STUDY OF MORPHOLOGY OF KIDNEY IN HUNDRED SPECIMENS

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CERTIFICATE

This is to certify that this dissertation titled **"STUDY OF MORPHOLOGY OF KIDNEY IN HUNDRED SPECIMENS"** is a bonafide research work of **DR.P.PRABAVATHI**, a student in M.D. Anatomy, Branch XXIII in partial fulfilment of the requirements for the award of MD degree by The Tamilnadu Dr. M.G.R. Medical university.

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DECLARATION

I, **DR.P.PRABAVATHI**, solemnly declare that the dissertation titled **"STUDY OF MORPHOLOGY OF KIDNEY IN HUNDRED SPECIMENS"** has been prepared by me.

This is submitted in partial fulfilment of the regulations for the award of MD Anatomy degree examination to be held in April 2013.

This work has not formed the basis for the award of any other degree or diploma to me previously from any other university.

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CONTENTS

INTRODUCTION

The Kidneys are pair of essential excretory organs situated retro-peritoneally in the posterior abdominal wall, one on each side of the vertebral column. They remove waste products of metabolism and excess of water and salts from the blood and maintain its pH.

Each kidney is bean shaped and extends from twelfth thoracic to third lumbar vertebrae. Right kidney is slightly lower than its left partner due to the presence of liver. Left kidney is longer, narrower and nearer to the vertebral column than the right one.

Each kidney has 2 poles (upper and lower) 2 borders (medial and lateral) and 2 surfaces (anterior and posterior). The upper pole is broad and is in close contact with the corresponding suprarenal gland. The lower pole is pointed. The medial border presents the hilum in its middle. The hilum admits the passage of renal vessels and renal pelvis.

The knowledge of the kidney dimensions is essential to understand the normal renal function and disease pattern If any pathological condition affecting the kidney will lead to alteration in the dimensions of the kidney and hence its functions.

Kidney anatomy is unique which allows it to perform many complex functions. The dimensions are used as diagnostic as well as prognostic

parameter in renal pathology. Precise knowledge of renal morphology along with renal hilar structure arrangements and its variations are very much essential for renal transplantation surgeries and in uro-radiology. Prior knowledge of kidney dimensions would be of immense help to radiologists who scan the kidney.

Morphology of kidney varies in different population depending on the ethinic background and the Body Mass Index. This present study highlights about the morphology of kidney in our population.

AIM OF THE STUDY

To analyse the morphology of kidney in relation to the length, breadth, thickness, hilar structures arrangement and its variations in hundred human kidneys.

REVIEW OF LITERATURE

Aristotle (384-322 BC) refers to the kidney in two of his works (Historia Animalium and De Partibus Animalium). According to Aristotle, the functions of the kidney were as follows:

- to separate the excess fluid from the blood and
- this fluid was excreted through the excretory system (the ureters, bladder and urethra).

Galen (130-200 A.D.) known as "prince of Physician" has discussed the mechanism of urine formation in earlier days.

Later, Leonardo da Vinci (1452-1519) artistically depicted the gross anatomical features of kidneys more accurately.

Andreas Vesalius' in his DeHumani Corporis Fabrica (1543) was observed that the production of urine was a result of the blood being filtered by the kidney.

Alexander Schumlansky (1788) presented the macroscopic anatomy of the kidney in detail in his work on De Structurarenum.

Later, many anatomists have contributed their work regarding the gross and microscopical details of the renal system in the early nineteenth century.

According to F.Wood Jones (1953)[44], the kidney length was 4 inches, width was 2.5inches and thickness was 1.25 inches and concluded that right kidney is shorter and broader than the left. He described about the size, hilar structure arrangements and extrarenal type of pelvis in the Buchanan's manual of anatomy. He signified the presence of foetal lobulations in the kidney which may persist in the adult life.

J. Parsons Schaeffer (1953)[29] stated that length of kidney was 10 to 12 cm, width was 5 to 6 cm, and thickness was 3 to 4 cm. He also described about the arrangements of structure at the renal hilum antero-posteriorly.

In autopsy studies, Allen AC (1952)[2] reported the presence of simple renal cyst in 3 to 5% of cases.

According to T.B.Johnston (1955)[20] in Gray's anatomy, each kidney is about 11cm in length, 6 cm in breadth and 3 cm in thickness. They described about the relative position of the main structures in the hilus are as follows:

- The renal vein is in front,
- The renal artery in the middle, and
- The pelvis of the ureter behind.

As a rule one of the branches of the renal artery enters the renal hilus behind the ureteral pelvis and it is not uncommon to find one of the tributaries of the renal vein issuing from the hilus in the same plane.

Mullick MH (1970)[25] observed the average measurements of kidney in Bangladeshi population and mentioned the dimensions as 9.9cm in length, 4.6cm in breadth and 3.7cm in thickness.

Harrison LH Jr et al (1978)[16] studied about Persistence of foetal lobulations and concluded that 4% kidneys showed the Persistence of foetal lobulations.

Barton EN et al (1982)[5] in a sonographic study of kidney dimensions studied the mean length of Right kidney was 9.7 +/- 0.7cm and left kidney was 10 +/- 0.7cm. They concluded that the Left kidney was longer than the right kidney and found that there was no difference in width between right or left kidneys.

Sampaio F J, Mandarim-de-Lacerda CA (1989)[33] studied the morphometry of the kidney on 100 human kidneys obtained by necropsies from 50 cadavers and showed the following averages:

- Length (right kidney 10.97 cm, left kidney 11.21cm)

- Width of the superior pole (Right kidney – 6.4cm and Left kidney – 6.48cm),
- Width of the inferior pole (Right Kidney 5.59 cm and left kidney 5.39 cm)
- Thickness of the right kidney was 3.21cm and the left kidney was 3.37 cm
- They concluded that Left kidney presented usually with greater length, greater width and greater thickness than Right Kidney.

Gebrehiwot M, Atnafu A (1998)[13] reported in his determination of normal renal dimensions that left kidney was longer than the right.

Niels – Peter – Buchholz et al (2000)[27], kidney measurements were done on 194 adult patients without known kidney lesions. Length, width and cortical thickness were measured. The renal size was estimated by multiplying the above three variables. They concluded in their ultrasonographic studies as follows:

- The mean kidney length was 10.4 +/-cm 0.8 cm.
- The mean width was 4.5 +/- 0.6 cm
- The mean renal size was 76 ±22 cm.

Kidney length did not significantly differ between right and left, but the size, kidney width and cortical thickness were significantly differ. They concluded as right kidneys were smaller than the left kidneys.

According to Bergman RA et al (2000)[6], the foetal lobulations were present in 7% of the adult.

D. Shani et al (2001)[35] had conducted a study on Northwest Indian population. The measurement of length, width, and thickness of kidney were reported in the study. According to their study,

- Length of the right kidney was 9.9 cm and left kidney was 10.0cm.
- Breadth of the both kidneys was 4.6cm.
- Thickness of the right kidney was 3.3cm and the left kidney was 3.4 cm.

Comparison was done and unexpectedly found that, the renal size of Indian population is relatively similar to the Malaysian. In their study, they found out that the kidney of Malaysian is slightly thicker than the Indian.

Isakovic E et al (2001)[18] studied about the anatomical variations of shape, size and relation of the kidneys. This study was done in 33 pairs of the human adult kidneys. They concluded that foetal lobularness was present in 27.27% on right side, 33.3% on left side kidneys.

A study was done by Mazzotta L et al (2002)[24] and concluded that the length of the kidney was the more precised measurement of size of the kidney.

A routine cadaveric dissection done in an adult male by Pushpa Dhar (2002)[30] AIIMS, Delhi; revealed that at the right renal hilum, the segmented branches of Right renal artery were sandwiched between the two veins. In addition, venous tributary was present posterior to the right renal pelvis.

Terada et al (2002) [41] stated the prevalence of simple renal cysts were 11.9%. Similarly, Carrim Z. I. and Murchison J. T. (2003)[8] studied the prevalence of simple renal cyst using spiral computed tomography (CT) and 41% were found to have simple renal cysts.

Garg P et al (2003)[12] reported a case of extra renal calyces which is rare variation of the renal pelvis.

K. Aravindan, K.R. Srinivasan (2003)[4] in their study found that the bilateral arrangements of hilar structures from anterior to posterior were renal artery, renal vein and ureter. In another cadaver, they found that the renal vein was present between artery and pelvis of the ureter on left side.

Ray B et al (2004)[31] measured the kidney dimensions in forty formalin-preserved adult kidneys in Nepalese population. They observed the following:

- Right kidney was 85.25 mm long, 50.65 mm wide and 34.6 mm thick.
- Left kidney was 91.65 mm long, 53.65 mm wide and 38.5 mm thick.

They concluded that the kidneys of Nepalese population were shorter than the people living in other parts of the world.

A study was done by S. Das and Sefan J. Paul (2006)[11] that they described on the right side, the arrangement of hilar structures from anterior to posterior was renal artery, renal vein and ureter.

OkoyeIJ, AgwuKK, Eze CU (2006)[28] reported in their sonographic study on kidneys that the range of renal length were 8.5-12.9 mm and the corresponding mean were 10.33+/-0.7cm and 10.45+/-0.63cm for the right and left kidneys respectively.

Chang-Chi Chang et al (2007)[9] studied about the simple renal cyst and observed that the prevalence was 10.7%. He also stated about the associated risk factors for the development of simple renal cyst. The risk factors were smoking and renal stones.

K.Y.Kang et al (2007)[21] conducted a study about kidney transplantation donors and observed the average measurements of human kidneys, the values were 11.1cm in length, 6.2cm in breadth and 4.73cm in thickness.

Hamida Khatun et al (2009)[15] studied to standardize the morphological data of kidney from 50 postmortem cases and it was found that there was no gross morphometric difference between right and left kidneys. They concluded as follows:

- The average length was 8.99 cm (7-11.5cm).
- The average breadth was 4.08cm (3-6.5cm).
- The average thickness was1.78cm (1.14-2.87cm).
- Kidneys of Bangladeshi people are shorter, narrower and thinner than the western people.

G.Nataraju et al (2009)[26] reported about a kidney specimen that showed the presence of Extrarenal pelvis with five long calyces and the renal dimensions to be of 8cm in length, 4cm width, and 3cm thickness.

Hitendra Kumar LOH et al (2009)[17] described about the variant disposition of structures at the left renal hilum as:

- Antero-posteriorly: inferior tributary of renal vein, both branches of Main renal artery and Accessory renal artery and the posterior-most was the superior tributary of left renal vein.
- From above downwards: artery-vein-artery-vein-artery.

The right renal vessels showed the usual anatomy in his study.

Joao A. Pereira-Correia et al (2009)[19] were dissected one hundred and thirteen renal hilum from adult Brazilian human cadavers. They analysed the hilar structures arrangement from the anterior border of the renal hilum at about 0.5cm distance in antero-posterior distribution. Only the renal artery, renal vein and renal pelvis were considered.

They were observed the following:

- 83% showed the classic hilar arrangement: renal vein -renal artery - renal pelvis.
- 3% of left kidneys were found to have the arrangement of renal vein-pelvis-artery.
- 3% kidneys were showed the renal artery-vein-pelvis arrangement.
- 1% left kidney presented the renal artery-pelvis-vein arrangement.
- 10%kidneys found to have an undefined organization of hilar structures.

An atypical distribution of segmentary arteries was also noted in relation to renal hilar structures.

For evaluation of kidney function in clinical practice, the kidney length was the most widely used measurement, as it provides the most precise results and also easy to perform. Vlajkovic S et al (2010)[43] studied

about the renal length in 95 adult cadaveric kidneys and was concluded that length of left kidney was longer than the right one.

Later, Trivedi et al (2011)[42] observed the antero posterior relationship of structures at the hilum of the kidney in 100 specimens. They are classified, the variable pattern of hilar structures in to five types.

Pattern 1A: Renal vein - Renal artery - Pelvis.

Pattern 1B: Renal vein - Anterior division of renal artery - Posterior division of renal artery - Pelvis.

Pattern 2: Anterior division of renal artery - Renal vein - Posterior division of renal artery - Pelvis.

Pattern 3: Anterior tributary of renal vein - Anterior division of renal artery - Pelvis - Posterior tributary of renal vein - Posterior division of renal artery

Pattern 4: Renal vein - Anterior division of renal artery - Pelvis - Posterior division of renal artery

Pattern 5: Anterior division of renal artery - Renal vein - Pelvis - Posterior division of renal artery. They concluded,

- 73% of the arrangement was not according to the textbook description (renal vein, renal artery and pelvis arranged antero-posteriorly)

- In 31% anterior division of renal artery was present in front of renal vein at the hilum.
- In 50% cases the pelvis was not the posterior most relation.

Knowledge of the variations of hilar structures were useful for operating surgeons while performing laparoscopic partial nephrectomy for identification and for clamping of individual hilar structures inspite of en-bloc clamping. Individual clamping was advantageous than the en-bloc clamping.

Sreekanth Tallapaneni, Mahesh Vemavarapu (2011)[37] observed, the presence of altered hilar anatomy with double pelvis in the left duplex kidney of a 55-year-old female cadaver during the routine dissection.

Zeb Saeed et al (2012)[45] stated that mean kidney length was 9.85cm on right side and 10cm on left, the mean breadth was 4.61cm.

Arora AK et al (2012)[3] repoted the arrangement of the structures in the hilum of right kidney, antero-posteriorly was right anterior segmental renal artery, right renal vein, right posterior segmental renal artery and ureter. The left renal artery had normal topographical relationships in the hilum.

Suresh Rao et al (2012)[39] found a rare case of bilateral extrarenal calyces and renal pelvis during their routine dissection.

MATERIALS AND METHODS

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MATERIALS:

The following materials were used,

- 100 human kidney specimens
- Stainless steel students scalpel
- Stainless steel forceps toothed and non toothed
- Stainless steel long and short straight scissors
- Thread, Cotton, Rubber sheet
- Digital vernier caliper:

  The length, breadth and thickness of the kidney were measured with the help of a Digital Vernier caliper (Fig – 1).
- Canon digital camera
- 10% formalin

METHOD OF STUDY:

The study was conducted in the Institute of Anatomy, Madurai medical college, Madurai.

The 100 human kidney specimens (50 specimens on right side and 50 specimens on left side) (Fig -2) for the present study were collected from the Forensic medicine department, Madurai medical college. The specimens

were obtained irrespective of any age, sex, socio-economic status and pathological bias.

The kidneys were removed during autopsy by Manual Dissection method in which the abdominal cavity of the post mortem body was opened by midline incision from xiphoid process to pubic symphysis. Liver, spleen, gastro intestinal system and other associated structures were removed leaving behind the retro peritoneal structures. The peritoneum was stripped off from the posterior abdominal wall. Aorta was traced from the diaphragm to the common hilar bifurcation. Renal pedicle was identified and carefully separated from the surrounding structures with the kidneys by careful blunt dissection. All the branches of the Aorta except the main and accessory renal arteries were cut. Aorta and Inferior venacava were cut below the diaphragm and above the level of bifurcation. Ureters were identified, traced and cut on both sides. Both kidneys along with perinephric fat and fascia with Aorta, Inferior venacava, ureters were removed enbloc from the posterior abdominal wall.

The specimens were then thoroughly washed in running water to remove the residual blood and specimens were then kept in 10% formalin for fixation and preservation.

Formalin fixed specimens were kept in tap water to wash out the excess formalin and to minimize the irritation of eyes and nasal mucosa. Specimens were then taken in a tray to remove the associated fat, fascia, nerves and other unwanted tissues were removed and care was taken to preserve the hilar structures.

Specimens were tied with disc and serially numbered from 1 to 50, each disc representing right and left kidney.

The observations were made pertaining to the following parameters:

1. The Length of the kidney:

Renal length was measured from upper pole to lower pole for right and left kidneys and the observations were recorded.

2. Breadth of the kidney:

Breadth of the kidney was measured on both sides. It was measured at the maximum breadth perpendicular to pole to pole length of the kidney. The measured values were recorded.

3. Thickness of the kidney:

Thickness of kidney was measured at the level of maximum antero-posterior diameter for right and left kidneys and recorded.

Length, breadth and thickness were measured with the help of digital vernier caliper (Fig -3).

4. Arrangement of hilar structures:

Arrangement of hilar structures was studied antero- posteriorly in relation to renal vein, renal artery and pelvis of the ureter. Classified in to five patterns as follows:

Pattern I: Renal vein - Renal artery - Pelvis (Fig -4).

Pattern II: Anterior division of renal artery - Renal vein - Posterior division of renal artery - Pelvis (Fig -5).

Pattern III: Anterior tributary of renal vein - Anterior division of renal artery - Pelvis - Posterior tributary of renal vein - Posterior division of renal artery (Fig -6).

Pattern IV: Renal vein - Anterior division of renal artery - Pelvis - Posterior division of renal artery (Fig -7).

Pattern V: Anterior division of renal artery - Renal vein - Pelvis - Posterior division of renal artery (Fig -8).

5. Variations of the kidney:

The following variations were looked for:

a. **Persistence of foetal lobulations:**

Persistent of foetal lobulation (Fig -9) is a normal variant seen occasionally in adult kidneys. Embryologically, the kidney develops from distinct lobules then the lobules unite to form a single one. So the persistence of foetal lobulations was due to incomplete fusion of the developing renal lobules.

b. Renal cyst:

Morphologically, simple renal cysts (Fig -10) are individually oval to round. They may be single or multiple. It is present in the normal sized kidneys.

Simple renal cysts are acquired and filled with clear or straw-colored fluid. The origin of the cyst was unknown. They are developed from diverticula of the distal convoluted or collecting tubules. These diverticula increase in number in senescent kidneys as a result of the weakening of the tubular basement membrane. This explains the possible relationship between senility and simple renal cysts. Simple renal cyst which present as solitary cyst may turn in to multiple in later life.

c. Extrarenal pelvis/calyces:

Extrarenal pelvis/calyces (Fig -11, 12) are characterized by renal pelvis and calyces that present outside the renal parenchyma which is the rare anomalies of the collecting system. Embryologically, it is due to a

disparity resulting from slow development of the metanephric tissue or a rapid development of the ureteric bud.

d. Horseshoe kidney and Single kidney:

Horseshoe kidney:

Horseshoe kidney is the common congenital fusion anomaly in which the kidneys were found to be fused. It occur 1 in 400 births. The kidneys are situated at lower level than its normal position. Opposite to the fourth lumbar vertebra, the lower poles of the kidneys were fused to form the isthmus.

Horseshoe kidney occurs due to the fusion of lower poles of the both kidneys. The inferior poles of the kidney usually fuse. It usually remains asymptomatic, as the collecting system develops normally and the ureters enter the bladder also in normal way. If there is any obstruction or infection it may produce the signs and symptoms. It is said to be associated with Turner syndrome, the incidence of which is about 7%.

Single kidney:

Sometimes only one kidney is present. This could be due to congenital absence of the other kidney. Thus imperfect development of one kidney or its absence leads to compensatory enlargement of the opposite side.

After the observation, the findings were recorded, tabulated and photographed.

ANATOMY OF THE KIDNEY:

Kidneys (Fig -13) are a pair of excretory organ situated behind the peritoneum in the posterior abdominal wall, on each side of the lumbar part of the vertebral column. It extends from the twelfth thoracic vertebra to the third lumbar vertebra. Left kidney is slightly at a higher level than the right kidney since the liver occupies the right hypochondrium.

The left kidney is longer, narrower, and lies close to the vertebral column than the right one. The upper pole of the right kidney reaches the eleventh intercostal space. The upper pole of left kidney reaches the eleventh rib. The upper poles of the both kidneys are nearer to the midline than the lower poles.

Average measurements of each kidney are as follows:

Length is 11 cm, breadth is 6 cm and thickness is 3 cm. Weight is about 150-170 gm in adult male and 130-150 gm in adult female.

Shape of the kidney:

It is bean shaped with medially directed hilum.

Coverings of the kidney (from within outwards):

Fibrous capsule (true capsule):

Fibrous capsule is formed by the condensation of fibrous stroma of the kidney. The entire organ is covered by the capsule.

Perinephric fat (adipose capsule):

The interval between the fibrous capsule and renal fascia is occupied by perinephric fat. The fat is abundant along the borders and is content of renal sinus.

Renal fascia (false capsule, fascia of Gerota):

Fascia of Gerota is formed by extra-peritoneal connective tissue condensation around the kidney which is continuous laterally with fascia transversalis. It consists of anterior layer known as fascia of Toldt which is a thin layer and posterior layer known as fascia of Zuckerkendl which is a thick layer.

Paranephric fat:

The interval between the renal fascia and anterior layer of thoraco-lumbar fascia is occupied by paranephric fat. The fat is abundant on posterior surface of the lower part of the kidney.

Presenting parts of the kidney:

Each kidney presents two ends (upper and lower) two surfaces (anterior and posterior), two borders (lateral and medial).

Anterior and Posterior surface:

Anterior surface is partially covered with peritoneum. It is convex and directed forwards and laterally. Posterior surface is entirely non-peritoneal, flat and directed downwards and medially.

Upper and Lower end:

Upper end is situated opposite to twelfth thoracic vertebra about 2.5 cm from the median plane. It is thicker and more rounded than the lower end. Lower end is situated opposite to third lumbar vertebra about 7.5 cm from the median plane and 2.5 cm above the highest point of iliac crest. It is directed downwards and laterally.

Lateral and Medial border:

Lateral border is thick, convex and lies on a more posterior plane than the medial border. Medial border is convex in the upper and lower parts and a central concavity in between them known as hilum of the kidney.

Hilum of the kidney:

Hilum is situated about 5 cm from the middle line, opposite the lower border of first lumbar vertebra. It is bounded by anterior and posterior lips and communicates with the renal sinus within the kidney. The anterior lip usually has two notches and the posterior lip presents only one notch which

lie close to the lower end of kidney. These notches denote lobulated development of the kidney

Structures passing through the hilum of the kidney:

The structures passing through the hilum of the kidney from before backwards are as follows:

- Renal vein.
- Renal artery.
- Pelvis of ureter.
- As a rule, one branch of renal artery and a corresponding tributary of renal vein pass behind the pelvis.
- It also transmits renal lymphatics,nerves and perinephric fat.

Arterial supply of kidney:

Each kidney is supplied by a renal artery which is a branch of abdominal aorta. Right artery is longer than the left one, because abdominal aorta lies on the left side of vertebral column. About 1 liter of blood circulates through both kidneys per minute.

Renal artery:

Branches of the renal arteries are end arteries. The renal artery reaches the hilum of the kidney between the renal vein in front and pelvis of ureter behind. It divides in to anterior and posterior trunks.

Anterior trunk passes in front of the renal pelvis and subdivides usually in to four segmental arteries. Posterior trunk passes behind the renal pelvis and is continued as posterior segmental arteries.

Venous drainage:

Each kidney drains into inferior vena cava by the corresponding renal vein. Left renal vein is longer than the right vein, drains the blood from the left kidney, left gonad and left supra renal gland.

Renal pelvis:

The renal pelvis (pelvis of the ureter) is the dilated end of the ureteric bud, lying partly within and partly outside the renal sinus, and continuous below with the ureter proper and above with the major calyces.

The renal pelvis is therefore essentially funnel-shaped; two, or sometimes three, short and wide tubules may arise from it, forms the major calyces, each of which in turn receives a number of minor calyces. The latter are cup-shaped tubes which surround the renal pappilae and receive the urine from the kidney.

DEVELOPMENT OF THE KIDNEY

Urinary system develops from the intermediate mesoderm, a derivative of intra embryonic mesoderm. In higher forms of vertebrates including man, three successive kidneys develop in the intermediate mesoderm in cranio-caudal direction.. The successive forms are the pronephros, mesonephros and metanephros. The pronephric and mesonephric kidneys are transitory. The metanephric kidney persists as permanent kidney.

Pronephric kidney:

Pronephric kidney develops first in the cervical and upper thoracic regions during the fourth week of development and disappears entirely except its duct. Pronephric duct is utilized by the metanephric kidney as its own.

Mesonephric kidney:

Mesonephric kidney develops next in the thoraco lumbar region. The cephalic part of the mesonephros disappears. The remaining caudal part of the mesonephric tubules and duct system persists in male and form the duct system of the testis. Mesonephric duct is also known as Wolffian duct. In

females most of the mesonephric tubules and duct disappears and some persist as vestiges within the broad ligament of uterus.

Metanephric kidney:

Metanephric kidney develops last in the lumbo-sacral region and consists of two parts, collecting and excretory parts.

The collecting part develops earlier. During the fifth week of development the collecting part develops as a ureteric diverticulum or the ureteric bud. The portion of the mesonephric duct between the cloaca and ureteric bud is known as common excretory duct. The upper end of ureteric bud dilates and invades intermediate mesoderm and subdivids successively into thirteen or more generations of branches. The terminal branches form ampullated blind extremities. The stalk of the ureteric bud forms the ureter its dilated end persists as pelvis of ureter. The branches of the first order form the major calyces and second to fourth order form the minor calyces, all branches from fifth and subsequent orders persist as the collecting tubules of the permanent kidney.

The excretory part is developed from the intermediate mesoderm which surrounds the branches of ureteric bud. This forms a cap like investment around the ureteric bud known as the metanephric blastema which is a solid mass of bilaminar cells. Some parts of the blastema which

are situated at the sides of collecting tubules form the renal vesicles. The renal vesicles are the precursor of nephrons. Vascular endothelial cells at the tips of renal tubules differentiate in to definitive glomerulus. Finally, blind ends of excretory and collecting tubules communicate with each other. The metanephric kidney starts functioning at about the ninth week of development.

The metanephric kidney at first situated in the pelvic cavity and receives its arterial supply from the median sacral artery. The kidney gradually ascends and reaches the iliac fossa, here it gets arterial supply from common and internal iliac arteries. The final ascent of the kidney is arrested by the diaphragm and receives its blood supply from lower supra renal artery which persists after birth as permanent renal artery.

The factors responsible for the ascent of the kidney are as follows:

- Continuous lengthening of the ureteric bud.
- Dimunition of the foetal curvature.
- Small capacity of the pelvic cavity.

Foetal kidneys are lobulated and this condition persists up to first year after birth.

Rotation of the kidney:

During the ascent of the kidney, the hilum is directed ventrally. When it reaches the permanent position, around the vertical axis it undergoes medial rotation. The hilum of the kidney is directed medially by this medial rotation.

OBSERVATIONS

One hundred human kidney specimens were studied. Data's were collected, recorded, and tabulated.

The collected Data's are as follows:

1. Length of the kidney
2. Breadth of the kidney
3. Thickness of the kidney
4. Arrangement of renal hilar structures
5. Variations:
    a. Persistence of foetal lobulations
    b. Renal cyst
    c. Extrarenal pelvis/calyces
    d. Horseshoe kidney and single kidney.

1. Length of the kidney:

Length of the kidney was measured and recorded values were tabulated.

Table 1. Length of the kidney

Specimen no	Right side kidney (cm)	Left side kidney (cm)
1	8.2	8.2
2	9.8	9.9
3	9.3	9.4
4	8.8	8.9
5	7	8.9
6	8.7	8.2
7	11.4	11.4
8	8.3	9.2
9	10.1	10.5
10	10.9	11.3
11	7.5	9.5
12	9.7	7.1
13	9.2	10.1
14	9.7	10.1
15	9.6	9.3
16	8.6	10
17	9	9
18	9.7	9.4
19	10	9.9
20	8.7	9.1
21	9.7	9.5
22	10.3	9.4
23	10.5	10.5
24	9.9	10
25	8.9	9.1

Table 1. Length of the kidney

Specimen no	Right side kidney (cm)	Left side kidney (cm)
26	10.6	10.2
27	10.4	11.1
28	8.6	9.3
29	9.9	9.9
30	8.4	8.4
31	8.4	8.6
32	8.7	8.6
33	9.8	9.9
34	8.5	8.7
35	10.1	10.3
36	8.4	8.4
37	10.2	9.7
38	9.7	9.6
39	9.5	9.6
40	9.3	9
41	10.5	10.6
42	9.8	9.2
43	10.3	8.3
44	8.4	8.5
45	10	10.1
46	10	10.9
47	9.7	9.9
48	10.4	11.1
49	8	8.4
50	9.1	10

Length of the right kidney:

From the above observations, it was evident that the maximum length of the right kidney was 11.4 cm and recorded in specimen 7 (Fig -14 a). The minimum length was 7.0cm has been recorded in specimen 5 (Fig -14 b).

In the present study, the length of the right kidney varies from 7.0 cm to 11.4cm.

Length of the left kidney:

The maximum length of the left kidney was 11.4 cm and recorded in specimen 7 (Fig -15 a). The minimum length was 7.1cm in specimen 12 (Fig -15 b). In the present study, the length of the left kidney varies from 7.1 cm to 11.4cm.

2. **Breadth of the kidney:**

The breadth of the kidneys were measured on right and left sides and the values were tabulated.

Table 2. Breadth of the kidney

Specimen no	Right side kidney (cm)	Left side kidney (cm)
1	5.1	5.7
2	5.5	5.4
3	5.2	5.1
4	5.1	5.4
5	4	5
6	4.3	5
7	6.3	6.3
8	5.1	5.4
9	5.9	5.8
10	4.4	4.3
11	5.2	4.6
12	4.4	4.3
13	5.3	4.4
14	5.8	5.9
15	5.0	5.4
16	5.5	5.6
17	4.4	4.7
18	5.6	5.5
19	5.5	5.6
20	4.4	4.7
21	5.0	4.8
22	5.5	6.1
23	5.1	5.6
24	5.3	4.8
25	5.4	5.4

Table 2. Breadth of the kidney

Specimen no	Right side kidney (cm)	Left side kidney (cm)
26	5.8	6.1
27	5	5
28	5.6	5.6
29	4.9	4.8
30	4.2	4.3
31	4.7	4.8
32	4.3	4.9
33	4.9	4.8
34	5.4	5.1
35	5.8	6.2
36	4.2	4.8
37	5.6	5.4
38	5.8	5.4
39	5.1	5.5
40	5.2	5
41	5.6	5.4
42	4.1	4.7
43	5.3	5.1
44	5.1	4.9
45	5.4	5.4
46	4.7	5.2
47	4.2	4.2
48	4.1	3.6
49	4.5	5
50	4.5	5.7

Breadth of the right kidney:

From the above table, Specimen 7 (Fig -16 a)of right side showed the maximum breadth of the kidney that was 6.3 cm. Specimen 5 (Fig -16 b) showed the minimum breadth of 4cm on right side. In the present study, the breadth of the right kidney was ranges from 4cm to 6.3 cm.

Breadth of the left kidney:

Specimen 7 (Fig -17 a) of left side found to have the maximum breadth that was 6.3cm. Specimen 47 (Fig -17 b)showed the minimum breadth of 4.2cm. In the present study, the breadth of the right kidney was ranges from 4.2 cm to 6.3 cm.

3. **Thickness of the kidney:**

Thickness of the kidney was measured on both kidneys and the obtained values are tabulated.

Table 3. Thickness of the kidney

Specimen no	Right side kidney (cm)	Left side kidney (cm)
1	3.2	3
2	2.3	2.3
3	4.7	4.9
4	3.5	3.7
5	3.7	3.8
6	4.5	4.2
7	4.9	5
8	2.3	3.2
9	2.4	2.5
10	3	3.6
11	3.9	3.7
12	2.9	2.7
13	2.9	3.5
14	2.4	3.0
15	3.8	4
16	4.1	4.2
17	3.9	3
18	4.7	4.6
19	2.9	2.7
20	3.3	3.3
21	3.6	3.2
22	3.6	3.4
23	2.5	2.8
24	2.5	2.9
25	2.1	2.6

Table 3. Thickness of the kidney

Specimen no	Right side kidney (cm)	Left side kidney (cm)
26	3	3.8
27	3.1	3.6
28	3.9	4.3
29	2.3	2.6
30	2.8	3
31	3.2	2.7
32	2.9	2.8
33	2.5	2.4
34	3.7	3.5
35	2.6	2.6
36	2.8	3.4
37	2.4	2.4
38	3.8	3.6
39	2.5	2.6
40	3	2.9
41	2.9	2.6
42	3.2	3.2
43	4.1	3.6
44	3.6	3.5
45	4.1	3.3
46	2.8	3
47	3.6	2.6
48	3.6	3.6
49	2.5	2.5
50	3.7	2.6

Thickness of the right kidney:

From the above recorded values, the maximum thickness of right kidney was 4.9cm in specimen 7 (Fig -18 a).The minimum thickness of right kidney was2.1cm in specimen 25 (Fig -18 b). In the present study the thickness of the right kidney ranges from 2.1cm to 4.9 cm.

Thickness of the left kidney:

The maximum thickness was 5.0cm in specimen 7(Fig -19 a). Specimen 2 (Fig -19 b) showed the minimum thickness of 2.3cm. In the present study the thickness of the left kidney ranges from 2.3cm to 5.0 cm.

4.Arrangement of hilar structures:

Arrangement of structures entering or leaving the hilum of kidney (Renal artery, Renal vein and Renal pelvis) were observed.

Table 4. Arrangement of hilar structures

Arrangement of Structures at the Hilum	Number of Specimens	
Pattern	Right Side	Left Side
I	19	15
II	5	15
III	10	8
IV	9	7
V	7	5

The arrangement of renal artery, renal vein and the pelvis, antero-posteriorly exhibited great variation in their relation at the hilum. Maximum number of specimens found to be of Pattern I (Fig -20) which is the normal arrangement. The variant patterns were II, III, IV and V (Fig -21, 22, 23 & 24).

4. Variations of the kidney:

The following variations were noticed, recorded and tabulated.

a. Persistence of Foetal lobulations:

Table 5. Persistence of Foetal lobulations

specimen no	Right side	Left side
2	+	+
6	+	-
14	+	-
18	+	+
22	+	-
25	-	+
28	+	-
30	+	+
32	+	+
35	+	+
36	-	+
42	+	+
47	-	+

Of the one hundred specimens studied, Persistence of foetal lobulations (Fig -25) was observed only in 19 specimens. Out of these 19 specimens, 10 specimens on the right side and 9 specimens on the left side were observed.

b. Renal cyst:

Table 6. Presence of renal cyst

Specimen no	Presence of Renal Cyst	
	Right Side	Left Side
6	+	+
19	+	+
21	+	+
29	-	+
45	+	+
47	+	+

According to the present study, specimen 6, 19,21,29,45 and 47 (Fig -26) were observed. Presence of cyst on right and left side were noticed and recorded. All the above specimens showed the presence of multiple cysts.

c. Extra renal pelvis/ calyces:

Table 7. Extra renal pelvis

Specimen no	Extra renal pelvis	
	Right side	Left side
1	+	+
13	-	+
21	-	+
23	+	-
40	+	+

Extra renal pelvis:

Extra renal pelvis was found in 7 specimens (Fig -27a, 27b, 27c, 27 d, 27 e, 27 f). 3 specimens on right side and 4 specimens on left side found to have extra renal pelvis.

Extra renal calyces:

Table 8. Extra renal calyces

Specimen no	Extra renal calyces	
	Right side	Left side
1	+	+
21	-	+

Extra renal calyces were found in 3 specimens (Fig - 28), 1 specimen on right side and 2 specimens on left side.

d. Horseshoe kidney and Single kidney:

In the present study, Horseshoe kidney and Single kidney were not found.

RESULTS

Table 9. Length of the kidney

Length	Right side (50 specimens)	Left side (50 specimens)	Total (100 specimens)
Maximum	11.4cm	11.4cm	11.4cm
Minimum	7.0cm	7.1cm	7.0cm
Average	9.4cm	9.5cm	9.46cm

Table 9, illustrated the maximum and minimum length of the 100 specimens of kidney study with a average length of 9.46cm irrespective of the sides.

Table 10. Breadth of the kidney

Breadth	Right side (50 specimens)	Left side (50 specimens)	Total (100 specimens)
Maximum	6.3cm	6.3cm	6.3cm
Minimum	4.0cm	4.2cm	4.0cm
Average	5.0cm	5.1cm	5.09cm

Table 10, illustrated the maximum and minimum breadth of the 100 specimens of kidney study with a average breadth of 5.09cm irrespective of the sides.

Table 11. Thickness of the kidney

Thickness	Right side(50 specimens)	Left side(50 specimens)	(100 specimens)
Maximum	4.9cm	5.0cm	5.0cm
Minimum	2.1cm	2.3cm	2.1cm
Average	3.2cm	3.3cm	3.26cm

Table 11, illustrated the maximum and minimum thickness of the 100 specimens of kidney study with a average thickness of 3.26cm irrespective of the sides.

Table 12. Arrangement of hilar structures

Pattern	Right side	Left side	Total	Percentage
I	19	15	34	34%
II	5	15	20	20%
III	10	8	18	18%
IV	9	7	16	16%
V	7	5	12	12%

Table 12, illustrated the normal and variation with regards to the structures that enter and leave the hilum.

- The normal arrangement of renal hilar structures was represented in pattern I.
- The variant arrangement of hilar structures was represented by pattern II, III, IV and V.

From the above (Table 12) table, it was found that most commonly observed pattern was pattern I (34%). The most common variant pattern observed was pattern II (20%). Least common variant pattern was found to be pattern V (12%).

Table 13. Variations of the kidney

Variations	Right side (50 specimens)	Left side (50 specimens)	Total (100 specimens)	Percentage
Persistence of foetal lobulations	10	9	19	19%
Renal cyst	5	6	11	11%
Extrarenal pelvis	3	4	7	7%
Extrarenal calyces	1	2	3	3%

Tables 13, (Diag -1) illustrated the different variations of the kidney observed in the present study.

The most common variation was found to be the Persistence of foetal lobulations in 19% of the specimens. The least common variation observed was Extrarenal calyces in 3% of the specimen.

DISCUSSION

Morphology of the kidney though appears to be simple, it is very significant to understand the fundamental structure of the kidney as it performs vital and complex functions.

Normal values of the morphology will help to rule out any pathological changes in the organ. Regardless of the etiology of kidney disease, the normal morphology of kidney would be of great importance in assessing the progression of renal diseases.

In the present study, size of kidney was analysed by means of length, width and thickness. These measurements are simple, consistent measurement and also reproducible. Data's were obtained for both left and right kidney

Size of the Kidney:

A normal kidney is the size of human fist or bigger than that. The renal parameters are subjected to variations which are influenced by body mass index, sex and age and also side of the kidney which it belongs. Any alteration in the dimensions can alter the kidney mass and affect the functional ability.

Unilateral kidney diseases are monitored by

- Comparing with the other side kidney which may be increased in size for compensation.
- Assessing the discrimination between upper and lower urinary tract infections.

Renal infections or inflammations, nephrologic disorders, diabetes mellitus and hypertension are the most important co-morbid conditions affecting renal size. A change in kidney size from one examination to the next may be an important indication of the presence or progression of disease.

Renal length and size also are important clinical parameters in the assessment and follow-up of patients with kidney transplant recipients, patients with hypertension and renal artery stenosis.

Comparison of kidney length on both sides:

Table 14. Comparison of kidney length on both sides

	Right > Left	Left > Right	Left= Right
Number of Specimens	14	30	6
Percentage	28%	60%	12%

In the present study (Table -14, Diag -2), 12% of the specimens showed equal length on both sides. In 60% of the specimens, length of the kidney on left side was more than the right side. In 25% of the specimens, right side of the kidney comparatively longer than the left side. From the above, the present study concluded that left kidney was longer than the right in 60% of the specimens.

According to Shani D et al at (2001)[35] Chandigarh, India, differences in measurements of both right and left kidneys were analysed and found that the left side measurements are significantly greater than the right side.

The same fact was emphasized by a sonographic study of kidney dimensions by Barton EN et al (2000)[5], in Jamaican population the mean length of Right Kidney was 9.7 +/- 0.7 cm and the Left kidney was 10 +/- 0.7 cm. Thus the present study correlates with the above studies.

A study conducted by Vlajkovic S et al (2010)[43], was concluded that the diseases in the kidney associated with their changes in size.

Normal morphological value of kidney length is helpful to analyse the pathological changes in the visceras. Association of kidney size with respect to nephron can be assessed. Lower values of the length may indicate the loss of nephrons in many diseases such as Diabetic Nephropathy, Hypertension and Ischemic Renal disease.

Measurement of the kidney is a fundamental importance as it facilitates the diagnosis of kidney diseases.

1. Large Kidney may denote Bilateral polycystic kidney disease, Amyloidosis and early stage of Diabetes.
2. Asymmetric Kidneys may suggest Urinary obstruction or Ischaemic renal disease.
3. Small Kidney may suggest Systemic sclerosis and Chronic glomerulo nephritis.

Variation in size could be attributed to the following:

- Adult polycystic kidney:

It is a relatively common autosomal dominant condition affecting roughly 1in every 1000 persons. The kidneys may be bilaterally enlarged

(large multi cystic kidney). External surface may found to be composed of mass of cyst up to 3 to 4 cm in diameter. The Cyst may be filled with clear serous fluid or turbid or red to brown sometimes hemorrhagic fluid. The cyst may encroach upon the pelvis of the ureter to produce pressure effects.

- Amyloidosis:

It is an Immune Disorder due to deposition of amyloid in various tissues and organs. On gross inspection the kidney may appear enlarged in size and colour or it may be pale grey, waxy and firm. In advance cases it may be shrunken and contracted due to deposition of amyloid within the vessels.

- Diabetic Nephropathy:

The kidneys are most severely damaged organs in Diabetes mellitus, renal failure accounts for more death in Juvenile and adults. As the kidneys suffer from ischemia, it undergoes overall contractions in size at later stages.

- Hypertension:

Depending on the duration and severity of the disease, the size of the kidney may vary. In Benign Hypertension the kidneys may be normal in

size. In Malignant Hypertension, due to rupture of arterioles gives a small pinpoint petechial hemorrhages named flea beaten appearance

- Urinary Obstruction :

If the urinary obstruction is sudden and complete, change in size may be significant. But when the obstruction is subtotal or intermittent progressive dilatation may occurs. Depending upon the level of urinary block, the dilatation may affect the bladder, ureter and then the kidneys.

- Ischemic Kidney:

It is usually reduced in size due to diffused ischemic atrophy, but they are usually protected from the effects of high blood pressure, in contrast to the contralateral non ischemic kidney which is more affected depending on the severity of the hypertension.

- Chronic glomerulo nephritis:

Kidneys are symmetrically contracted and reduced in size in chronic glomerulo nephritis. It is an end stage of all kidney diseases. In the present study, significantly symmetrically contracted kidneys were not found.

- Systemic sclerosis:

It is due to collagen deposition, two - third of patients of sclerosis will have renal abnormalities with reduce in size, 50% death in sclerosis due to renal failure.

1. **Length of the Kidney:**

In the present study, the average length of the kidney was found to be 9.46 cm in hundred kidney specimens.

Average length of the right kidney was 9.4cm.

Average length of the left kidney was 9.5cm.

Mazzotta et al. (2002)[24] found that length of the kidney is the essential parameter while calculating the kidney size. So it is important to form a pattern of renal parameters for specific diagnosis.

Mullick MH (1970)[25] absorbed, normal length of the kidney was 9.9cms. According to the present study, left kidney was longer than the right kidney which correlated with Sampaio F J et al(1989)[33], Barton EN et al (1982)[5], Gebrehiwot M et al (1998)[13], Niels – Peter – Buchholz et al (2000)[27] studies.

2. Breadth of the kidney:

In the present study, the average breadth of the kidney was found to be 5.09 cm in hundred specimens.

The average breadth of the right kidney was 5.0 cm.

The average breadth of the left kidney was 5.1cm.

Ray B et al (2004)[31] stated that the breadth of the right kidney was 5.0cm and the left was 5.3cm. Sampaio F J, Mandarim-de-Lacerda CA (1989)[33] concluded as left kidney was broader than the right kidney and this correlated with the present study.

3. Thickness of the kidney:

In the present study, the average thickness of the kidney was 3.26cm in hundred specimens.

The average thickness of the right kidney was 3.2cm.

The average thickness of the left kidney was 3.3cm.

Mullick MH (1970)[25] reported the average thickness of kidney was 3.7cm and also Sampaio F J, Mandarim-de-Lacerda CA (1989)[33] concluded that the Thickness of the right kidney was 3.21cms and the left kidney was 3.37 cm. The present study correlates with the above mentioned studies.

From the above parameters it was found that the average length breadth and thickness of the left kidney was more than that of the right kidney. Hence, the present study concluded as left kidney was larger than the right kidney.

4. Renal hilar structures:

There are a number of studies done on the anatomical analysis of renal hilar structures. Such studies usually focused on the accessory arteries,

rare anatomical variations and the distribution of the renal veins. The present study aims to describe about the anatomical relationship of the main renal hilar structures, consisting of the renal artery, renal vein and pelvis in the antero-posterior direction**.**

According to Grays (Standring et al., 2005)[38], the normal arrangement of hilar structures were Renal Vein, Renal Artery and Pelvis of the Ureter. In the present study, the variant arrangement of hilar structures was noted.

Considering the position of variant arrangements of hilar structures, past studies have prohibited anterior incisions at the ureteropelvic junction and also the postero and posterolateral aspect (Sampaio and Favorito, 1993)[34].They have advised a deep lateral incision along the ureteropelvic junction (Sampaio and Favorito, 1993)[34]. Such incisions may be useful during endopyelotomies and may reduce the cost incurred during preoperative imaging.

According to Trivedi et al (2011)[42], dissection of Renal Hilar structures was carried out to observe the antero posterior relationship of structures at the hilum of kidney in hundred specimens. It was concluded that 73% arrangement was not according to normal description (Renal vein, Renal artery, Pelvis of the ureter). In 31% anterior division of renal artery

was seen in the front of renal vein at the hilum. In 50% cases the pelvis was not the posterior most relation.

In the present study most commonly observed pattern was pattern I (Renal vein - Renal artery – Pelvis of the ureter)

Table 15. Comparison of Pattern of Hilar structure arrangements

Pattern	Trivedi et al (2011)		Present Study	
	Right	Left	Right	Left
I	19	8	19	15
II	6	17	5	15
III	12	10	10	8
IV	11	9	9	7
V	3	5	7	5

Table 15 (Diag.3, 4) illustrated the comparison of the hilar structures arrangement pattern between the Trivedi et al (2011)[42] study and the present study.

It was observed that the most common hilar structures arrangement was pattern I which was found to be same on the right side in both the studies and more on the left side in the present study.

The least common pattern of hilar structures arrangement was pattern IV which was of similar incidence of the left side in both the studies and comparatively more on the right side in the present study.

Table 16. Comparison of Patterns of hilar structure arrangements

Pattern	Trivedi et al (2011)	Present Study
I	27%	34%
II	23%	20%
III	22%	18%
IV	20%	16%
V	8%	12%

The Diag.5 illustrated that 34% of the specimens showed the pattern I arrangement that was the most commonly observed pattern. 12% of the specimens were found be of pattern V that was the least pattern.

Normal hilar arrangements of the kidney:

- The normal arrangement of structures at the hilum of the kidney, antero-poteriorly as described in standard anatomical text was renal vein, renal artery and renal pelvis.
- In the present study, the normal arrragements of hilar structures (pattern I) were present in 34% of specimens. 19 specimens on right side,15 specimens on left side of kidney
- Trivedi et al (2011) [42] the normal arrragements of hilar structures were present in 27% of specimens. 19 specimens on right side,8 specimens on left side of kidney
- Normal hilar arrangements were present more on right side of kidney. This correlates with the study done by Trivedi et al at (2011) [42].
- The knowledge of renal hilar structures was useful in case of renal transplantation and renal surgeries.

From the above, it was concluded that the normal morphology of kidney regarding the hilar arrangements was observed only in 34% (Renal Vein – Renal Artery – Renal Pelvis) and 66% showed the variant hilar structure arrangements.

Trivedi et al (2011) [42] concluded that three - fourth of the specimens, arrangements of hilar structures was not confirmed to normal arrangements.

Variant hilar arrangements of the kidney:

- 4 types of variant hilar patterns were studied and described as pattern II, III, IV, V.
- In the present study showed the variant arrangement of hilar structures were present in 66% of specimens.
- Trivedi et al (2011) [42] stated that the variant hilar patterns were present in 73%.
- Past studies have prohibited the anterior incisions at the uretero pelvic junction (Sampaio and Favorito, 1993)[34] during endopyelotomies because of the position of variant arrangements of hilar structures

In the present study as shown in Diag.4 analysed that more variant patterns were seen on the left side. The variant patterns on the left side were found to be in 35% specimens and on the right sided was 31% specimens. Trivedi et al (2011) [42] concluded that 41% and 32% specimens on left and right side respectively. Thus variant forms were more commonly seen on the left side. This could be explained that embryologically left renal vein is composite structure derived from multiple anastomotic channels, whereas, the right renal vein is derived from a single anastomotic channel.

Most anteriorly placed structure at the Renal Hilum:

According to Grays (Standring et al., 2005)[38] at the renal hilum, the most anteriorly placed structure was renal vein.

- In the present study, 32 specimens showed the renal artery was the most anteriorly placed structure.
- Trivedi et al (2011) [42] observed in their studies, 31 specimens showed that renal vein was not the anterior most structure.
- From the above, the present study correlates with the Trivedi et al (2011) study.
- It could be kept in mind during enbloc clamping of hilar structures in cases of renal transplantation surgeries.

Trivedi et al (2011)[42] concluded that one - third of specimens showed anterior division of Renal Artery was most anteriorly placed structure at the Renal Hilum.

In the present study 32% of specimens, Anterior division of Renal Artery was the most anteriorly placed structure. Such variant will cause technically challenging to the surgeons as in such cases enbloc clamping may result in arterio venous fistula as a late complication of nephrectomy (Gill et al 2005)[14],(Rogers et al, 2008)[32].

Retro pelvic structures at hilum of the kidney:

- The posterior division of renal artery and posterior tributary of renal vein may present posterior to renal Pelvis.
- In the present study, 26% on right side and20% on left side specimens were showed the presence of retropelvic structures.
- According to Trivedi et al (2011) [42] the retropelvic structures were found in 26% on right side and 24% on left side.
- The present study correlated with the above study.
- This study could be very useful for the urological surgeons.

In the present study 46% of specimens were observed to have retroplevic structures at hilum. Knowledge of retroplevic structures will be kept in mind to prevent injury to the vessels during surgical procedures.

According to Trivedi et al (2011)[42] about 50% of the specimens were observed as retropelvic structures.

In conclusion,

- 66% of the specimens the arrangement of hilar structures are not confirmed to the normal descriptions (Renal Vein – Renal Artery – Pelvis of the Ureter).
- Variant patterns were more commonly on left side (35% on the left side, 31% on the right side).

- In 32% of specimens, anterior division of the Renal artery was the most anteriorly placed structure at renal hilum.
- In 46% of the specimens, retro pelvic structures were observed at the hilum.

To summarize, the surgical anatomy of the kidney is very much useful for all conventional surgical procedures on kidney. Advanced development in the field of laproscopic nephrectomy and pylolithotomy procedures, the knowledge of anatomy renal hilar structures arrangement is inevitable to the surgeons and to the radiologist who interpret renal angiograms.

5. Variations of the kidney:

a. Persistence of foetal lobulations:

Foetal lobulation is a comman finding and is a normal variant of the kidney. In the present study, Persistence of foetal lobulations was present in 19% of the kidneys (Fig- 25).

10% foetal lobulations found on right side, 9% foetal lobulations were found on left side.

According to Bergman RA et al (2000)[6], the characteristic foetal lobulations may persist in 7% of the adult. In addition, Harrison LH Jr et

al (1978)[16] also stated that 4% of kidneys showed the Persistence of foetal lobulations.

A study conducted by Isakovic E et al (2001)[18], concluded that foetal lobularness were present in 27.27% on right side, 33.3% on left side.

Thus the foetal lobulations were common on left side compare to right side.

In the present study persistence of foetal lobulations were found to be more on right side.

b. Renal cyst:

Simple cyst may occur multiple or single in normal sized kidneys. These are common post mortem findings without any clinical significance.

Renal cyst can manifest as either simple are polycystic. Polycystic kidney disease is the condition were the cysts are multiple with the size of the kidney also enlarged, where as cyst present in normal sized kidneys are known as simple renal cyst. In the present study cyst was present in normal sized kidneys. The presence of cyst and length was correlated and tabulated in Table 17.

Table 17. Correlation between the Renal cyst and length of the kidney

Specimen No	Side	Presence of cyst	Length of the kidney (cm)
6	Right	+	8.7
	Left	+	8.2
19	Right	+	10
	Left	+	9.9
21	Left	+	9.5
29	Right	+	9.9
	Left	+	9.9
45	Right	+	10
	Left	+	10.1
47	Right	+	9.7
	Left	+	9.9

From the above table (table 17), simple renal cysts were found unilaterally in 1 specimen but bilaterally found in 5 specimens. All specimens showed the presence of multiple cyst which could be explained by the fact that cyst increases in number as age progresses.

In the present study, length of the kidney ranges between 7cm and 11.4 cm. Thus the length of the kidney presenting with cyst falls within the normal range and hence the cysts were simple renal cyst.

From the present study 11% of the specimens showed the presence of simple renal cysts (Fig- 26).

Chang-Chi Chang et al (2007)[9] investigated about simple renal cysts to understand the prevalence and evaluate their clinical characteristics in 577 individuals. They analysed with the help of abdominal sonography. They found out the prevalence of simple renal cysts were 10.7%.

Terada et al (2002)[41] stated that the prevalence of simple renal cysts were 11.9 % and Carrim et al (2003)[8] concluded as 41.0%.

This present study, the percentage of simple renal cyst was correlates with Chang-Chi Chang (2007)[9] studies.

c. Extrarenal pelvis/ Extra renal calyces:

Size and shape of the renal pelvis is markedly influenced by the renal calyces. Thus renal pelvis may lie almost entirely within the renal sinus as an intrarenal pelvis or its main portion may be a dilated sac and lie outside the kidney proper, extrarenal pelvis

Variations in major calyces and renal pelvis are more marked. The major calyces pass downwards for some distance beyond the hilum and end to form the ureter without undergoing any expansion which is pelvis is absent. If the calyces dilate one or two pelvis may be present.

Significance of extrarenal pelvis/calyces:

The exact cause of the extrarenal pelvis/calyces was not known.

Suresh Rao et al (2012)[39] mentioned the presence of extra renal calyces were associated with presence of accessory renal arteries and it was found that accessory renal artery lie anterior to renal vein, so while performing pyelostomy care should be taken, not to injure the branches of renal vessels.

Table 18. Variations – Extrarenal pelvis/Extrarenal calyces.

Side	No of Extrarenal pelvis	No of Extrarenal calyces
Right	3	1
Left	4	2
Both side	2	1

In the present study, 7% of the specimens showed the presence of extra renal pelvis (Fig – 27) and 3% specimens showed the presence of extra renal calyces (Fig – 28).

Garg P et al (2003)[12] reported a case of extra renal calyces to create an awareness of this rare entity can prevent inadvertent injury to the pelvicalyceal system during surgery.

Suresh Rao et al (2012)[39] reported that extra renal calyces usually associated with other manifestations like bifid ureter, renalectopia, horseshoe kidney and renal dysplasia. These anomalies do not affect the normal function of the kidney.

Difference in Renal Parameters and Ethinicity:

Morphological study of kidney conducted in different population does not have an accurate reference value, because the standard data of one population cannot be compared with another population.

Many factors have to be taken in to consideration while standardizing the normal values. However, values obtained cannot be used for all group of population universally. The values may differ in different ethinicities.

Usually, the dimensions of kidney are compared with the standard data, which are used widely, are derived from studies based on western population. The Present study is based on findings in south Indian population group.

Adeela Arooj (2011)[1] developed a specific ethnic based nomogram for Malaysian population to provide a better accuracy of renal measurements. D. Shani et al (2001)[35] observed that the size of Indian population is

relatively similar to Malaysian. K.Y.Kang et al (2007)[21,] studied in Korean population having a larger renal size than Asians.

Studies done by Niels – Peter – Buchholz et al (2000)[27] and Mario et al (2002)[23] in Pakistani population showed the following:

- Highlighted the necessity of investigating renal dimensions for each population and
- The Western population data cannot be used as standard nomogram because these persons are taller and bigger than the other ethnics such as Asians, as the organ size is closely related to the body size.

Adeela Arooj (2012)[1] had stated that diversities in values in different population would be due to their genetic background and environmental conditions.

Table 19. Comparison of renal size among different ethinics.

Authors	Ethinicity	Side	Length(cm)	Breadth(cm)	Thickness(cm)
D.Shani et al (2001)	Northwest Indian	Left	10	4.6	3.4
		Right	9.9	4.6	3.3
Taraka et al (1988)	Japanese	Left	11.5	5.7	3.5
		Right	11.3	5.5	3.2
K Y Kang et al (2007)	Korean	Left	11.1	6.2	4.73
		Right	11.1	6.2	4.73
Mc Minn et al (1994)	Caucasians	Left	12	6	3
		Right	12	6	3
Adeela Arooj et al (2011)	Malaysian	Left	9.9	4.4	4.3
		Right	9.7	3.8	3.8
Ray B et al (2004)	Napalese	Left	9.1	5.3	3.8
		Right	8.5	5.0	3.4
The present study	South Indian	Left	9.5	5.1	3.3
		Right	9.4	5.0	3.2

In the present study that is in the south Indian population, the length and breadth of the kidney which were comparatively smaller than that observed by McMinn in Caucasians .Thickness of kidney was observed in Korean which was much higher than others.

In the present study that is in South Indian population, the morphology of the kidney with regards to the length, breadth and thickness were comparatively similar to Northwest Indians, Malaysian and Nepalese.

SUMMARY AND CONCLUSION

Hundred human kidneys were studied and analysed morphologically. The salient data's of the study were the following:

- The average length of the kidney was 9.46 cm.

The average length of the right kidney was 9.4cm. The average length of the left kidney was 9.5cm. Length of the kidney ranges from 7 cm to 11.4 cm.

- Average Breadth of the kidney was 5.09 cm.

The average breadth of the right and left kidney were 5.0 cm and 5.1cm respectively. The breadth of the kidney ranges from 4.0 cm to 6.3 cm.

- Average thickness of kidney was 3.26cm.

The average thickness of the right and left kidney were 3.2cm and 3.3cm respectively. The thickness of the kidney ranges from 2.1 cm to 5.0 cm.

- 66% of specimens were showed the variant hilar structure arrangements

- The most common pattern of hilar structures arrangement was pattern I being renal vein - renal artery - renal pelvis which was observed in 34% of specimens.

- 35% of variant pattern were noted on left side.
- In 32% of specimens, anterior division of the renal artery was the most anteriorly placed structure at renal hilum.
- 46% of the specimens, retro pelvic structures were observed at the hilum.
- 19% of specimens showed Persistence of Foetal lobulations.
- Simple Renal cysts were present in 11% of the specimens.
- 7% of specimens showed the Extrarenal pelvis and 3% of specimens showed the Extrarenal calyces.
- 37% specimens were found to have the variations of the kidney.

The knowledge of the average renal parameters, various patterns of hilar structures arrangement and the morphological variations will be of immense help to the nephrologists, surgeons and radiologists.

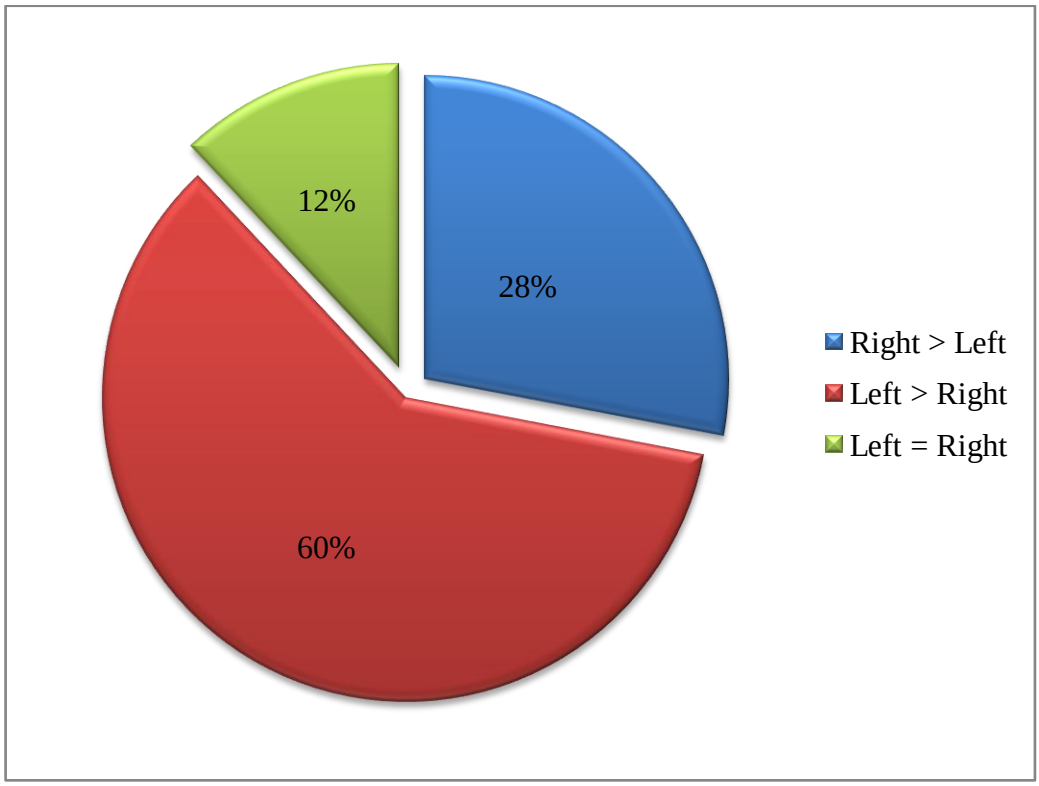
End stage renal diseases and chronic kidney failure are accounts for major cause of deaths. Various studies reveal that 1 in 10 adults suffer from kidney problems.

The morphology of kidney will be a valuable contribution to all medical personnel to identify the pathological changes. Emphasis on the

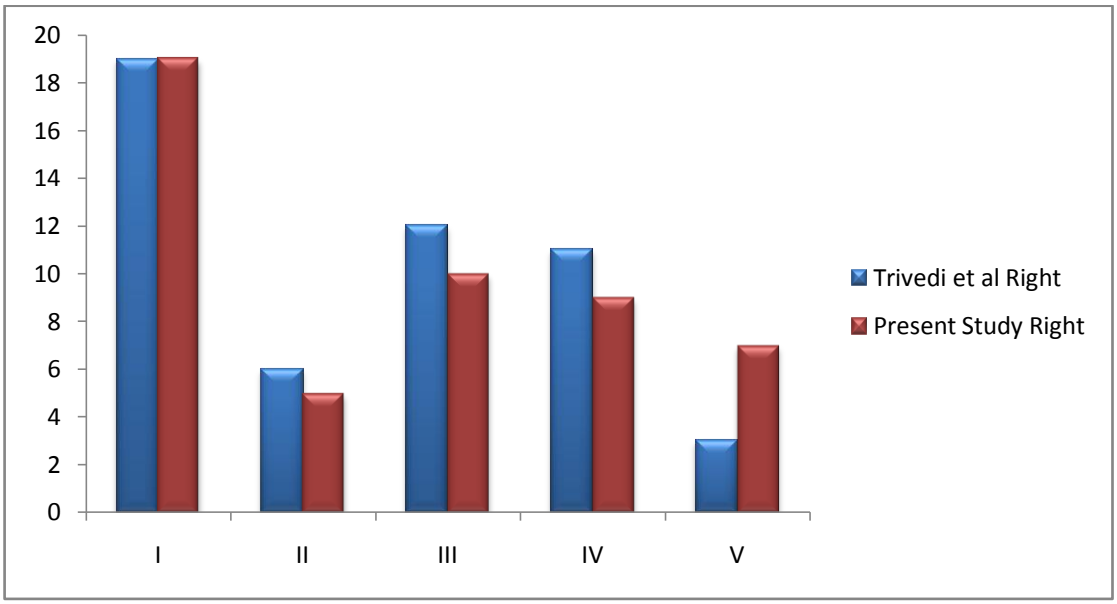
variations in the patterns of the hilar structures and the rare variations of the extra renal calyces are essential for the surgeons performing pyelostomy and renal transplantation.

Though Contrast radiography, Ultrasonography, Magnetic resonance imaging technique are advances in the investigatory methods to study the renal morphology in living. A cadaveric study is still a valuable method to study the morphology of kidney.

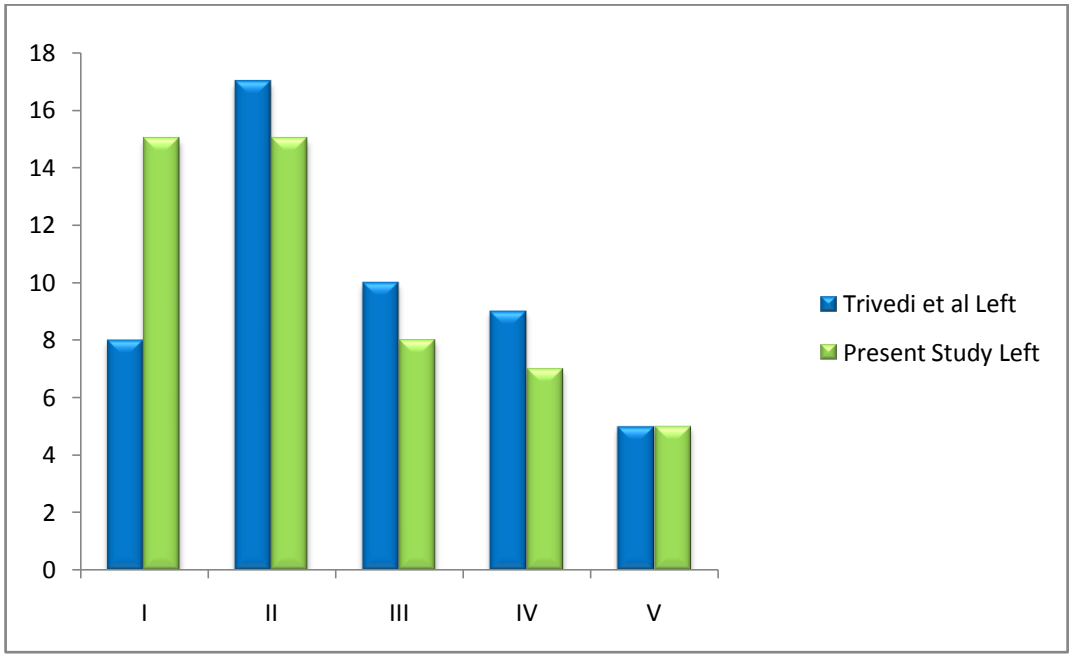
Diag. 2 Comparison of kidney length on both sides



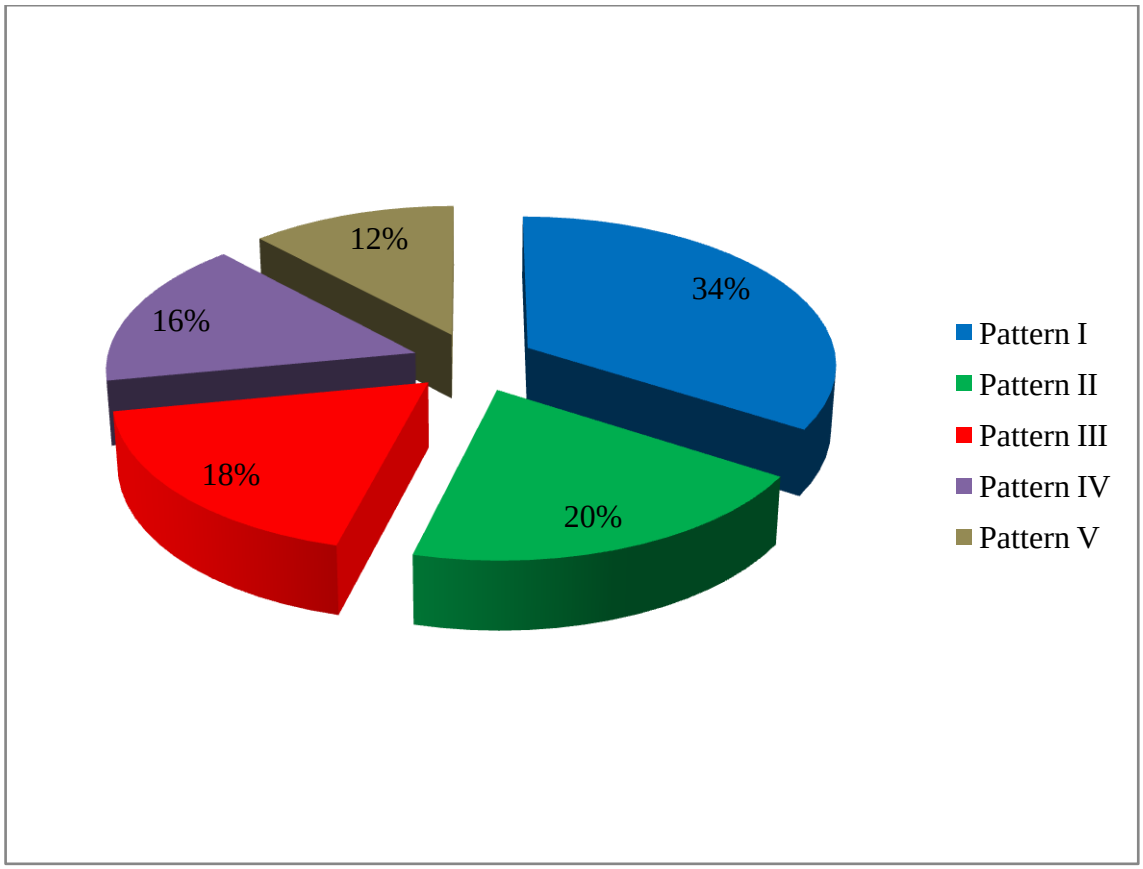
Diag.3 Comparison of Pattern of Hilar structure arrangements on Right side



Diag. 4 Comparison of Pattern of Hilar structure arrangements on Left side



Diag .5 Percentage of hilar structures arrangement



Diag. 1 Variations of the Kidney

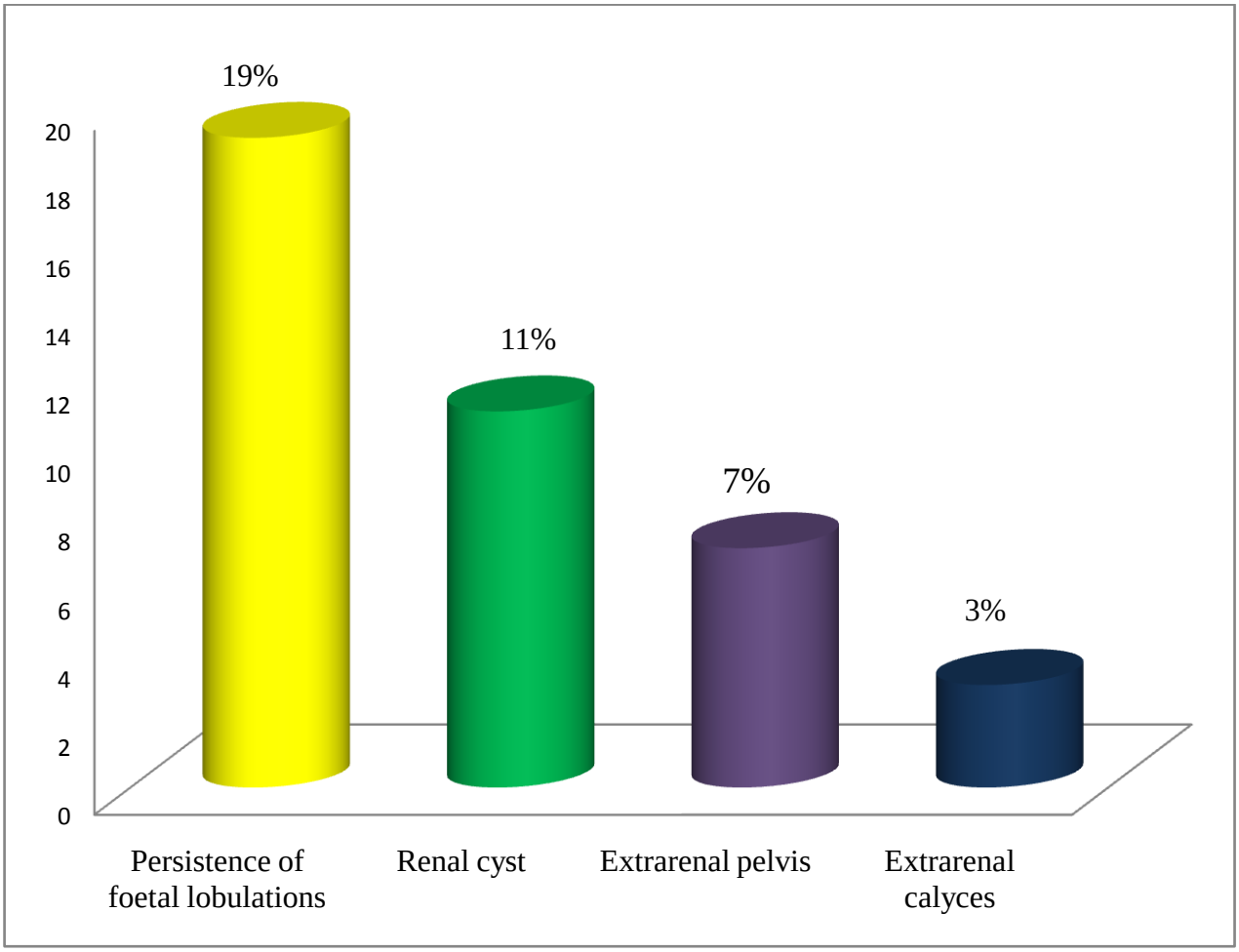


FIG -1: DIGITAL VERNIER CALIPER

FIG -2: THE HUNDERD SPECIMENS OF THE PRESENT STUDY

FIG – 3: MEASUREMENTS DONE BY VERNIER CALIPER

FIG -4: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – I (Renal Vein -- Renal Artery – Pelvis)

a.Anterior view

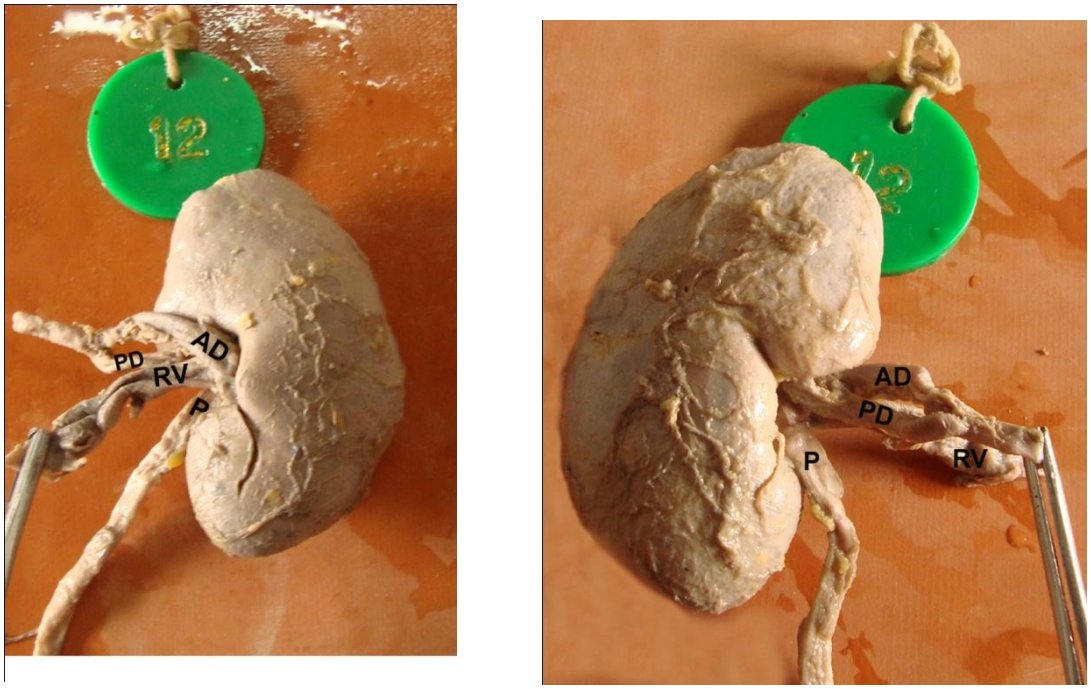
b.Posterior view

RRA – Right renal artery **LRA – Left renal artery**
RRV- Right renal vein **LRV – Left renal vein**
U - Ureter

FIG – 5: ARRANGEMENT OF HILAR STRUCTURES

PATTERN –I I (Anterior division of renal artery -- Renal vein -- Posterior division of renal artery – Pelvis)

a.Anterior view **b. Posterior view**



AD - Anterior division of renal artery

RV -Renal vein

PD - Posterior division of renal artery

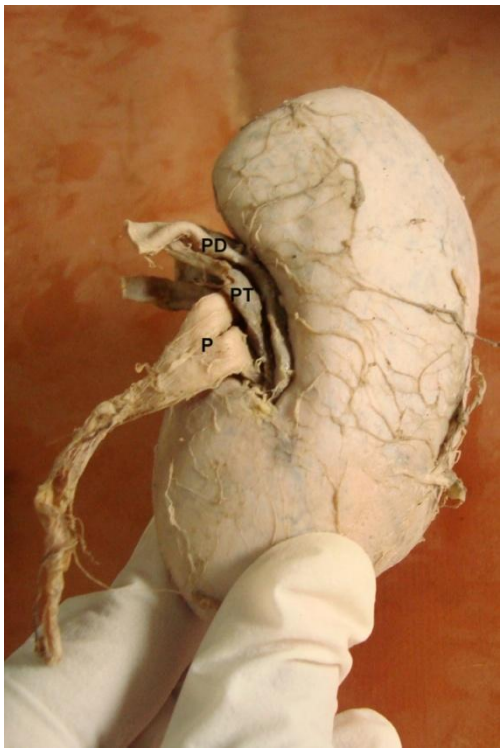
P - Pelvis

FIG – 6: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – III (Anterior tributary of renal vein -- Anterior division of renal artery -- Pelvis -- Posterior tributary of renal vein – Posterior division of renal artery)

a. **Anteriorview**

b. **Posterior view**



AT - Anterior tributary of renal vein

AD - Anterior division of renal artery

P - Pelvis

PT - Posterior tributary of renal vein

PD - Posterior division of renal artery

FIG - 7: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – IV (Renal vein -- Anterior division of renal artery -- Pelvis – Posterior division of renal artery)

a. Anterior view **b. Posterior view**

RA - Renal vein

AD - Anterior division of renal artery

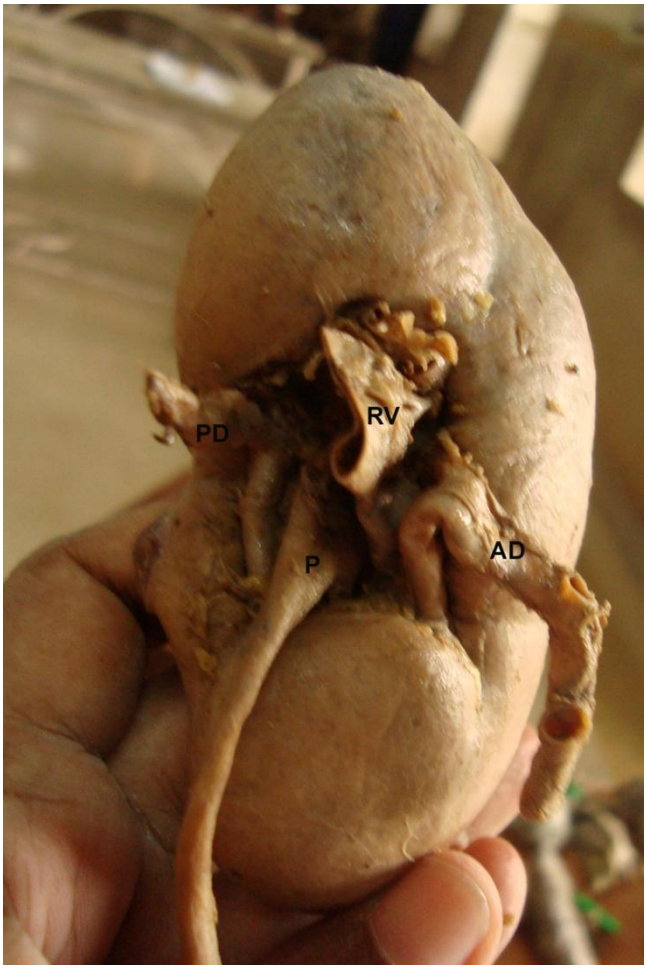
P - Pelvis

PD - Posterior division of renal artery

FIG - 8: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – V (Anterior division of renal artery -- Renal vein -- Pelvis – Posterior division of renal artery)

Medial view



AD - Anterior division of renal artery

RV - Renal vein

P - Pelvis

PD - Posterior division of renal artery

FIG – 9: PERSISTENCE OF FOETAL LOBULATIONS

FIG – 10: RENAL CYST

FIG – 11: EXTRARENAL PELVIS

FIG – 12: EXTRARENAL CALYCES

SMC – Superior major calyx P - Pelvis

IMC – Inferior major calyx

FIG - 13: KIDNEYS WITH HILAR STRUCTURES

FIG - 14: LENGTH OF THE RIGHT KIDNEY

14a. Maximum Length

14b. Minimum Length

FIG – 15: LENGTH OF THE LEFT KIDNEY

15a. Maximum Length

15b. Minimum Length

FIG - 16: BREADTH OF THE RIGHT KIDNEY

16a. Maximum Breadth

16b. Minimum Breadth

FIG – 17: BREADTH OF THE LEFT KIDNEY

17a. Maximum Breadth

17b. Minimum Breadth

FIG – 18: THICKNESS OF THE RIGHT KIDNEY

18a. Maximum Thickness

18b. Minimum Thickness

FIG – 19: THICKNESS OF THE LEFT KIDNEY

19a. Maximum Thickness

19b. Minimum Thickness

FIG – 20: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – I (Renal Vein -- Renal Artery – Pelvis)

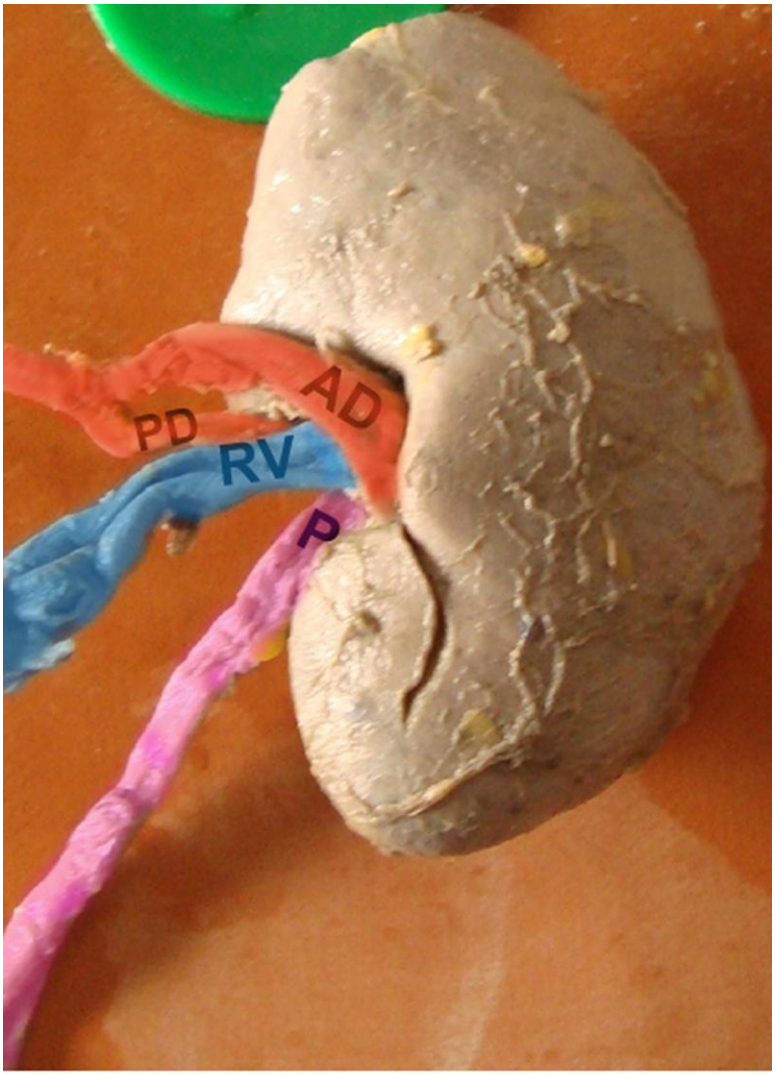
RV - Renal Vein

RA - Renal Artery

P - Pelvis

FIG - 21: ARRANGEMENT OF HILAR STRUCTURES

PATTERN –I I (Anterior division of renal artery -- Renal vein -- Posterior division of renal artery – Pelvis)



AD - Anterior division of renal artery

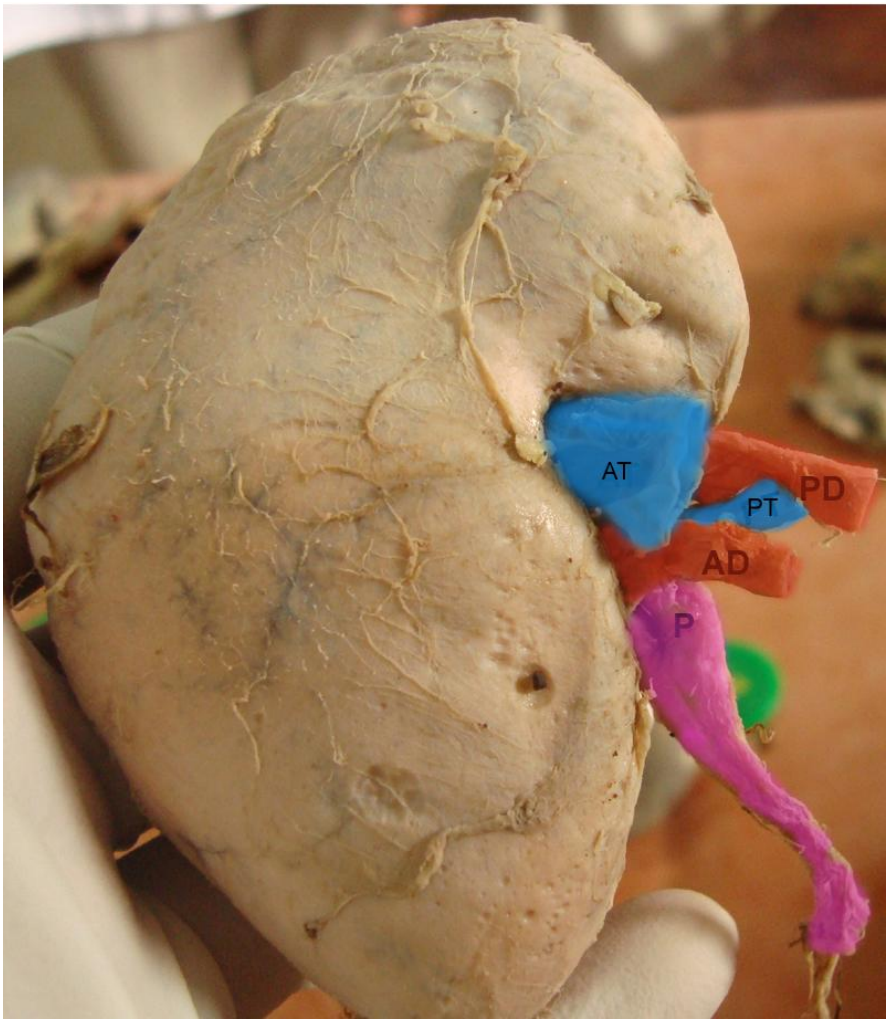
RV -Renal vein

PD - Posterior division of renal artery

P – Pelvis

FIG – 22: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – III (Anterior tributary of renal vein - Anterior division of renal artery - Pelvis - Posterior tributary of renal vein - Posterior division of renal artery)



AT - Anterior tributary of renal vein

AD - Anterior division of renal artery

P - Pelvis

PT - Posterior tributary of renal vein

PD - Posterior division of renal artery

FIG - 23: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – IV (Renal vein - Anterior division of renal artery - Pelvis - Posterior division of renal artery)

a. Anterior view **b. Posterior view**

RA - Renal vein

AD - Anterior division of renal artery

P - Pelvis

PD - Posterior division of renal artery

FIG – 24: ARRANGEMENT OF HILAR STRUCTURES

PATTERN – V (Anterior division of renal artery - Renal vein - Pelvis - Posterior division of renal artery)

Medial view

AD - Anterior division of renal artery

RV - Renal vein

P - Pelvis

PD - Posterior division of renal artery

FIG - 25: PERSISTENCE OF FOETAL LOBULATIONS

FIG - 26: RENAL CYST

FIG – 27: EXTRARENAL PELVIS

27a

27b

27c

FIG : 22 EXTRARENAL PELVIS

27d

27e

27f

FIG - 28: EXTRARENAL CALYCES

28a

28b

SMC – Superior major calyx

IMC – Inferior major calyx

P – Pelvis

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STUDY OF MORPHOLOGY OF KIDNEY IN HUNDRED SPECIMENS

Dissertation submitted in partial fulfillment of the requirement

for the award of

M.D. DEGREE EXAMINATION
(ANATOMY)

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MASTER CHART

Specimen No	Length (cm)	Length (cm)	Breadth (cm)	Breadth (cm)	Thickness (cm)	Thickness (cm)	Hilar Structures arrangement - Pattern		Variations of the Kidney							
									Foetal Lobulations		Renal Cyst		Extrarenal pelvis		Extrarenal calyces	
	Average = 9.4	Average = 9.5	Average = 5 .0	Average = 5.1	Average = 3.2	Average = 3.3										
	Right side	Left side	Right side	Left side	Right side	Left side	Right Side	Left Side	Right	Left	Right	Left	Right	Left	Right	Left
1	8.2	8.2	5.1	5.7	3.2	3	III	II	-	-	-	-	+	+	+	+
2	9.8	9.9	5.5	5.4	2.3	2.3	II	III	+	+	-	-	-	-	-	-
3	9.3	9.4	5.2	5.1	4.7	4.9	I	V	-	-	-	-	-	-	-	-
4	8.8	8.9	5.1	5.4	3.5	3.7	I	I	-	-	-	-	-	-	-	-
5	7	8.9	4	5	3.7	3.8	IV	IV	-	-	-	-	-	-	-	-
6	8.7	8.2	4.3	5	4.5	4.2	I	I	+	-	+	+	-	-	-	-
7	11.4	11.4	6.3	6.3	4.9	5	III	V	-	-	-	-	-	-	-	-
8	8.3	9.2	5.1	5.4	2.3	3.2	I	IV	-	-	-	-	-	-	-	-
9	10.1	10.5	5.9	5.8	2.4	2.5	III	II	-	-	-	-	-	-	-	-
10	10.9	11.3	4.4	4.3	3	3.6	I	I	-	-	-	-	-	-	-	-
11	7.5	9.5	5.2	4.6	3.9	3.7	V	V	-	-	-	-	-	-	-	-
12	9.7	7.1	4.4	4.3	2.9	2.7	I	II	-	-	-	-	-	-	-	-
13	9.2	10.1	5.3	4.4	2.9	3.5	IV	IV	-	-	-	-	-	+	-	-
14	9.7	10.1	5.8	5.9	2.4	2.3	III	II	+	-	-	-	-	-	-	-
15	9.6	9.3	5	5.4	3.8	4	III	III	-	-	-	-	-	-	-	-
16	8.6	10	5.5	5.6	4.1	4.2	I	I	-	-	-	-	-	-	-	-
17	9	9	4.4	4.7	3.9	3	I	I	-	-	-	-	-	-	-	-
18	9.7	9.4	5.6	5.5	4.7	4.6	V	I	+	+	-	-	-	-	-	-
19	10	9.9	5.5	5.6	2.9	2.7	II	II	-	-	+	+	-	-	-	-
20	8.7	9.1	4.4	4.7	3.3	3.3	V	III	-	-	-	-	-	-	-	-
21	9.7	9.5	5	4.8	3.6	3.2	IV	IV	-	-	+	+	-	+	-	+
22	10.3	9.4	5.5	6.1	3.6	4.6	III	III	+	-	-	-	-	-	-	-
23	10.5	10.5	5.1	5.6	2.5	2.8	II	II	-	-	-	-	+	-	-	-
24	9.9	10	5.3	4.8	2.5	2.9	I	I	-	-	-	-	-	-	-	-
25	8.9	9.1	5.4	5.4	2.1	3.6	III	II	-	+	-	-	-	-	-	-

Specimen No	Length (cm)	Length (cm)	Breadth (cm)	Breadth (cm)	Thickness (cm)	Thickness (cm)	Hilar Structures arrangement - Pattern		Variations of the Kidney							
									Foetal Lobulations		Renal Cyst		Extrarenal pelvis		Extrarenal calyces	
	Average = 9.4	Average = 9.5	Average = 5 .0	Average = 5.1	Average = 3.2	Average = 3.3										
	Right side	Left side	Right side	Left side	Right side	Left side	Right Side	Left Side	Right	Left	Right	Left	Right	Left	Right	Left
26	10.6	10.2	5.8	6.1	3	2.8	III	II	-	-	-	-	-	-	-	-
27	10.4	11.1	5	5	3.1	3.6	II	III	-	-	-	-	-	-	-	-
28	8.6	9.3	4.6	5.6	3.9	4.3	I	II	+	-	-	-	-	-	-	-
29	9.9	9.9	4.9	4.8	2.3	2.6	IV	II	-	-	-	+	-	-	-	-
30	8.4	8.4	4.2	4.3	2.8	3	III	III	+	+	-	-	-	-	-	-
31	8.4	8.6	4.7	4.8	3.2	2.7	I	II	-	-	-	-	-	-	-	-
32	8.7	8.6	4.3	4.9	2.9	2.8	v	II	+	+	-	-	-	-	-	-
33	9.8	9.9	4.9	4.8	2.5	2.4	I	I	-	-	-	-	-	-	-	-
34	8.5	8.7	5.4	5.1	3.7	3.5	I	I	-	-	-	-	-	-	-	-
35	10.1	10.3	5.8	6.2	2.6	2.6	II	II	+	+	-	-	-	-	-	-
36	8.4	8.4	4.2	4.8	2.8	2.4	I	IV	-	+	-	-	-	-	-	-
37	10.2	9.7	5.6	5.4	2.4	2.4	IV	IV	-	-	-	-	-	-	-	-
38	9.7	9.6	5.8	5.4	3.8	3.6	IV	I	-	-	-	-	-	-	-	-
39	9.5	9.6	5.6	5.5	2.5	2.6	III	III	-	-	-	-	-	-	-	-
40	9.3	9	5.2	5	3	2.9	V	IV	-	-	-	-	+	+	-	-
41	10.5	10.6	5.6	5.4	2.9	2.6	IV	II	-	-	-	-	-	-	-	-
42	9.8	9.2	4.1	4.7	3.2	3.2	V	II	+	+	-	-	-	-	-	-
43	10.3	8.3	5.3	5.1	4.1	3.6	I	I	-	-	-	-	-	-	-	-
44	8.4	8.5	5.1	4.9	3.6	3.5	IV	III	-	-	-	-	-	-	-	-
45	10	10.1	5.4	5.4	4.1	3.3	IV	V	-	-	+	+	-	-	-	-
46	10	10.9	4.7	5.2	2.8	4	I	I	-	-	-	-	-	-	-	-
47	9.7	9.9	4.2	4.2	3.6	4	V	V	-	+	+	+	-	-	-	-
48	10.4	11.1	4.1	3.6	3.6	3.6	I	I	-	-	-	-	-	-	-	-
49	8	8.4	4.5	5	2.5	2.5	I	I	-	-	-	-	-	-	-	-
50	9.1	10	4.5	5.7	3.7	2.6	I	I	-	-	-	-	-	-	-	-