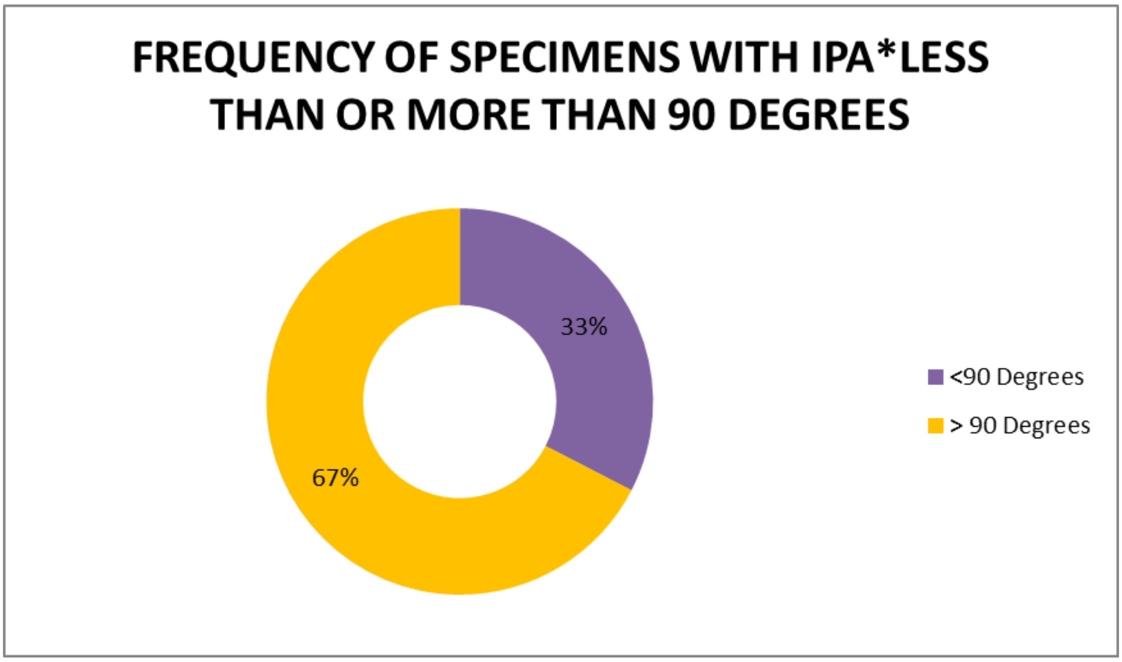
The infundibulopelvic angle is measured between the lower infundibular axis and the ureteropelvic axis.

The cut off value for infundibulopelvic angle below which fragment clearance becomes easier was found to be 90 degrees by many authors. In the present study, the percentage of specimens with infundibulopelvic angle more than 90 degrees was found to be 67%. There are different methods to measure the infundibulopelvic angle and only when it is measured as angle between the lower pole infundibular axis and ureteropelvic axis, the cutoff value is set at 90 degrees.

In 33% of specimens, the infundibulopelvic angle was found to be less than or equal to 90 degrees. Another interesting observation made in the present study is that the obtuse infundibulopelvic angle was more commonly seen in left sided kidneys. The lowermost range of 65 degrees in left sided kidneys was seen in only one specimen. Thus it is also evident that there is a difference in position of infundibulum, renal pelvis and ureter on both sides of the same individual. Such a difference in value between the two sides was not seen pertaining to other values of the lower pole infundibulum like infundibular length, width or height.

The doughnut chart representation of specimens with lower pole infundibulopelvic angle less than or more than 90 degrees is as follows.

FIGURE 26: LOWER POLE INFUNDIBULO PELVIC ANGLE



.*lower pole infundibulopelvic angle.

PHOTOGRAPHS SHOWING DIFFERENT POSITION OF RENAL PELVIS

INTRARENAL POSITION OF PELVIS:

1.

2.

3.

The position of renal pelvis varies in relation to the renal sinus. The intrarenal type completely lies within the renal sinus.

PHOTOGRAPHS SHOWING DIFFERENT POSITION OF RENAL PELVIS

EXTRARENAL POSITION OF PELVIS:

4.

5.

Extra renal pelvis

The extrarenal pelvis lies entirely outside the renal sinus.

PHOTOGRAPHS SHOWING DIFFERENT POSITION OF RENAL PELVIS

BORDERLINE POSITION OF PELVIS:

6.

7.

8.

. The borderline type lies partly inside and outside the renal sinus.

PHOTOGRAPHS SHOWING DIFFERENT POSITION OF RENAL PELVIS

ABSENT RENAL PELVIS

9.

10.

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(CLASSIFIED ACCORDING TO SAMPAIO'S CLASSIFICATION)

TYPE A I

11.

12.

13.

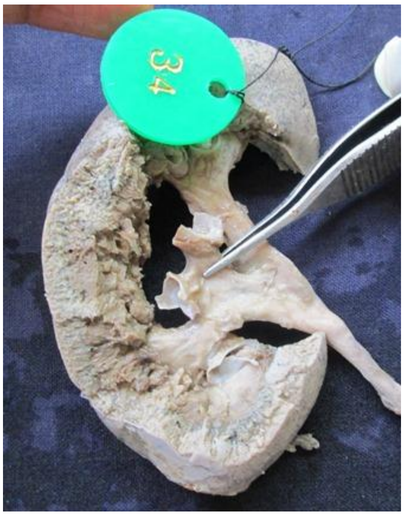
TYPE A I – two major calyces from superior and inferior poles with middle zone drainage dependent on any one of them or both .

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(CLASSIFIED ACCORDING TO SAMPAIO'S CLASSIFICATION)

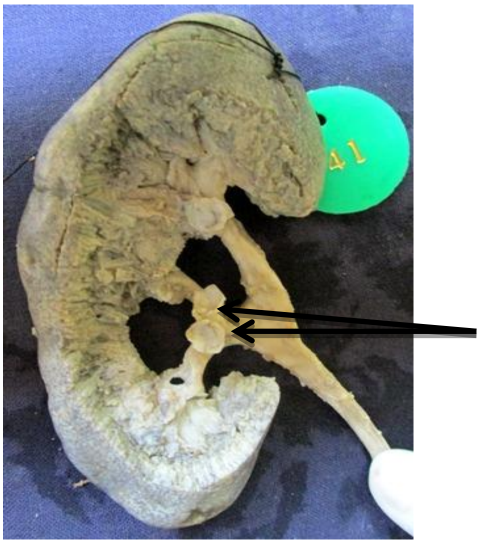
TYPE A II

14.



15.

16.



Crossing calyces in the middle zone

TYPE A II – Same as A I, but with crossing calyces in the middle zone.

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(CLASSIFIED ACCORDING TO SAMPAIO'S CLASSIFICATION)

TYPE B I

17.

18.

TYPE B I : There is a separate calyx draining the middle zone which is not connected to both the superior and inferior calyceal groups

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(CLASSIFIED ACCORDING TO SAMPAIO'S CLASSIFICATION)

TYPE B II

19.

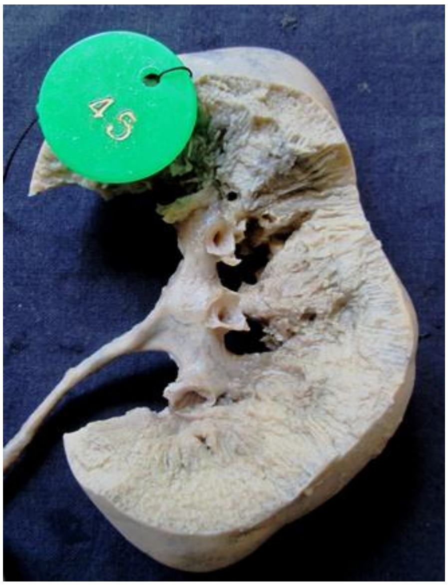
20.

TYPE B II : Middle zone is drained by one to four minor calyces that end directly into the renal pelvis.

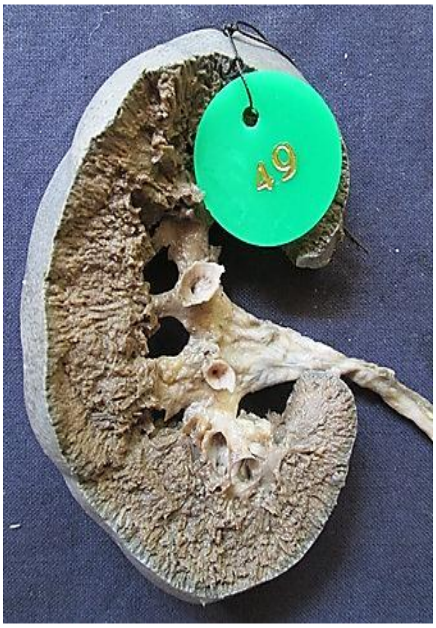
PHOTOGRAPHS SHOWING ORIENTATION OF MINOR CALYCES

ANTERIOR ORIENTATION OF MINOR CALYCES

21.



22.



PHOTOGRAPHS SHOWING ORIENTATION OF MINOR CALYCES

POSTERIOR VIEW OF KIDNEYS TO SHOW POSTERIOR ORIENTATION OF MINOR CALYCES

23.

24.

PHOTOGRAPHS SHOWING PATTERN OF DRAINAGE OF

LOWER POLE MINOR CALYCES

SIMPLE PATTERN OF DRAINAGE

25.

26.

In simple pattern, the minor calyces open directly into the major calyces separately.

PHOTOGRAPHS SHOWING PATTERN OF DRAINAGE OF

LOWER POLE MINOR CALYCES

COMPLEX PATTERN OF DRAINAGE

27.

28.

In complex pattern, the minor calyces unite with each other before draining into the major calyces.

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(AS PROPOSED BY NINGTHOUJAM DD et al)

MULTICALYCEAL PATTERN:

29.

30.

Multicalyceal type, the minor calyces appear to drain in a radiating manner into the major calyces or directly into the renal pelvis.

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(AS PROPOSED BY NINGTHOUJAM DD et al)

TRICALYCEAL PATTERN:

31.

32.

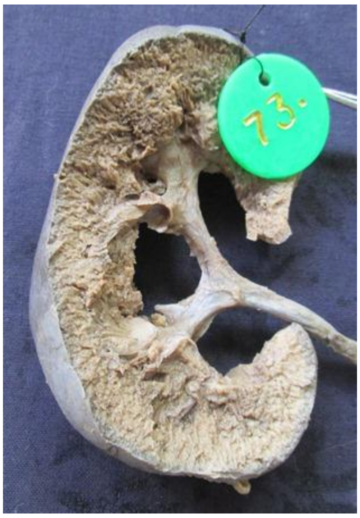
In tricalyceal type, there is the presence of three major calyceal groups in upper, middle and lower regions.

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(AS PROPOSED BY NINGTHOUJAM DD et al)

BICALYCEAL PATTERN:

33.



34.

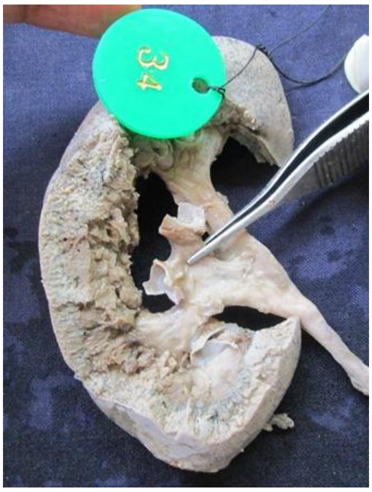
In bicalyceal type, there are two major calyces – one from upper pole and the other from lower pole.

PHOTOGRAPHS SHOWING DIFFERENT PELVICALYCEAL PATTERNS

(AS PROPOSED BY NINGTHOUJAM DD et al)

UNCLASSIFIED :

35.



36.

Unclassified type : Consists of cross draining calyces in the middle zone or extrarenal calyces opening directly into ureter.

PHOTOGRAPHS SHOWING PELVICALYCEAL PATTERNS IN ENDOCASTS

(DONE BY LUMINAL CASTING)

37.

Left sided cast with bicalyceal pattern.

Type A I (Sampaio's classification)

38,

Right sided cast with bicalyceal pattern.

Type A I (Sampaio's classification)

39.

Right sided cast belonging to Type AI of Sampaio's classification. The specimen had extrarenal pelvis on gross examination.

40.

The specimen had extrarenal pelvis on gross examination. The left sided cast shows minor calyces directly opening into renal pelvis.

PHOTOGRAPHS SHOWING PELVICALYCEAL PATTERNS IN ENDOCASTS

(DONE BY LUMINAL CASTING)

41.

Right sided cast showing bicalyceal pattern and simple pattern of drainage of lower pole minor calyces.

42.

Left sided cast showing complex pattern of drainage of lower pole minor calyces

43.

The left sided cast with bicalyceal pattern . The asterix shows an anteriorly oriented minor calyx.

44.

The posterior view of a left sided cast with bicalyceal pattern . The asterix shows an posteriorly oriented minor calyx.

Discussion

DISCUSSION

The present study was conducted on 100 cadaveric human kidneys by dissection method. The observations of the present study is discussed and compared with those given in scientific literature by various authors.

PELVICALYCEAL PATTERNS:

The knowledge of pelvicalyceal system gained relevance with the advent of newer and effective treatment modalities and investigative procedures to diagnose pathologies involving kidneys. The collecting system anatomy is important to endourologists and interventional radiologists for planning a procedure and to assess the outcome of a treatment method chosen.

In the present study, the pelvicalyceal patterns are classified according to Sampaio's classification and percentage of specimens belonging to each category are compared with that of Sampaio's study.

TABLE 16 : COMPARISON OF PELVICALYCEAL PATTERNS (grouped based on sampaio's classification)

S.No	Author	No.of kidneys	A I (%)	A II (%)	B I (%)	B II (%)	Type of study
1.	**Sampaio FJB[5]**	**146**	**45**	**17**	**21**	**16**	**Corrosion cast**
2.	**Present study**	**100**	**38.4**	**12.2**	**29.2**	**20.2**	**Cadaveric kidney dissection**

A I – Two major calyces from superior and inferior poles with middle zone drainage dependent on any one of them or both. A II – Same as A I, but with crossing calyces in the middle zone. BI, there is a separate calyx draining the middle zone which is not connected to both the superior and inferior calyceal groups. In type BII, middle zone is drained by one to four minor calyces that end directly into the renal pelvis.

In the present study, the most common type of pelvicalyceal pattern seen is type A I on grouping the patterns according to Sampaio. The next common type is type B I followed by B II and then A II. The order of frequency of specimens is almost same as in Sampaio's study. This grouping is important for clinicians because type A I patterns with two long major calyces from the upper and lower poles donot allow easy passage of flexible nephroscopes when approached from the poles.

The only drawback of grouping the patterns according to Sampaio's classification is that, in the present study the specimen with extrarenal calyces cannot fit into any of the above categories and hence another method of classifying the patterns as proposed by Ningthoujam DD et al is done.

TABLE 17: COMPARISON OF PELVICALYCEAL PATTERNS (as proposed by Ningthoujam DD et al)

S.No	Author	No.of kidneys	M (%)	T (%)	B (%)	U (%)	Type of study
1.	Ningthoujam DD et al[4]	200	45	17	21	16	IVU
2.	Present study	100	23	27	35	15	Cadaveric kidney dissection

M – Multicalyceal, T – Tricalyceal, B – Bicalyceal, U – Unclassified.

*As proposed by Ningthoujam DD et al. In multicalyceal type, the minor calyces appear to drain in a radiating manner into the major calyces or directly into the renal pelvis. In tricalyceal type, there is the presence of three major calyceal groups in upper, middle and lower regions. In bicalyceal type, two major calyces – one from the upper pole and other from the lower pole are present. Each calyx has the drainage of four to five minor calyces. The unclassified type consists of cross draining calyces in the middle zone or extrarenal calyces opening directly into ureter.

The bicalyceal type is the most common type in the present study when compared with Ningthoujam DD et al study. The difference could be attributed to the difference in population groups in which the study was conducted.

MINOR CALYCES :

In the present study, the maximum number of minor calyces observed is 11 when compared to the other study done by Ningthoujam DD et al where it is 12. Also in the present study, the minimum number of minor calyces seen is 3, whereas in the other study it is 6. The difference in number can be attributed to difference in the population of study(South India and North East India).

TABLE18: PERCENTAGE OF NUMBER OF MINOR CALYCES – COMPARISON BETWEEN STUDIES

S. No	Author	Number of minor calyces								
		3 (%)	4 (%)	5 (%)	6 (%)	7 (%)	8 (%)	9 (%)	11 (%)	12 (%)
1.	Ningthoujam DD et al[4]	-	-	-	24	-	36	37	-	3
2.	Present study	1	1	23	28	27	15	4	1	-

From the table it is evident that the average number of calyces seen in both studies is around 6 . The number was calculated separately for the upper, middle and lower zones. Apart from studying the total number of minor calyces, the lower pole calyceal distribution is also considered in the present study. Not only does gravity dependent position of lower pole calyces influence stone formation and fragment clearance following Extracorporeal Shock Wave Lithotripsy but also the lower pole calyceal distribution. When the number of lower pole calyces is more than four, the chances of stone formation and also fragment retention following Extracorporeal

Shock Wave Lithotripsy is higher. The number of lower pole calyces expressed as mean + S.D is calculated and compared with those by other authors.

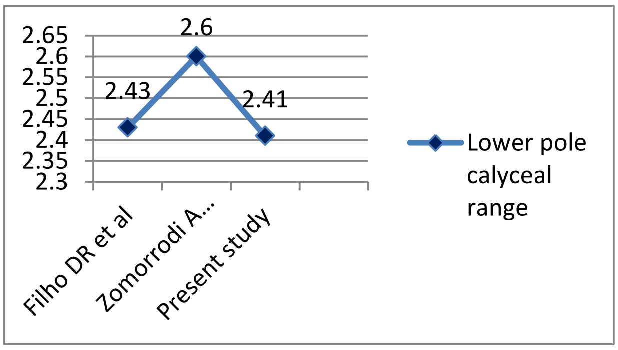
TABLE 19: LOWER POLE CALYCEAL RANGE IN DIFFERENT STUDY GROUPS

S.No	Author	Year of study	Number of kidneys	Lower pole calyceal range*
1.	Filho DR et al [7]	2009	52	2.43 + 0.67**
2.	Zomorrodi et al [61]	2010	400	2.6 + 0.6***
3.	Present study	2012	100	2.41 + 0.81

*** values are expressed as mean + S.D.**P > 0.05 when comparing the values of the present study with values of Filho DR et al study. *** P < 0.05 on comparing the present study with the values of Zomorrodi A et al study.**

The difference in the values between the present study and Zomorrodi A et al study is statistically significant and could be due to difference in the number of kidneys studied because the method of study was the same in Filho DR and Zomorrodi A et al study (intravenous urography studies) in contrast to dissection method in the present study.

Fig 26: LOWER POLE CALYCEAL RANGE – IN VARIOUS STUDIES



The mean value of lower pole calyceal range is compared between groups.

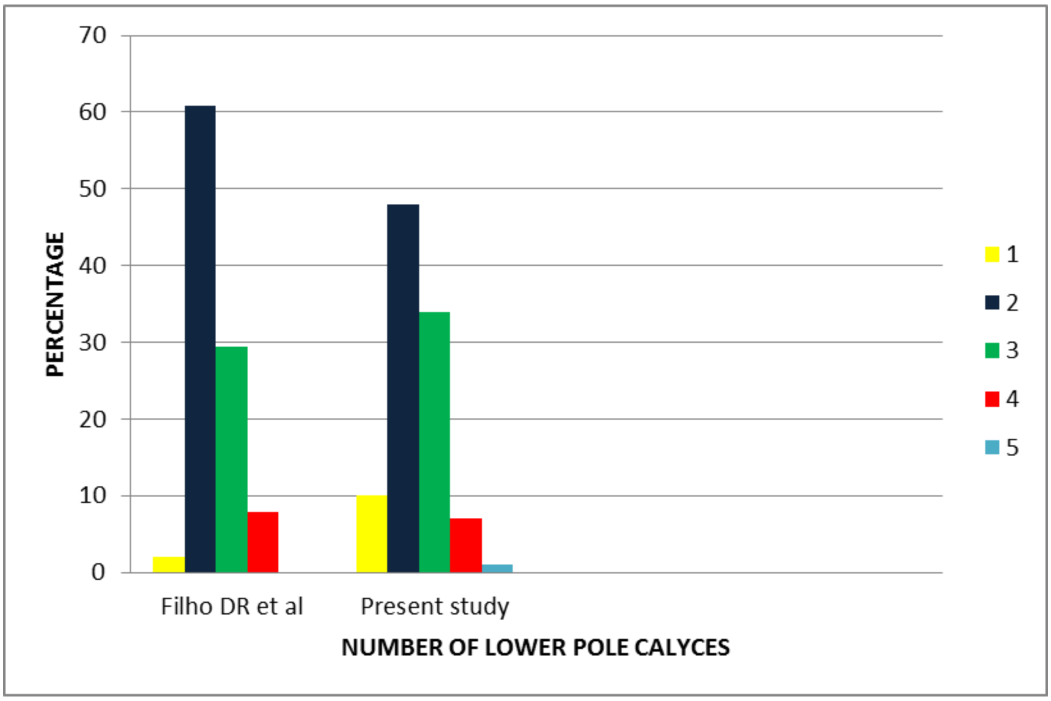
TABLE 20: COMPARISON OF LOWER POLE CALYCEAL DISTRIBUTION

S.no	Author	Number of kidneys	Lower pole calyceal distribution*				
			1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
1.	Filho DR et al	52	2	60.8	29.4	7.8	-
2.	Present study	100	10	48	34	7	1

* It includes the minor calyces present in the lower zone. It does not include the minor calyces in the middle zone whose drainage is dependent on the lower pole major calyx.

In the present study, the number of minor calyces in the lower pole being three is found in 48% of individuals and is most common as in Filho DR et al study. There were five minor calyces in only one specimen of the present study .

FIGURE 27: COMPARISON OF LOWER POLE CALYCEAL DISTRIBUTION



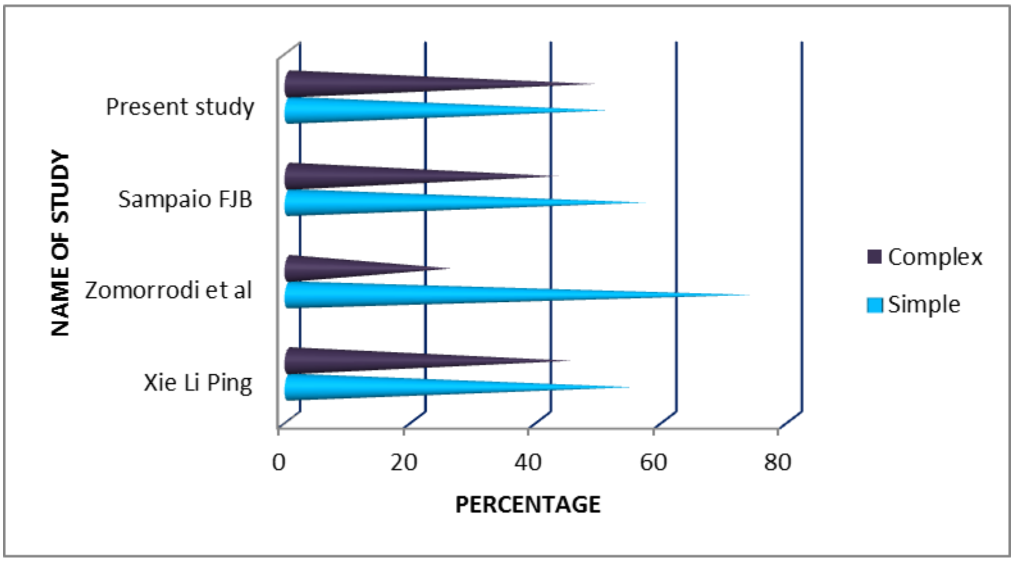
From the above bar diagrammatic representation , it is clear that the calyceal distribution in the present study follows almost a similar pattern as in the study by Filho DR et al.

TABLE 21: PATTERN OF DRAINAGE OF LOWER POLE MINORCALYCES –COMPARISON BETWEEN STUDIES

S.no	Author	Number of kidneys	Pattern of drainage of lower pole minor calyces*		Type of study
			Simple (%)	Complex (%)	
1.	Xie Li Ping et al[62]	145	55	45	IVU
2.	Zomorrodi A et al	400	74	26	IVU
3.	Sampaio FJB	146	57	43	Corrosion cast
4.	Present study	100	51	49	Cadaveric kidney dissection

* Pattern of drainage is studied for minor calyces in the lower pole. In simple pattern, the minor calyces open directly into the major calyces separately. In complex type, the minor calyces unite with each other before draining into the major calyces.

FIGURE 28: PATTERN OF DRAINAGE OF LOWER POLE CALYCES



The above bar diagrammatic representation clearly indicates that the simple pattern of drainage is commonly seen than the complex pattern of drainage in the lower pole minor calyces.

The predominant pattern of drainage is of simple type in almost all the studies. The complex pattern of drainage of lower pole minor calyces predisposes to stone formation and fragment retention following Extracorporeal Shock Wave Lithotripsy.

LOWER POLE INFUNDIBULUM:

In order to find out the numerous causes for formation of stones more commonly in the lower pole and to improve the results of various treatment procedures for the same, there is a recent focus on studying the various anatomic factors contributing to stone formation. One such area of study is morphometric evaluation of different parameters of lower pole infundibulum including infundibular length, width, length by width ratio, height and infundibulopelvic angle. In the present study, all the above mentioned parameters are measured and compared with the previous studies.

LOWER POLE INFUNDIBULAR HEIGHT:

TABLE 22: INFUNDIBULAR LENGTH – COMPARISON BETWEEN STUDIES

S.no	Author	No.of kidneys	Infundibular length (mm) Mean $\pm$ S.D	Type of study
1.	Fabregas MA et al [63]	78	25.9 $\pm$ 6.7	IVU
2.	Fong YK et al[64]	42	21.7 $\pm$ 6.9	IVU
3.	Ozgur Tan M et al[65]	34	23.6 $\pm$ 6.2	IVU
4.	Zomorrodi A et al	400	22.5 $\pm$ 4.1	IVU
5.	Madbouly K et al[66]	108	20.9 $\pm$ 6.5	CT
6.	Present study	100	17.5 $\pm$ 3.4*	Cadaveric kidney dissection

*The values of the present study are statistically significant ($P< 0.001$) when compared to the values of the other studies . The infundibular length is measured as the distance between the distal point of the lowermost calyx and the midpoint of the lower lip of the renal pelvis.

The value of lower pole infundibular length measured in the present study differ significantly (P<0.001) from the values of other studies . This might be due to the fact that the other authors measured these values in live persons by IVU and CT.

LOWER POLE INFUNDIBULAR WIDTH:

TABLE 23 : INFUNDIBULAR WIDTH – COMPARISON OF MEAN VALUES

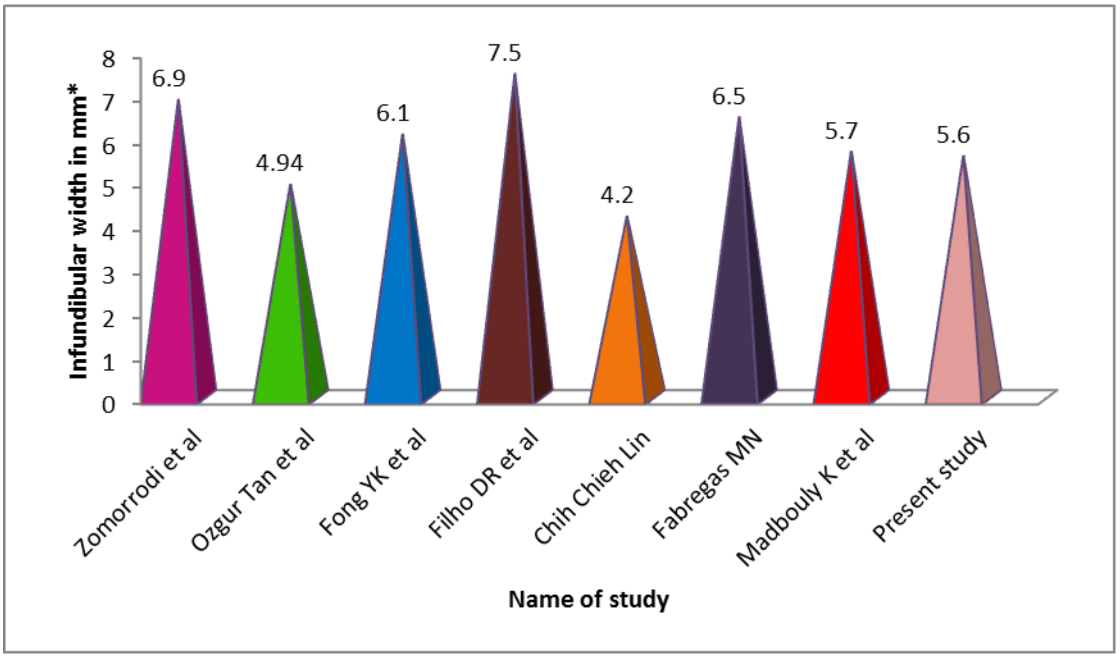
S.no	Author	No.of kidneys	Infundibular length (mm) Mean $\pm$ S.D	Type of study
1.	Fabregas MA et al	78	6.5 $\pm$ 8.2**	IVU
2.	Fong YK et al	42	6.1 $\pm$ 2.38**	IVU
3.	Ozgur Tan M et al	34	4.94 $\pm$ 1.48**	IVU
4.	Zomorrodi A et al	400	6.9 $\pm$ 1.6*	IVU
5.	Chih-Chieh Lin et al[67]	112	4.2 $\pm$ 0.6***	IVU
6.	Filho DR et al	52	7.5 $\pm$ 2.92*	CT
7.	Madbouly K et al	108	5.65 $\pm$ 2.34**	CT
8.	Present study	100	5.63 $\pm$ 2.2	Cadaveric kidney dissection

*****P<0.01. when the present study is compared with the study by Zomorrodi A and Filho DR et al. **P>0.05 on comparing the present study with that of Fabregas MA, Fong YK, Ozgur Tan M and Madbouly K et al. ***P<0.05.on comparing the present study with Chih Chieh Lin et al study. The lower pole infundibular width is measured at the narrowest point of the lower pole infundibulum.

The values of the present study are extremely significant statistically (P<0.01)when compared with studies by Zomorrodi A et al and Filho DR et al. Those values of Chih-Chieh Lin et al study is also statistically significant when compared with the present study. The differences between the studies could be due to difference in the population groups in which the study was conducted.

The following is a diagrammatic representation of comparison of mean values of lower pole infundibular width between groups.

FIGURE 29 : INFUNDIBULAR WIDTH – COMPARISON OF MEAN VALUE BETWEEN GROUPS.



*Expressed as mean value. The lower pole infundibular width is measured at the narrowest point of the lower pole infundibulum. The mean value of infundibular width of the present study is compared with those by different authors.

Apart from measuring the infundibular width and comparing the mean $\pm$ S.D values between groups, the specimens are categorized into two groups based on a cutoff value of lower pole infundibular width value of 4mm. This value is considered to be the point above which a patient is considered suitable for Extracorporeal Shock Wave Lithotripsy for treating nephrolithiasis. The following table compares the percentage of specimens belonging to these categories based on the cutoff value of 4mm.

TABLE 24: INFUNDIBULAR WIDTH – COMPARISON BETWEEN GROUPS

S.no	Author	Number of kidneys	Infundibular width (mm)*		Type of study
			< 4 (%)	≥ 4 mm (%)	
1.	Chih-Chieh Lin et al	112	42	58	IVU
2.	Xie Li Ping et al	145	33	67	IVU
3	Sampaio FJB et al	146	40	60	Corrosion cast
4.	Present study	100	30	70	Cadaveric kidney dissection

* The lower pole infundibular width is measured at the narrowest point of the lower pole infundibulum.The critical value above which the fragment clearance following Extra ShockWave Lithotripsy becomes easier was 4mm for infundibular width.

In the present study, majority of specimens (70%) are with infundibular width more than 4mm. The values are almost the same in the study by Xie Li Ping et al and in other studies also the percentage of kidneys with infundibular width more than 4mm is higher.

The infundibular length and width are considered as separate factors in predicting the outcome of Extracorporeal Shock Wave Lithotripsy for treating nephrolithiasis in the beginning. Later some others tried to evaluate infundibular length by width ratio to predict the outcome and to choose an optimal mode of therapy for treating nephrolithiasis. In the present study, the infundibular length by width ratio is expressed as mean ± standard deviation value and it is compared with the values of other studies.

LOWER POLE INFUNDIBULAR LENGTH BY WIDTH RATIO:

This ratio is calculated from the infundibular length and infundibular width values calculated above.

TABLE 25 : LOWER POLE INFUNDIBULAR LENGTH BY WIDTH RATIO – COMPARISON BETWEEN STUDIES

S.no	Author	Number of kidneys	L/W (mean ± S.D)	Type of study
1.	**Fabregas MA et al**	**78**	**7.8 ± 6.2***	**IVU**
2.	**Fong YK et al**	**42**	**4.3 ± 2.8****	**IVU**
3.	**Present study**	**100**	**3.6 ± 1.5**	**Cadaveric kidney dissection**

L/W-Infundibular length by width ratio. *P < 0.001.when the values of the present study are compared with the values of Fabregas MA et al study. **P>0.05, when the present study is compared with Fong YK et al study.

The difference in the values between the present study and Fabregas MA et al study is statistically significant (P <0.001). The difference in the values might be due to difference in the population groups taken for study. The other study by Fong YK et al does not differ significantly(P > 0.05) from the present study.

The specimens in the present study are divided into two groups based on the infundibular length by width ratio. The value beyond which the fragment clearance becomes better was found to be 3.5 and the percentage of specimens belonging to two groups based on that value is calculated and it is compared with that of other studies by different authors.

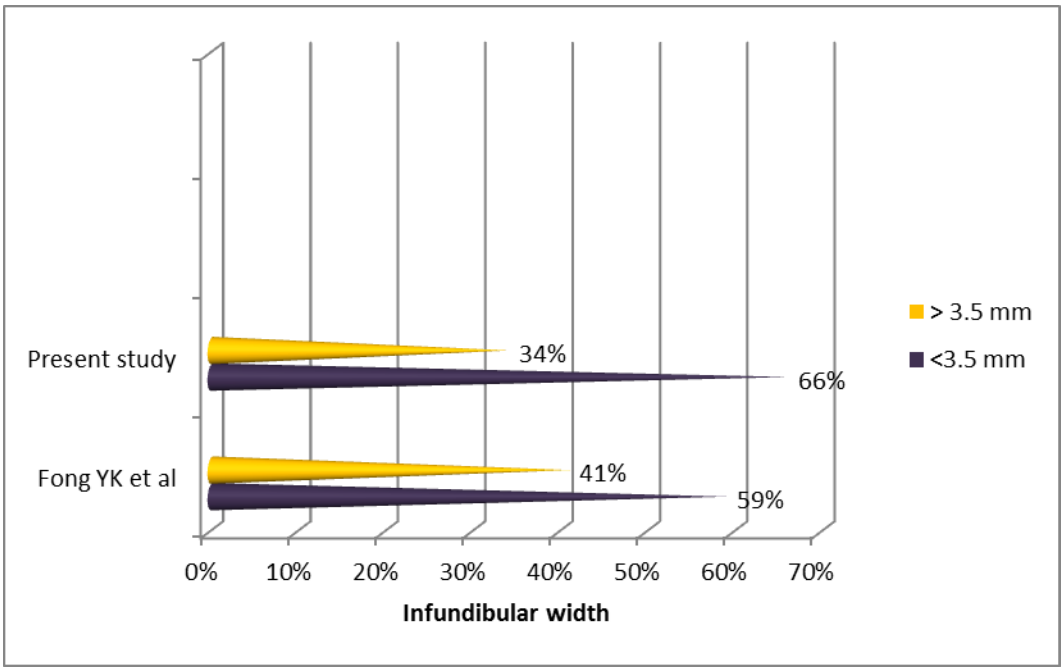
TABLE 26 : LOWER POLE INFUNDIBULAR LENGTH BY WIDTH RATIO - ≤ 3.5 AND > 3.5 – COMPARISON BETWEEN STUDIES

S.no	Author	Number of kidneys	Infundibular L/W		Type of study
			≤ 3.5 (%)	> 3.5 (%)	
1.	Fong YK et al	42	59	41	IVU
2.	Present study	100	66	34	Cadaveric kidney dissection

The infundibular length by width ratio(L/W) with clinically significant value was 3.5. It is the value beyond which fragment clearance is better after Extracorporeal Shock Wave Lithotripsy.

In both the studies, the percentage of specimens with infundibular length by width ratio less than 3.5 was higher than the specimens with values more than 3.5.

FIGURE 30: PERCENTAGE OF SPECIMENS WITH INFUNDIBULAR LENGTH BY WIDTH RATIO LESS THAN OR MORE THAN 3.5mm.



LOWER POLE INFUNDIBULAR HEIGHT:

The lower pole infundibular height is measured as the distance between the horizontal line passing through the distal point of the lowermost calyx and the horizontal line passing through the highest point on the lower lip of renal pelvis. When the lower pole infundibular height is more than 15mm, the chances of fragments getting retained following ESWL for treating nephrolithiasis is more. This fragment retention is more dangerous because it predisposes to repeated urinary tract infections, repeated stone formation and leading to complications like hydronephrosis. Hence only ideal patients must be subjected to this mode of treatment.

TABLE 27 : LOWER POLE INFUNDIBULAR HEIGHT – COMPARISON BETWEEN STUDIES

S.no	Author	Number of kidneys	Infundibular height (mm) Mean ± S.D	Type of study
1.	Fabregas MA et al	78	24.1 ± 7	IVU
2.	Present study	100	12.5 ± 3.93*	Cadaveric kidney dissection

*P < 0.0001. when the values of the present study are compared with Fabregas MA et al study. The lower pole infundibular height is measured as the distance between the horizontal line passing through the distal point of the lowermost calyx and the horizontal line passing through the highest point on the lower lip of renal pelvis.

The values of the present study differ significantly when compared with Fabregas MA et al study and the difference is statistically significant(P < 0.0001). The difference might be due to different population groups taken for study and the method of study. The study by Fabregas A et al proposed that this factor infundibular height can be considered as a single determining factor in clinical evaluation of patients.

LOWER POLE INFUNDIBULOPELVIC ANGLE:

Different methods were proposed for measuring the lower pole infundibulopelvic angle. In the present study, the infundibulopelvic angle is measured as the angle between the axis passing through the lower most infundibulum and the ureteropelvic axis[62]. The persons with acute infundibulopelvic angle are not considered suitable for Extracorporeal Shock Wave Lithotripsy.

TABLE 28: LOWER POLE INFUNDIBULOPELVIC ANGLE – COMPARISON BETWEEN STUDIES

S.no	Author	Number of kidneys	Infundibulopelvic angle(degrees) Mean ± S.D	Type of study
1.	Ozgur Tan et al	34	96.3 ± 22.1*	IVU
2.	Zomorrodi A et al	400	112.5 ± 10.78**	IVU
3.	Filho DR et al	52	77.46 ± 17.17** 75.79± 15.3**	IVU 3D – HCT
4.	Present study	100	94.7 ± 11.7	Cadaveric kidney dissection

*P>0.05. when the present study is compared with the values of Ozgur Tan et al study. **P<0.001.on comparing the values of present study with the studies by Zomorrodi A et al and Filho DR et al.

The values of the present study differ significantly(P < 0.001) from the studies by Zomorrodi A et al and Filho DR et al. The difference in the values could be due to the difference in population groups in which the study was conducted.

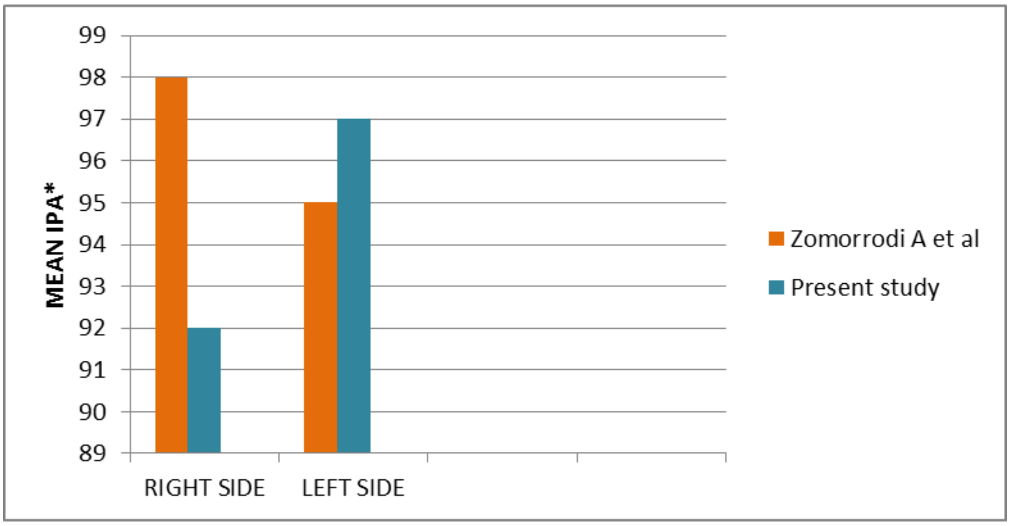
TABLE 29: **LOWER POLE INFUNDIBULOPELVIC ANGLE – COMPARISON BETWEEN STUDIES FOR BOTH SIDES**

S.no	Author	Number of specimens	Infundibulopelvic angle (degrees)		Type of study
			Right	Left	
1.	Zomorrodi A et al	400	98 ± 29.4	95.2 ± 28.4	IVU
2.	Present study	100	92.4 ± 11.03	97.1 ± 12.2	Cadaveric kidney dissection

In the present study, on the right side the infundibulopelvic angle ranged from 70 degrees to 110 degrees and on the left side it ranged from 65 degrees to 120 degrees in the present study.

In the present study, the angle is more obtuse on the left side than the right side when compared to Zomorrodi A et al . The following bar diagrammatic representation compares the angle between two sides in different studies.

FIGURE 31: COMPARISON BETWEEN STUDIES OF INFUNDIBULOPELVIC ANGLE ON BOTH SIDES



* infundibulopelvic angle

TABLE 30 : LOWER POLE INFUNDIBULOPELVIC ANGLE – PERCENTAGE OF SPECIMENS WITH $\leq$ OR > 90 DEGREES

S.no	Author	Number of specimens	Infundibulopelvic angle (degrees)		Type of study
			> 90 degrees (%)	$\leq$ 90 degrees (%)	
1.	Sampaio FJB[68]	146	74	26	Corrosion cast
2.	Present study	100	67.4	32.6	Cadaveric kidney ddissetion

As in the other parameters of the lower pole infundibulum, a cut off of 90 degrees is clinically significant and the specimens are categorized based on that value.

The percentage of specimens with obtuse infundibulopelvic angle is more in the present study (67%) and is similar to that of Sampaio FJB study.

STRENGTHS OF THE STUDY:

1. The presence of anterior and posterior orientation of minor calyces can be clearly made out by dissection method.

2. The variations in the pelvicalyceal patterns along with the dimensions of the lower pole infundibulum can be made out clearly.

LIMITATIONS OF THE STUDY:

Since the study was done on cadaveric specimens, the angle of orientation of anteriorly and posteriorly oriented minor calyces relative to the frontal plane could not be made out.

FUTURE DIRECTIONS:

The pelvicalyceal patterns and the exact angle of orientation of anteriorly and posteriorly oriented minor and major calyces measured using 3D-HCT studies will allow proper positioning of patients on the table before performing percutaneous procedures. This positioning of patients is especially useful for approach through posteriorly oriented minor calyces.

Summary

SUMMARY

The pelvicalyceal patterns and the morphometric parameters of the lower pole infundibulum were studied in 100 cadaveric human kidneys by dissection. The predominant position of renal pelvis was found to be intrarenal(79%) position. When the specimens were grouped according to Sampaio's classification, type A I (38%) was more common in the present study and it is similar to Sampaio's study. Similarly the Bicalyceal pattern was observed in 35% of specimens when specimens were classified by a method proposed by Ningthoujam DD et al. An interesting variation of extrarenal calyces with absent pelvis was observed in one specimen in the present study.

The minimum number of minor calyces was three and the maximum number of minor calyces was eleven in the present study. The lower pole calyceal range was 2.41± 0.81. In the present study, 36% of specimens had anteriorly oriented minor calyces and 27% of specimens had posteriorly oriented minor calyces. The common pattern of drainage of lower pole minor calyces was simple pattern(51%). The lower pole infundibular length had a mean±S.D value of 17.5 ± 3.4 mm. The infundibular width had a mean value of 5.63±2.2 mm. The mean value of length by width ratio was 3.6±1.5. The mean value of infundibular height was 12.5±3.93 mm. The mean infundibulo pelvic angle was 94.7±11.61 degrees.

Conclusion

CONCLUSION

The varying patterns of the collecting system of the kidney must be taken into consideration while examining a radiological report of a patient with pathologies involving the kidneys. This is because for many pathologies, the treatment procedure involves approaching the area involved through the calyces. Also in case of rare variation like the presence of extrarenal calyces, the calyces may become dilated on injection of contrast material as they are not well supported. The radiologic picture offers differential diagnosis for hydronephrosis. But such a possibility of extrarenal calyces should be borne in mind before making a final diagnosis. The difference in pelvicalyceal patterns and variations in different parameters help urologists and radiologists in choosing the right mode of treatment for the patients. This is not only helpful in reducing post procedural complications but also in minimising the economical burden upon the patients.

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Annexures

ANNEXURE 1:

List of Tables, Figures and Photographs

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Figures	Page no.

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4, 5 _ Extrarenal position of pelvis.

6 – 8 _ Borderline position of pelvis.

9, 10 _ Absent renal pelvis.

11-13_ Type A I of Sampaio's classification.

14-16_ Type A II of Sampaio's classification.

17, 18_ Type B I of Sampaio's classification.

19, 20_Type B II of Sampaio's classification.

21, 22 _ Anterior orientation of minor calyces.

23, 24_ Posterior orientation of minor calyces.

25, 26_Simple pattern of drainage of minor calyces.

27, 28_ Complex pattern of drainage of minor calyces.

29, 30_Multicalyceal type.

31, 32_ Tricalyceal type.

33, 34_ Bicalyceal type.

35, 36_Unclassified .

37-44_Pelvicalyceal patterns in endocasts done by luminal casting.

ANNEXURE - 2

Abbreviations:

Fig. - Figure.

3 D - 3 Dimensional.

3D HCT - 3 Dimensional Helical Computed Tomography.

No. - Number.

ANOVA -Analysis Of Variance.

mm - millimeters.

S.D - Standard Deviation.

IVU - Intravenous Urography.

ESWL - Extracorporeal Shock Wave Lithotripsy.

ANNEXURE-3

MASTER CHART

S.no	Side	Renal pelvis				Sampaio's classification				Pelvicalyceal patterns*				Minor calyces								Lower pole infundibulum				
		I	E	B	A	A I	AII	B I	BII	Mu	T	B	Un	TOT	U	M	LO	AO	PO	S	C	Lh	W	L/W	H	IPA
1.	R	+	-	-	-	-	-	+	-	-	+	-	-	8	3	2	3	-	2	-	+	15	6	2.5	9	100
2.	R	-	-	-	+	+	-	-	-	-	-	+	-	8	4	1	3	1	-	+	-	22	7	3.1	17	85
3.	L	+	-	-	-	-	-	+	-	-	+	-	-	7	3	2	1	-	1	+	-	17	3	5.7	11	105
4.	R	+	-	-	-	-	-	+	-	-	+	-	-	5	1	2	2	1	-	-	+	13	7	1.9	16	85
5.	L	+	-	-	-	-	-	-	+	+	-	-	-	5	1	2	2	-	-	+	-	-	-	-	-	-
6.	R	-	+	-	-	-	-	+	-	-	+	-	-	6	3	1	2	-	-	+	-	17	3	5.7	9	105
7.	L	+	-	-	-	+	-	-	-	-	-	+	-	8	2	3	3	-	2	-	+	19	8	2.3	18	80
8.	R	+	-	-	-	+	-	-	-	-	-	+	-	7	2	2	3	-	2	+	-	17	4	4.3	8	75
9.	R	-	-	+	-	-	-	-	+	+	-	-	-	7	2	1	4	-	-	+	-	24	8	3	19	70
10.	R	-	-	-	+	+	-	-	-	-	-	+	-	6	1	2	3	1	-	+	-	22	3	7.3	19	100
11.	R	+	-	-	-	+	-	-	-	-	-	+	-	6	2	1	3	1	-	-	+	23	8	2.9	17	100
12.	R	+	-	-	-	-	-	-	+	+	-	-	-	6	3	2	1	-	-	+	-	17	3	5.7	9	75
13.	L	+	-	-	-	-	-	-	+	+	-	-	-	5	2	2	1	-	2	+	-	-	-	-	-	--
14.	R	+	-	-	-	-	-	-	+	+	-	-	-	7	2	3	2	-	-	+	-	21	6	3.8	12	80
15.	R	+	-	-	-	+	-	-	-	-	-	+	-	6	2	1	3	1	-	-	+	15	4	3.8	11	80
16.	L	+	-	-	-	-	-	+	-	-	+	-	-	6	2	2	2	-	1	-	+	16	8	2.0	20	60
17.	L	-	-	+	-	+	-	-	-	-	-	+	-	5	2	1	2	1	-	-	+	25	9	2.8	18	85
18.	R	-	+	-	-	-	-	+	-	-	+	-	-	6	2	2	2	1	-	-	+	15	6	2.5	12	85
19.	R	-	-	+	-	+	-	-	-	-	-	+	-	6	2	1	3	-	-	+	-	19	6	3.2	17	100
20.	R	-	+	-	-	-	+	-	-	-	-	-	+	8	3	3	2	2	-	-	+	13	9	1.4	8	85
21.	R	+	-	-	-	+	-	-	-	+	-	-	-	8	2	4	2	-	3	-	+	17	3	5.7	12	85
22.	L	+	-	-	-	-	-	-	+	-	-	-	+	7	1	2	4	1	-	-	+	13	8	1.6	16	100

S.no	Side	Renal pelvis				Sampaio's classification				Pelvicalyceal patterns*				Minor calyces								Lower pole infundibulum				
		I	E	B	A	A I	AII	B I	BII	Mu	T	B	Un	TOT	U	M	LO	AO	PO	S	C	Lh	W	L/W	H	IPA
23.	L	+	-	-	-	-	-	+	-	-	+	-	-	5	1	2	2	-	-	-	+	14	3	4.7	11	95
24.	L	+	-	-	-	+	-	-	-	-	-	+	-	5	2	1	2	1	-	+	-	15	6	2.5	9	110
25.	R	+	-	-	-	-	-	-	+	+	-	-	-	9	5	1	3	3	-	-	+	13	6	2.2	10	85
26.	R	+	-	-	-	+	-	-	-	-	-	+	-	6	2	2	2	1	-	-	+	13	9	1.4	10	85
27.	L	+	-	-	-	+	-	-	-	-	-	+	-	7	3	1	3	-	1	+	-	14	3	4.7	9	90
28.	L	+	-	-	-	-	+	-	-	-	-	-	+	5	5	2	1	-	-	-	+	16	4	4	12	110
29.	R	-	-	-	+	-	-	-	-	-	-	-	+	6	2	-	4	1	-	+	-	-	-	-	-	-
30.	R	-	-	+	-	+	-	-	-	-	-	+	-	5	2	2	1	1	-	+	-	21	10	2.1	9	105
31.	L	+	-	-	-	-	-	-	+	+	-	-	-	5	2	2	1	-	1	+	-	-	-	-	-	-
32.	L	+	-	-	-	+	-	-	-	-	-	+	-	7	3	1	3	-	1	-	+	17	8	2.1	16	95
33.	L	+	-	-	-	+	-	-	-	-	-	+	--	8	4	-	4	3	-	-	+	15	3	5	9	95
34.	R	+	-	-	-	-	+	-	-	-	-	-	+	6	2	2	2	-	-	-	+	17	3	5.7	16	85
35.	L	-	-	+	-	+	-	-	-	-	-	+	-	5	1	1	3	-	-	+	-	22	6	3.7	7	100
36.	R	-	-	+	-	-	-	-	+	+	-	-	-	5	2	1	2	-	-	+	-	-	-	-	-	-
37.	R	+	-	-	-	-	-	+	-	-	+	-	-	7	2	2	3	-	-	-	+	13	6	2.2	8	75
38.	R	+	-	-	-	-	-	-	+	+	-	-	-	6	2	3	1	-	2	+	-	19	5	3.8	9	100
39.	L	-	-	+	-	-	-	+	-	-	+	-	-	7	2	2	3	-	-	-	+	14	7	2	8	95
40.	R	-	-	+	-	+	-	-	-	-	-	+	-	6	3	-	3	1	-	-	+	16	5	3.2	10	105
41.	L	-	-	+	-	-	+	-	-	-	-	-	+	7	2	3	2	-	3	+	-	19	3	6.3	17	90
42.	R	+	-	-	-	-	-	+	-	-	+	-	-	7	3	2	2	-	-	-	+	14	6	2.3	9	100
43.	L	+	-	-	-	-	-	+	-	-	+	-	-	8	3	2	3	2	1	-	+	14	5	2.8	10	90
44.	R	-	+	-	-	+	-	-	-	-	-	+	-	5	1	2	2	1	1	-	+	14	6	2.3	9	90

S.no	Side	Renal pelvis				Sampaio's classification				Pelvicalyceal patterns*				Minor calyces								Lower pole infundibulum				
		I	E	B	A	A I	AII	B I	BII	Mu	T	B	Un	TOT	U	M	LO	AO	PO	S	C	Lh	W	L/W	H	IPA
45.	L	+	-	-	-	-	-	+	-	-	+	-	-	6	2	2	2	2	-	-	+	15	7	2.1	12	95
46.	L	+	-	-	-	-	-	+	-	-	+	-	-	9	4	2	3	1	2	-	+	19	4	4.8	16	95
47.	R	+	-	-	-	-	-	+	-	-	+	-	-	8	2	3	3	1	3	-	+	14	9	1.5	16	75
48.	L	+	-	-	-	-	-	+	-	-	+	-	-	6	1	3	2	-	-	-	+	16	9	1.8	15	95
49.	R	+	-	-	-	+	-	-	-	+	-	-	-	7	2	2	3	2	-	-	+	18	6	3	15	105
50.	L	+	-	-	-	-	+	-	-	-	-	-	+	6	2	2	2	1	1	-	+	14	4	3.5	8	95
51.	R	+	-	-	-	-	+	-	-	-	-	-	+	5	1	3	1	2	-	+	-	13	6	2.2	9	80
52.	R	+	-	-	-	+	-	-	-	-	-	+	-	5	2	2	1	-	-	+	-	13	6	2.2	10	105
53.	L	+	-	-	-	-	+	-	-	-	-	-	+	6	1	2	3	-	-	+	-	15	3	5	9	65
54.	L	+	-	-	-	+	-	-	-	+	-	-	-	6	2	2	2	-	1	-	+	14	6	2.3	14	100
55.	R	+	-	-	-	+	-	-	-	-	-	+	-	6	2	1	3	-	-	-	+	23	9	2.6	15	100
56.	L	+	-	-	-	-	-	-	+	+	-	-	-	8	3	2	3	-	-	+	-	18	6	3	16	100
57.	R	+	-	-	-	-	-	-	+	+	-	-	-	7	2	1	4	2	-	+	-	17	6	2.8	13	95
58.	R	-	-	+	-	+	-	-	-	-	-	+	-	7	1	1	5	-	2	-	+	19	6	3..2	12	110
59.	R	+	-	-	-	+	-	-	-	-	-	+	-	5	2	-	3	-	-	-	+	15	9	1.7	7	100
60.	L	+	-	-	-	-	-	+	-	-	+	-	-	4	1	1	2	-	-	-	+	17	3	5.7	11	95
61.	R	-	-	+	-	+	-	-	-	-	-	+	-	5	2	-	3	1	-	+	-	18	3	6	16	115
62.	L	-	-	+	-	+	-	-	-	-	-	+	-	3	1	-	2	-	-	-	+	13	3	4.3	9	120
63.	R	+	-	-	-	-	-	+	-	-	+	-	-	6	2	2	2	-	-	-	+	14	4	3.5	11	95
64.	L	+	-	-	-	-	-	-	+	+	-	-	-	5	1	3	1	-	-	+	-	-	-	-	-	-
65.	R	+	-	-	-	-	-	+	-	-	+	-	-	8	3	2	3	-	1	-	+	14	6	2.3	13	90
66.	R	+	-	-	-	+	-	-	-	-	-	+	-	6	2	1	3	-	1	+	-	17	7	2.4	16	80

S.no	Side	Renal pelvis				Sampaio's classification				Pelvicalyceal patterns*				Minor calyces								Lower pole infundibulum				
		I	E	B	A	A I	AII	B I	BII	Mu	T	B	Un	TOT	U	M	LO	AO	PO	S	C	Lh	W	L/W	H	IPA
67.	L	+	-	-	-	+	-	-	-	-	-	+	-	7	3	1	3	-	2	-	+	15	3	5	9	110
68.	R	+	-	-	-	+	-	-	-	-	-	+	-	9	4	3	2	1	2	-	+	17	3	5.7	16	110
69.	L	-	-	+	-	-	-	+	-	-	+	-	-	11	4	3	4	-	1	+	-	23	3	7.7	17	100
70.	L	+	-	-	-	-	-	+	-	-	+	-	-	7	2	2	3	-	-	-	+	15	5	3	10	115
71.	R	+	-	-	-	+	-	-	-	-	-	+	-	6	2	2	2	1	-	+	-	13	3	4.3	15	80
72.	L	+	-	-	-	+	-	-	-	-	-	+	-	7	3	1	3	1	-	-	+	13	3	4.3	9	105
73.	R	+	-	-	-	+	-	-	-	-	-	+	-	7	3	-	4	-	-	-	+	15	3	5	12	105
74.	L	+	-	-	-	-	-	+	-	-	+	-	-	6	2	1	3	-	-	-	+	14	8	1.7	10	110
75.	R	+	-	-	-	+	-	-	-	-	-	+	-	5	2	1	2	-	1	-	+	14	7	2	12	80
76.	L	+	-	-	-	-	-	-	+	+	-	-	-	7	2	3	2	-	-	+	-	19	3	6.3	13	105
77.	R	+	-	-	-	-	-	-	+	+	-	-	-	8	3	3	2	-	-	+	-	22	6	3.7	16	95
78.	R	+	-	-	-	-	+	-	-	-	-	-	+	7	2	2	3	-	-	+	-	18	7	2.6	13	100
79.	L	+	-	-	-	-	-	-	+	+	-	-	-	5	1	3	1	-	-	+	-	-	-	-	-	-
80.	R	+	-	-	-	-	+	-	-	-	-	-	+	7	3	2	2	-	-	+	-	23	9	2.6	19	95
81.	L	+	-	-	-	-	-	+	-	-	+	-	-	6	2	2	2	-	1	+	-	18	3	6	10	85
82.	L	+	-	-	-	+	-	-	-	-	-	+	-	8	3	3	2	3	-	+	-	14	3	4.7	9	100
83.	R	+	-	-	-	+	-	-	-	-	-	+	-	9	3	3	3	-	-	+	-	13	3	4.3	7	110
84.	R	+	-	-	-	-	-	+	-	-	+	-	-	5	2	1	2	-	-	+	-	24	4	6	15	95
85.	L	+	-	-	-	-	-	+	-	-	+	-	-	5	1	2	2	1	-	-	+	25	7	3.6	21	80
86.	R	+	-	-	-	-	-	+	-	+	-	-	-	6	2	2	2	1	-	+	-	14	3	4.7	8	100
87.	R	+	-	-	-	+	-	-	-	-	-	+	-	7	3	2	2	-	-	+	-	15	3	5	7	85
88.	L	+	-	-	-	-	-	+	-	-	+	-	-	8	4	2	2	-	2	-	+	27	9	3	16	100

S.no	Side	Renal pelvis				Sampaio's classification				Pelvicalyceal patterns*				Minor calyces							Lower pole infundibulum					
		I	E	B	A	A I	AII	B I	BII	Mu	T	B	Un	TOT	U	M	LO	AO	PO	S	C	Lh	W	L/W	H	IPA
89.	R	+	-	-	-	-	+	-	-	-	-	-	+	7	2	3	2	-	-	+	-	19	6	3.1	8	100
90.	L	+	-	-	-	-	-	+	-	-	+	-	-	6	2	2	2	-	-	+	-	18	6	3	9	100
91.	R	+	-	-	-	-	-	-	+	+	-	-	-	7	2	3	2	-	-	+	-	19	6	3.1	8	100
92.	R	+	-	-	-	-	-	-	+	+	-	-	-	8	3	2	3	-	-	-	+	23	8	2.9	20	95
93.	L	+	-	-	-	-	+	-	-	-	-	-	+	7	3	2	2	1	-	+	-	21	3	7	18	110
94.	R	+	-	-	-	-	-	-	+	+	-	-	-	5	2	1	2	1	-	+	-	-	-	-	-	-
95.	L	+	-	-	-	+	-	-	-	-	-	+	-	7	3	2	2	-	-	+	-	18	3	6	8	95
96.	R	+	-	-	-	-	+	-	-	-	-	-	+	6	2	2	2	-	-	+	-	24	8	3	17	75
97.	L	+	-	-	-	+	-	-	-	-	-	+	-	5	2	1	2	-	-	+	-	27	7	3.9	16	85
98.	L	+	-	-	-	-	-	-	+	+	-	-	-	6	2	2	2	-	-	-	+	24	8	3	17	95
99.	R	-	+	-	-	-	-	+	-	-	-	-	+	7	3	2	2	1	-	+	-	20	10	2	7	100
100.	L	+	-	-	-	-	-	+	-	-	+	-	-	8	3	2	3	1	-	+	-	21	8	2.6	8	105

R - Right.
L - Left.
I - Intrarenal.
E - Extrarenal.
B - Borderline(or both I and E).
A - Absent.
*** - As proposed by Ningthoujam DD et al.**
Mu - Multicalyceal.
T - Tricalyceal.
B - Bicalyceal.

Un - Unclassified.
TOT - Total number.
U - Number of minor calyces in Upper zone.
M - Number of minor calyces in Middle zone.
LO - Number of minor calyces in Lower zone.
AO - Anteriorly Oriented minor calyces.
PO - Posteriorly Oriented minor calyces.
S - Simple pattern of drainage of lower pole minor calyces.
C - Complex pattern of drainage of lower pole minor calyces.

Lh - Length (mm).
W - Width (mm).
L/W - Length by width ratio.
H - Height (mm).
IPA - Infundibulo Pelvic Angle(degrees)