INTRODUCTION

Percutaneous nephrolithotomy (PCNL) has become the choice of modality for treatment of large and complicated renal calculi (Cracco et al; 2010).

Prone position remains the standard method for positioning patients for PCNL and has several advantages including wide operation field, and a large room for instrument maneuvering (Miano et al; 2010).

However a major drawback to prone position is the poor tolerance by the patient. When operation time is long patient may experience difficulty in breathing; this is especially true in obese and old patients or in patients with poor health or compromised health function (Autorino et al; 2008).

To reduce these drawbacks several other methods for positioning of the patient have been developed for PCNL including supine, supine oblique, flank positions, and others have also been used with varying results (Manohar et al; 2007).

The supine position has many advantages: reduced cardio circulatory or ventilatory dysfunction, better tolerance when the operation is performed under local anesthesia, and less time needed because patients do not have to be turned after induction of general anesthesia and positioning of the ureteral catheter. Moreover, the surgeon can comfortably sit during the operation and X-ray exposure is reduced because puncture and dilatation of the nephrostomy tract are quite
perpendicular to the body and the operating hands are outside the fluoroscopic field (*Marco et al.*, 2008).

PCNL in the supine position has also certain disadvantages that make it a disputable alternative. The first problem with the supine position is that there is no enough space for a third tract if needed (*Zhou et al.*, 2008).

Also, access to the anterior and upper calyces is more difficult, as the angle between the plane of the operation table and the anterior calyces is smaller than that in other positions; it is difficult to access calculi in the anterior calyces (*Rana et al.*, 2008).

A new positioning called the flank suspended supine position (FSSP) is proposed to avoid most of the inherit draw backs of supine and prone position. First we raise the patient flank and align the body contour to the side of the table. These modifications provide bigger room for puncture and maneuver of the instruments. Second the jack knife position of the table can immopalize of the kidney and facilitate the puncture. Third the FSSP position can lower the affected kidney making most calices easily accessible. Fourth immopalization of the abdomen with a V shaped tapes places pressure on the abdomen resulting in shorter track and a less mobile kidney (*Pan Tie-Jun et al.*, 2015).
AIM OF THE WORK

The aim of the work is to compare the outcome of PCNL in flank suspended supine position, standard prone and standard supine position.
Anatomy of the kidney

Gross Anatomy:

Grossly, the kidneys are bilaterally paired reddish brown organs; typically each kidney weighs 150 gm. in the male and 135 gm. in the female. The kidneys generally measure 10 to 12 cm vertically, 5 to 7 cm transversely, and 3 cm in the anteroposterior dimensions. Because of compression by the liver, the right kidney tends to be somewhat shorter and wider (Anderson et al., 2007).

They are retroperitoneal structures located in the Para-vertebral gutters between the levels of the 12th thoracic vertebra and the second or third lumbar vertebrae (Fig.1). The superior poles are located more medially than the inferior poles, and both kidneys are angled 30 degrees posterior to the frontal plane of the body. The longitudinal axis of each kidney parallels the oblique course of the adjacent psoas major muscle and forms also 30 degrees with the median plane (Gupta et al., 2007).
(Fig. 1): Location of kidneys in the retro peritoneum (Gupta et al., 2007).

**Renal coverings:**

The kidney surface is enclosed in a continuous covering of fibrous tissue called the renal capsule (or “true renal capsule”). Each kidney within its capsule is surrounded by a mass of adipose tissue lying between the peritoneum and the posterior abdominal wall and called the perirenal fat. The perirenal fat is enclosed by the renal fascia (Gerota’s fascia). The renal fascia is enclosed anteriorly and posteriorly by another layer of adipose tissue, which varies in thickness, called the pararenal fat (Fig. 2&3) (Sampaio, 2000).
The renal fascia comprises a posterior layer (a well-defined and strong structure) and an anterior layer, which is a more delicate structure that tends to adhere to the peritoneum (Fig. 2 & 3). The anterior and posterior layers of the renal fascia (Gerota’s fascia) subdivide the retroperitoneal space in three potential compartments: (1) the posterior pararenal space, which contains only fat; (2) the intermediate perirenal space, which contains the suprarenal glands, kidneys and proximal ureters, together with the perirenal fat; (3) the anterior pararenal space, which unlike the posterior and intermediate spaces, extends across the midline from one side of the abdomen to the other. This space contains the ascending and descending colon, the duodenal loop and the pancreas (Sampaio, 2000).

Inferiorly, the layers of the renal fascia end weakly fused around
the ureter. Superiorly, the two layers of the renal fascia fuse above the suprarenal gland and fused with the infradiaphragmatic fascia. An additional fascial layer separates the suprarenal gland from the kidney. Laterally, the two layers of the renal fascia fuse behind the ascending and descending colons. Medially, the posterior fascial layer is fused with the fascia of the spine muscles. The anterior fascial layer merges into the connective tissue of the great vessels (aorta and IVC) (*Sampaio, 2000*). (Fig. 2&3).

(Fig. 3): Organization of the fat and fascia surrounding the kidney (*Drake et al., 2005*).

These anatomic descriptions of the renal fascia show that right and left perirenal spaces are potentially separated, and therefore, it is exceptional that a complication of an endourologic procedure (e.g., hematoma, urinoma, perirenal abscess) involves the contra-lateral perirenal space (*Drake et al, 2007*).

The true capsule and Gerota’s fascia are of importance when performing a percutaneous renal surgery. As the needle is passed through
the skin into the kidney, two areas of resistance are felt, the first is at the lumbo-dorsal fascia, and the second is at the true capsule. The renal capsule is a firm fibrous membrane that adheres to the underlying parenchyma. Passing needle through this capsule is much like pushing a needle through cardboard in that there is some initial resistance to the needle's passage followed by sudden “give”. At this point, the needle lies within the renal parenchyma and therefore moves to and fro as the kidney moves with respiration. The renal capsule is richly innervated; accordingly, puncture or dilatation of a unanaesthized renal capsule causes considerable discomfort (Sampaio, 2000).

Gerota's fascia serves as an anatomic barrier to the spread of malignancy as well as a means of containing perinephric fluid collections. Thus, perinephric fluid collections can track inferiorly into the pelvis without violating Gerota's fascia (Anderson et al., 2007).

**Relationships to other structures:**

- **Anterior relations:**

  The anterior surface of the right kidney is related to numerous structures, some of which are separated from the kidney by a layer of peritoneum, and some of which are directly against the kidney (Fig. 4).

  - A small part of the superior pole is covered by the right suprarenal gland.
  - Moving inferiorly, a large part of the rest of the upper part of the anterior surface is against the liver and is separated from it by a layer of peritoneum.
- Medially, the descending part of the duodenum is retroperitoneal and contacts the kidney.
- The inferior pole of the kidney, on its lateral side, is directly associated with the right colic flexure and on its medial side, is covered by a segment of the intra-peritoneal small intestine (Drake et al., 2005).

(Fig. 4-A): Structures related to the anterior surfaces of each kidney. (Drake et al., 2005)

The anterior surface of the left kidney is also related to numerous structures, some with investing layer of peritoneum and some directly against the kidney (Fig. 4).

- A small part of the superior pole, on its medial side, is covered by the left suprarenal gland.
- The rest of the superior pole is covered by the intra-peritoneal stomach and spleen.
• Moving inferiorly, the retro-peritoneal pancreas covers the mid-part of the kidney.
• On its lateral side, the lower half of the kidney is covered by the left colic flexure and the beginning of the descending colon, and on its medial side, by the parts of the intra-peritoneal jejunum. 

(Fig. 4-B): Structures related to the anterior surfaces of each kidney (Drake et al., 2005)

Occasionally, it was observed in the course of routine abdominal CT scan examinations, that the retroperitoneal colon is lying in a posterolateral or even a post renal position. Hence, in these cases, it is at great risk of being injured during the intra-renal percutaneous approach. This event (retro renal colon) more commonly occurs with regard to the inferior poles of the kidneys. In a controlled study, it was demonstrated by CT scan that, when the patient is in the supine position, the retro-renal colon was found in 1.9% of the cases. Nevertheless, when the patient
assumes the prone position (the more frequent position used for percutaneous access to the kidney), the retro-renal colon was found in 4.7% of the cases. Therefore, special attention should be given, under fluoroscopy and with the patient in the prone position, to detect patients with retro-renal colon prior any invasive percutaneous renal procedure. *(Hopper and Yakes, 1990).*

**Posterior relations:**

Posteriorly, the right and left kidneys are related to similar structures (Fig. 5). Superiorly, is the diaphragm and inferior to this, moving in a medial to lateral direction, are the psoas major, quadratus lumborum, and transversus abdominis muscles. The superior pole of the right kidney is anterior to the rib XII, while the same region of the left kidney is anterior to ribs XI and XII. The pleural sacs, and specifically, the costo-diaphragmatic recesses, therefore extends posterior to the kidneys. Also passing posterior to the kidneys, are subcostal vessels and nerves and ilio-hypogastric and ilio-inguinal nerves *(Drake et al., 2005).*

The posterior surface of the diaphragm attaches to the extremities of the 11th and 12th ribs. Close to the spine, the diaphragm is attached over the posterior abdominal muscles and forms the medial and lateral arcuate ligaments on each side. In this way, the posterior aspect of the diaphragm (posterior leaves) arches as a dome above the superior pole of the kidneys, on each side. Therefore, when performing an intra-renal access by puncture, the endourologist may consider that the diaphragm is traversed by all intercostal punctures, and possibly by some punctures below the 12th rib *(Hopper and Yakes, 1990).*
(Fig. 5): Structures related to the posterior surface of the kidney (*Drake et al., 2005*)

Generally, the posterior reflection of the pleura extends inferiorly to the 12th rib; nevertheless, the lowermost lung edge lies above the 11th rib (at the 10th intercostal space) (Fig. 6). Regardless of the degree of respiration (mid- or full expiration), the risk of injury to the lung from a 10th intercostal percutaneous approach to the kidney is prohibitive. Any intercostal puncture should be made in the lower half of the intercostal space, in order to avoid injury to the intercostal vessels above (*Hopper and Yakes 1990*).
(Fig. 6): Schematic drawing from a lateral view of the kidney and its relationships with the diaphragm, ribs, pleura, and lung. PR = posterior reflection of the pleura, L = lower edge of the lung; K = kidney; X = 10th rib; XI = 11th rib; XII = 12th rib. (Sampaio, 2000).

**Internal structure of the kidney:**

Each kidney has a smooth anterior and posterior surfaces covered by a fibrous capsule, which is easily removable except during disease. On the medial margin of each kidney, is the **hilum of kidney**, which is a deep vertical slit through which renal vessels, lymphatics, and nerves enter and leave the substance of the kidney. Internally, the hilum is continuous with the renal sinus. Externally, continuous with the perinephric fat (Drake et al., 2005).

Each kidney consists of an outer renal cortex and an inner renal medulla. The renal cortex is a continuous band of pale tissue that
completely surrounds the renal medulla. Extensions of the renal cortex (the renal columns) project into the inner aspect of the kidney, dividing the renal medulla into discontinuous aggregations of triangular-shaped tissue (the renal pyramids) (Fig. 7) (*Drake et al., 2005*).

(Fig. 7) Internal structure of the kidney. (*Drake et al., 2005*)

The bases of the renal pyramids are directed outward, towards the renal cortex, while the apex of each renal pyramid projects inward, towards the renal sinus. The apical projection (renal papilla) is surrounded by a minor calyx. The minor calices receive urine and represent the proximal parts of the tube that eventually form the ureter (Fig. 7). In the renal sinus, several minor calices unite to form a major
calyx, and two or three major calices unite to form the renal pelvis (Drake et al., 2005).

**Calyceal anatomy of the kidney:**

- **Renal Papillae, Calyces and Pelvis:**

  The renal papillae are the tips of medullary pyramids and constitute the first gross structure of the renal collecting system. Typically, there are 7 to 9 papillae per kidney, but this number is variable, ranging from 4 to 18. The papillae are aligned in two longitudinal rows situated approximately 90 degrees from one another. There is an anterior row that owing to the orientation of the kidney faces in a lateral direction and a posterior row that extends directly posterior (Figs. 8). Each of these papillae is cupped by a minor calyx (Fig. 7). At the upper and lower poles, compound calyces are often encountered (Fig. 9). These compound calyces are the result of renal pyramid fusion and because of their anatomy, are more likely to allow reflux into the renal parenchyma. (Anderson et al., 2007)
(Fig. 8) Transverse view of the left kidney: Showing approximate 30-degrees anterior rotation from the coronal plane, relative positions of the anterior and posterior rows of calyces, and location of the relatively avascular plane separating the anterior and posterior renal circulation (Anderson et al., 2007)

(Fig. 9): Schematic drawing representing single and compound calyces: A single minor calyx drains only one papilla and a compound minor calyx drains two or three papillae. p = renal papilla; pd = papillary ducts; ac = area cribrosa; mc = minor calix; Mc = major calix; imc = infundibulum of a minor calix (caliceal neck); i = infundibulum. (Sampaio 2000).

The minor calyces, from seven to thirteen in number, are cup shaped structures which surround the apices of pyramids forming the fornix, each of which embraces one or more of the renal papillae. The neck of the minor calyces is a narrow structure called infundibulum which unite together to form two to three major calyces. These in tern join to form a funnel shaped sac, the renal pelvis (Hanif et al., 2004).

- Calyceal arrangement:
Recent advances in endourology have revived interest in collecting system anatomy, since a full understanding of such anatomy is necessary to perform reliable endourologic procedures as well as uro-radiologic analysis. (Kim and Clayman 2006).

The renal calyces lie at different angles with respect to frontal (coronal) plane of the kidney. Calyces in the upper and lower poles of the kidney are usually compound and are directed at various angles within the frontal plane while rest of calyces are arranged in two distinct rows, one in the anterior half and one in the posterior half of the kidney (Fig. 10) (Hanif et al., 2004).

(Fig. 10): Basic pelvicalyceal anatomy (Gupta et al., 2007)

The paired calyces have been observed to display one of two configurations, the Brödel's type, and Hodson's type configurations (Hanif et al., 2004).

- **Brödel's type configuration:**

  The anterior calyces form an angle of 70 degrees with frontal plane and thus are directed straightforward facing the anterior
surface of the kidney. The posterior calyces form an angle of approximately 20 degrees with frontal plane of the kidney and face a line slightly posterior to lateral convex border of the kidney (Fig. 11). In the body, kidneys are lying obliquely against the psoas muscles at an angle of approximately 30-45 degrees. Therefore on a standard IVU, the anterior row of calyces usually is seen more peripherally and laterally as cup shaped structures. Whereas, posterior rows of calyces are seen more medially and frontally, as rounded concentration of contrast medium. (Hanif et al., 2004).

(Fig. 11): Calyceal orientation in the Brödel's configuration, the longer posterior calyx is positioned 20 degrees from the frontal plane of the kidney and the shorter anterior calyx forms a 70-degrees angle with the frontal plane. (Smith and pardalidis., 1995).Quoted from (Gupta et al., 2007).

- **Hodson's type configuration:**

  The anterior calyces are lying 20 degrees while the posterior calyces lie at 70 degrees with respect to the frontal plane of the kidney.
Changing the position of the patient from supine to prone position does not change the relative position of calyces significantly (Sengupta et al., 2000).

(Fig. 12): Calyceal orientations in the Hodson configuration, the shorter posterior calyx is positioned 70 degrees from the frontal plane of the kidney and the longer anterior calyx forms 20 degrees from the frontal plane. (Smith and Pardalidis, 1995). quoted from (Gupta et al., 2007).

The Brödel's type is more observed on the right side as compared to the left side (67% & 32% respectively) whereas Hodson's type is more observed on the left side as compared to the right side (63% & 29% respectively). As there is wide range of angles, therefore not all the kidneys follow the classic picture of either Brödel or Hodson type. (Hanif et al., 2004).

**Posterior rotation of the lateral renal margin:**

Degree of the posterior rotation of frontal aspect of the kidney from the coronal plane of the body was measured. On the average it was found to be 29 ± 2 degrees (ranging from 8-50 degrees). Right kidney
was rotated more posterior as compared to left one i.e. 35 degrees on the right and 22 degrees on the left. When operating on the right kidney, 30 degrees elevation of operative side makes the posterior calyx almost end on in fluoroscope in most of the cases. (Post. rotation of patient + post. rotation of kidney + post. Calyceal angle = 30+35+26=90). This makes relatively easy target for puncture and prevents overshooting of the puncture needle. Similarly on the left side elevating the patient 20 degrees upward on the left side in the prone position will make the posterior calyx of left kidney end on in most of the cases. Post. Rotation of patient + post. Rotation of kidney + post. Calyceal angle = 20+22+48=90) (Hanif et al., 2004).

- Appearance of the pelvi-calyceal system in IVU:

It was noted that on the average, anterior calyx was projected more lateral in 67.5% of kidneys, the anterior and posterior calyces were projecting almost equally from the lateral renal margin in 21% of kidneys and the posterior calyx was more laterally projected than the anterior in only 6% of kidneys (Hanif et al., 2004).

So when we examine the standard IVU (antero-posterior view), the compound polar calyces, and anterior calyces appear as cup shaped positioned laterally, while the posterior calyces appear as end on positioned medially. As the kidney is placed along the posterior abdominal wall in oblique fashion, their hilum is rotated anteriorly and medially while lateral renal margin is rotated postero-laterally. So this swing the anterior calyces more laterally and posterior calyces medially (Hanif et al., 2004).
Variation in the anatomy of the renal collecting system:

Number of calyces, diameter of the infundibulae, and size of the renal pelvis, all vary significantly between normal individuals. Even in the same individual, the renal collecting systems may be similar but are rarely identical (Fig.13, 14, and 15) (Anderson et al., 2007).

(Fig. 13) Normal bilateral renal collecting systems, demonstrated by excretory urography. (Anderson et al., 2007).
(Fig. 14) Significant variation between two normal renal pelves, demonstrated by excretory urography. **A.** Large, extra renal pelvis. **B.** Narrow, completely intrarenal pelvis, barely larger in caliber than the ureter. *(Anderson et al., 2007).*

(Fig. 15): Examples of normal variations in the architecture of the renal collecting system, demonstrated by excretory urography. **A)** Absence of calyces. **B)** Minor calyces arising directly from the renal pelvis. **C)** Megicalyces. **D)** “Orchid” calyces. **E)** Multiple minor calyces and nearly absent renal pelvis *(Anderson et al., 2007).*
Crossed Calices:

In 17.2% of the cases, the kidney midzone (hilar) was drained by crossed calices, one draining into the superior calyceal group and the other draining into the inferior calyceal group simultaneously. On the pyelograms, the crossed calyces (laterally) and the renal pelvis (medially) outlined a radiolucent region that termed the interpelvicaliceal region (Fig. 16). When the crossed calyces were in the mid kidney, the calyx that drained into the inferior caliceal group was in ventral position in 87.5% (Sampaio 2000)

(Fig.16): Comparative study between radiographic view of a left kidney and its corresponding three-dimensional cast. A, Anterior view of a retrograde pyelogram shows a radiographic image of the interpelvicaliceal region (arrow). B, Anterior view of the corresponding three-dimensional endocast. The asterisk demonstrates interpelvicaliceal space. The arrowhead shows a minor calyx perpendicular and superimposed to the surface of a superior major calyx, which cannot be seen on the pyelogram. Open arrow shows anterior minor calyx superimposed on the posterior minor calyx. On pyelogram, making a distinction between them can be difficult. C, Oblique view of the same cast. The arrow shows a perpendicular minor calyx into the superior caliceal group. Arrowheads demonstrate distinction between the
anterior and posterior minor calices, which are superimposed on the pyelogram (Sampaio 2000).

**Renal blood supply:**

The renal pedicle classically consists of a single artery and a single vein that enter the kidney via the renal hilum (Fig. 17). These structures branch from the aorta and inferior vena cava just below the superior mesenteric artery at the level of the second lumbar vertebra. The vein is anterior to the artery. The renal pelvis and ureter is located further posterior to these vascular structures (Anderson et al., 2007).
(Fig. 17): Renal vasculature (from anterior to posterior, renal vein, renal artery and renal pelvis). Note path of left renal vein under the superior mesenteric artery. *(Drake et al., 2005)*

- **Renal Artery:**

  Specifically, the right renal artery leaves the aorta and progresses with a caudal slope under the inferior vena cava (IVC) toward the right kidney. The left renal artery courses almost directly laterally to the left kidney. Given the rotational axis of the kidney (Fig. 17), both renal arteries move posteriorly as they enter the kidneys. Also, both arteries have branches to the respective adrenal gland, renal pelvis, and ureter *(Anderson et al., 2007)*.

  Upon approaching the kidney, the renal artery splits into four or more branches, with five being the most common. These are the renal segmental arteries (Fig. 18). Each segmental artery supplies a distinct portion of the kidney with no collateral circulation between them. Thus, occlusion or injury to a segmental branch will cause segmental renal infarction. Generally, the first and most constant branch is the posterior segmental branch, which separates from the renal artery before it enters the renal hilum. There are typically four anterior branches, which from superior to inferior are apical, upper, middle, and lower. The relationship of these segmental arteries is important because the posterior segmental branch will pass posterior to the renal pelvis while the others pass anterior to the renal pelvis (Fig. 19) *(Anderson et al., 2007)*.
(Fig. 18) **A** and **B**: Segmental branches of the right renal artery demonstrated by renal angiogram (*Anderson et al., 2007*).

(Fig. 19): Arterial supply to the kidney. The kidney is supplied by the anterior and posterior segmental branches of the main renal artery. The anterior segmental artery supplies both the anterior half of the kidney and the Polar Regions. The posterior
segmental artery supplies only the posterior aspect of the kidney (represented by the shaded region). An avascular plane, known as Brödel's line, separates the anterior and posterior circulations (Gupta et al., 2007).

Ureteropelvic junction obstruction caused by a crossing vessel can occur when the posterior segmental branch passes anterior to the ureter causing occlusion. This division between the posterior and anterior segmental arteries has an additional surgical importance in that between these circulations is an avascular plane (Figs. 8 and 19). This longitudinal plane lies just posterior to the lateral aspect of the kidney. Incision within this plane results in significantly less blood loss than outside this plane. However, there is significant variation in the location of this plane, requiring delineation before incision. This can be done with either preoperative angiography or intra-operative posterior segmental arterial injection of a dye, such as methylene blue (Gupta et al., 2007).

Once in the renal sinus, the segmental arteries branch into lobar arteries, which further subdivide in the renal parenchyma to form interlobar arteries (Fig. 20). These interlobar arteries progress peripherally within the cortical columns of Bertin, thus avoiding the renal pyramids but maintaining a close association with the minor calyceal infundibula. At the base (peripheral edge) of the renal pyramids, the interlobar arteries branch into arcuate arteries. Instead of moving peripherally, the arcuate arteries parallel the edge of the corticomedullary junction. Interlobular arteries branch off the arcuate arteries and move radially, where they eventually divide to form the afferent arteries to the glomeruli. The 2 million glomeruli within each kidney represent the core of the renal filtration process. Each glomerulus is fed by an afferent arteriole. As blood flows through the glomerular capillaries, the urinary
filtrate leaves the arterial system and is collected in the glomerular (Bowman's) capsule. Blood flow leaves the glomerular capillary via the efferent arteriole and continues to one of two locations: secondary capillary networks around the urinary tubules in the cortex or descending into the renal medulla as the vasa recta (Anderson et al., 2007).

(Fig. 20): Branches of the segmental renal artery (Anderson et al., 2007).

- Renal Vein:

  The renal venous drainage correlates closely with the arterial supply. The interlobular veins drain the post glomerular capillaries. These veins also communicate freely via a sub capsular venous plexus of stellate veins with veins in the perinephric fat. After the interlobular veins, the venous drainage progresses through the arcuate, interlobar, lobar, and segmental branches, with the course of each of these branches paralleling the respective artery. After the segmental branches, the venous drainage coalesces into three to five venous trunks that
eventually combine to form the renal vein. Unlike the arterial supply, the venous drainage communicates freely through venous collars around the infundibula, providing for extensive collateral circulation in the venous drainage of the kidney (Fig. 21). Surgically, this is important, because unlike the arterial supply, occlusion of a segmental venous branch has little effect on venous outflow (Anderson et al., 2007).

(Fig. 21): Venous drainage of the left kidney showing potentially extensive venous collateral circulation (Anderson et al., 2007).

The renal vein is located directly anterior to the renal artery, although this position can vary up to 1-2 cm cranially or caudally relative to the artery. The right renal vein is generally 2 to 4 cm in length and enters the right lateral to postero-lateral edge of the IVC. The left renal vein is typically 6 to 10 cm in length and enters the left lateral aspect of the IVC after passing posterior to the superior mesenteric artery and anterior to the aorta (Fig. 17). Compared with the left renal vein, the right renal vein enters the IVC at a slightly more cranial level and a more antero-lateral location. Additionally, the left renal vein receives the left adrenal vein superiorly, lumbar vein posteriorly, and left gonadal vein
inferiorly (Fig. 21). The right renal vein typically does not receive any branches (Anderson et al., 2007).

**Common Anatomic Variants:**

Anatomic variations in the renal vasculature are common, occurring in 25% to 40% of kidneys. The most common variation is supernumerary renal arteries, with up to five arteries reported. This occurs more often on the left. These additional arteries can enter through the hilum or directly into the parenchyma. Lower pole arteries on the right tend to cross anterior to the IVC whereas lower pole arteries on either side can cross anterior to the collecting system, causing a uretero-pelvic junction obstruction (Anderson et al., 2007).

**Applied anatomy:**

It can be seen that the safest way to enter the collecting system percutaneously is end-on through the fornix of a calyx, usually the lowermost calyx. An approach through infundibulum, especially the superior infundibulum may be dangerous because of the large vessels and major branches that cross the infundibular surfaces. The superior pole infundibulum for example, may almost be encircled by the upper segmental artery anteriorly and the posterior segmental artery posteriorly. It can be also seen that the safest place to puncture the kidney is just posterior to the line of maximal convex curvature (Brodel's line) (Hopper and Yakes, 1990).

The safety and efficacy of all endo-urologic procedures are dependent on the understanding of practical renal anatomy. This
knowledge truly enables the physician to "see" inside the kidney (Sampaio, 2000).
IMAGING MODALITIES FOR PERCUTANEOUS ACCESS

The most critical step in performing successful PCNL is establishing safe and effective percutaneous access. The ideal site of percutaneous puncture should be selected to maximize the use of rigid instruments, minimize the risk of complications, and achieve stone-free status. Intra-operative imaging is necessary for obtaining percutaneous access, and facilitating endoscopic inspection of the collecting system. *(Park, Margaret and Pearle, 2006).* Access is usually achieved using fluoroscopy, ultrasonography, or computed tomography (CT) guidance *(Inglis et al., 1989 and Lee, 1990)*

(1) Fluoroscopy

Fluoroscopy is the most common imaging modality used to obtain percutaneous renal access, although the choice between fluoroscopy and US is dependent on surgeon preference and experience. Regardless of the imaging modality used to gain access, intra-operative fluoroscopy is indispensable for the successful completion of PCNL *(Park et al, 2006).*

Endourologic procedures most often rely on fluoroscopy, although the risk is relatively small, the patient, surgeon, and participating staff will be exposed to some level of ionizing radiation. The endourologist in particular, must undertake protective measures,
because he or she will likely be exposed to radiation on a regular and cumulative basis. These protective measures include: Putting fluoroscopy beam under table, using minimal fluoroscopic time: “Think before or after fluoroscopy, not during.” Collimation, Wearing radiation detection devices and Wearing lead-impregnated glasses (Gupta et al., 2007).

(2) Ultrasound:

Percutaneous ultrasound-guided nephrostomy is perhaps the simplest and most direct technique to access and drain a hydronephrotic collecting system. It is most often utilized to place a temporary urinary diversion in the instances of an obstructing stone or pyonephrosis and has also been used successfully to relieve obstruction secondary to malignant compression. Although the technique has been especially popular among interventional radiologists, it has gained popularity among endourologists who are comfortable with ultrasonography. Allergies to topical or injectable local anesthetic and coagulopathy are the only relative contraindications to ultrasound-guided renal access. (Gupta et al., 2007).

When the kidney is evaluated with ultrasound, its various compartments have different sonographic appearances that can be seen quickly and accurately in three-dimensional orientation. The renal capsule is clearly visible. The renal cortex produces low-level homogeneous echoes, and the medulla presents as a relatively sonolucent structure. Most importantly, hydronephrosis can easily be identified as a hypoechoic cavity surrounded by a central echo complex (Kumari-Subaiya and Phillips, 1995).
(3) Computed Tomography:

Another imaging method that is an alternative to fluoroscopy is CT. This technology is rarely used for PCNL because it is not available in the operating room. Radiation exposure with the CT scan may be greater than exposure during fluoroscopy. CT is also an expensive imaging modality (Falahatkar and Allahkhah, 2010). It needs to be considered only if the aforementioned techniques are not feasible or do not provide good results or if sophisticated preoperative planning is necessary (Gupta et al., 2007).

Although some investigators have advocated the use of CT-guided percutaneous access (Barbaric et al., 1997), cross sectional imaging is only needed to facilitate safe percutaneous access in special circumstances, as Patients with a retrorenal colon or a severely distorted body habitus due to spinal dysraphism predictably require cross-sectional imaging to facilitate safe access before percutaneous nephrolithotomy (Matlaga et al., 2003). In addition, the CT-guided approach may be useful in obtaining renal access in patients with ileal conduits, renal uric acid stones, or nephrolithiasis in the presence of angiomyolipomas at risk for bleeding (Eiley et al., 1999).

Three-dimensional CT has been described as a valuable tool for obtaining percutaneous access in the morbidly obese with malrotated kidneys and large staghorn calculi (Buchholz, 2000).

Preoperative evaluation with the aid of either CT or MRI may aid in minimizing the risk of pulmonary, visceral, splenic, or hepatic
injury if a percutaneous puncture of the upper pole of the kidney above the 11th rib is necessary (Robert et al, 1999).

(4) CT Fluoroscopy:

The introduction of CT fluoroscopy, whereby CT live can be performed in the operating room, has the potential to allow percutaneous access to be performed under CT guidance with real-time visualization (Sakurai et al., 2004) when difficult access to the pelvicalyceal system has been encountered (LeMaitre et al, 2000). This newer imaging modality can maximize operator hand distances away from the gantry (>25 cm) and reduce the radiation dose to the operator's hand to 0.4 mrad/s (4 μGy/s) (De Mey et al, 2000). CT fluoroscopy also has the potential to allow more accurate detection of residual fragments intraoperatively, thereby precluding the need for second-look flexible nephroscopy (Sakurai et al., 2004). In the instance of nephrostomy dislodgement or malpositioning, CT may be used to successfully reposition drainage tubes into the collecting system (Jones and McGahan, 1999).

(5) MRI:

There are no specific indications for MRI-guided percutaneous nephrostomy, although the technique has been shown to be feasible and

(6) Percutaneous Access without Imaging—“Blind Access”:

Percutaneous access without imaging is a final alternative. However, blind access is reserved primarily for emergency situations (Falahatkar and Allahkhah, 2010). The rare instances when retrograde or intravenous opacification is precluded, the pelvicalyceal system cannot be opacified, or imaging machinery such as a fluoroscopic unit or sonography is inaccessible. Poor renal function in the presence of ureteral obstruction, for example, may represent such a situation, especially if emergent collecting system decompression is required (i.e., urosepsis from pyonephrosis). Percutaneous access without imaging relies on anatomic landmarks and the assumption that anatomy is not aberrant. (Gupta et al., 2007).

The lumbar notch, bounded superiorly by the latissimus dorsi muscle and the 12th rib, medially by the sacrospinalis and the quadratus lumborum muscles, laterally by the transversus abdominis and the external oblique muscles, and inferiorly by the internal oblique muscle, has been shown to be a useful anatomic window for successful blind percutaneous calyceal access. An 18-gauge access needle can be inserted into the notch at a 30-degrees angle directed cephalad under the 12th rib to a depth of 3 to 4 cm (Fig.22). (Chien and Bellman, 2002)
The lumbar notch is a useful anatomic landmark for blind percutaneous access to the renal collecting system. It is bounded superiorly by the latissimus dorsi muscle and the 12th rib, medially by the sacrospinalis and quadratus lumborum muscles, laterally by the transverses abdominis and external oblique muscles, and inferiorly by the internal oblique muscle. (Gupta et al., 2007).

Alternatively, the renal pelvis may be accessed at a point 1.0 to 1.5 cm lateral to the L1 vertebral body. A 22-gauge “skinny” needle may be used to perform a blind perpendicular puncture lateral to the psoas and just below the level of the 12th rib. Once urine can be aspirated from the access needle, contrast material can be instilled to outline the upper collecting system and direct an appropriate calyceal puncture. If a smaller access needle is used, there is less chance of causing an arteriovenous fistula should any vessels be traversed. If doubt exists as to whether the collecting system has been entered with the puncture needle (e.g., no return of urine), attempts to opacify the system should not be undertaken.
Positions for percutaneous nephrolithotomy

As PCNL was used more frequently it became evident that the prone position was not optimal for all patients, particularly the morbidly obese or those with respiratory compromise. This insight, and the demand for easier and more comfortable access to the entire urinary tract to combine retrograde and antegrade endoscopic surgery, led to the introduction of alternative patient positions for PCNL (Papatsoris A et al; 2012).

I-Prone positions:

-(1)Classic prone:

The classic prone position (Fig.23). When PCNL was initially described in 1976 the prone position was chosen because it was believed that this would be the safest way to avoid damage to the colon and visceral organs. The technique was standardised over the following years as a two-stage procedure. The first part is with the patient supine, to give anesthesia and gain retrograde access to the upper urinary tract. Then the patient is repositioned prone for the main part of the procedure. Rolled supports are placed under the thorax and the upper abdomen or on both sides, extending from shoulder to hip, to facilitate ventilation. Padding is placed under all pressure points (knees, feet, forehead, eyes, elbows, fingers) and the shoulders, and the elbows are carefully positioned to
prevent brachial plexus injury. The percutaneous tract to the kidney is established under fluoroscopy or ultrasonographic guidance, and the stone is removed (Smith AD et al; 2012).

Fig 23. the classic prone position (Smith AD et al; 2012).

The main advantage of the prone position is that it exposes completely the lumbar area. This gives the surgeon enough room to place the puncture, allows several accesses/tracts, and provides enough space for manipulation with the instruments. Upper-pole puncture is facilitated in the prone position because of the posteromedial location of the upper pole, which is closer to the posterior abdominal wall (Ray AA et al; 2009).

However, PCNL with the patient prone has several disadvantages. First, the patient must be repositioned after the first stage. This increases the operating time, and could cause injury to the patient and jeopardise the airway access. It is very difficult or almost impossible for the anaesthetist to manage an eventual cardio-respiratory emergency. Lying
on the abdomen creates further anaesthesiological difficulties by reducing lung compliance as a result of the abdominal compression, and by reducing cardiac output (Cheng MA et al; 2001).

The patient is bedded uncomfortably with the risk of creating pressure lesions. The prone position is generally associated with an increased rate of ophthalmological complications, as seen mostly from spinal operations. Direct compression might cause injury to the orbit and corneal abrasions. Also, intraocular pressure is raised during the operation and is suspected to lead to the rare complication of postoperative visual loss due to ischaemic oculopathy (Hunt K et al; 2004).

A better patient positioning were developed for the classic prone position(fig.24). Through various supporting equipments to minimise the risk of pressure injury, reduce the risk of position-related complications, and improve the ventilation and circulation of the patient. The Montreal mattress which embed the patient in a comfortable, slightly flexed posture with less pressure on the abdomen (Turner ED et al; 2011)

Fig.24 The Montreal mattress (Turner ED et al; 2011)
(2) The reverse lithotomy position:

To allow simultaneous retrograde access to the upper urinary tract during PCNL, a modification of the classic prone position became necessary. Successful results with this combined approach were achieved. According to the initial description, the patient is placed prone with the legs abducted at the hips, and the thighs and knees fixed in plastic cradles specifically modified for this purpose. The caudal end of the operating table is lowered as far as possible. The operator approaching from the caudal end of the table has access to the urethra, bladder and ureter with flexible instruments.

(3) The split-leg prone position (Fig. 25):

The split-leg prone position allows easier simultaneous percutaneous and transurethral access both in female and male patients. The patient is anaesthetised while supine and then turned prone on a standard endourological table with split-leg adapters. The patient’s legs are appropriately padded, secured independently and solely abducted at the hips without being flexed. The genitalia are positioned at the bottom of the operating table, making room for retrograde access. The flank and the genital area are separately prepared and draped. Using flexible instruments, the bladder and upper urinary tract are accessed, although this can be challenging (Theocharis K et al; 2013).
(4) The prone-flexed position (Fig.26):

Recently a modification of the prone position was described which incorporates a flexed position of the patient during the procedure. After the patient is turned to prone the table is flexed 30–40° to open the space between the 12th rib and the posterior iliac crest. This flexion prevents the exaggeration of the anterior lordosis that occurs in the classic prone position. More working space is created, potential interference from the buttock with the nephroscope during rigid nephroscopy through the lower pole is minimised, and the kidneys are displaced inferiorly in the retroperitoneum. As a result the puncture can be made more caudally. However, this position impairs even more the patient’s respiration and circulation. Airway pressures are increased, the cardiac index is decreased and the inferior vena cava can be transiently obstructed (Ray AA et al; 2009)
II-lateral positions:

(1)-The lateral decubitus and lateral flexed position:

Some patients are unable to tolerate anaesthesia while prone because of their body habitus. Later other authors reported good results using this technique in obese, kyphotic and high-risk patients. Urologists are familiar with this position, as it is used in open and laparoscopic renal surgery (Gofrit ON et al; 2004).

Initially the patient is anaesthetised while supine, when the retrograde contrast studies are conducted. The patient is then turned into the lateral position with the legs slightly bent, lying on the unaffected side and exposing the flank through which the access is made. A wedge support can be placed under the patient’s torso. Both arms are supported in separate adapters and flexed slightly at the elbow. A modification of the pure lateral position, the lateral flexed position, has the additional advantage of significantly increasing the operating field. The operating table is flexed, which widens the space between the 12th rib and the iliac crest, flattening the folds of adipose tissue and facilitating percutaneous access (Smith AD, 2012).

The advantage of the lateral position is that they can be used in patients who could not tolerate being prone. Especially helpful for the morbidly obese patients is that in the lateral position the pendulous abdomen is displaced sideways, either on the operating table or on an additional support, facilitating respiration and general anaesthesia. Furthermore, as the patient is not lying prone, the procedure can be carried out safely even under
The main disadvantage in this position is the unusual fluoroscopic view of the kidney, which can also be obscured by the underlying spine. Maintaining the correct orientation and accurately puncturing the selected calyx is difficult, and can result in increased exposure to radiation of the surgical team. Using the ‘bull’s-eye’ puncture technique might not be possible, as the metal side-rails of the table interfere with the fluoroscopic image. Alternatively, the ‘triangulation’ technique or ultrasonographic guidance can be used, but this requires additional expertise and equipment (Karami H et al; 2009).

The patient must be repositioned during the procedure, although this is easier and poses fewer risks than repositioning towards the prone position, regional anaesthesia, thus avoiding the risks of general anaesthesia, and allowing the patient to communicate with the anaesthetist and observe the procedure (El-Husseiny T et al; 2010).

(2) The modified lateral for simultaneous antegrade and retrograde access – the 'Barts technique'(Fig. 27):

This modified hybrid position was described to combine the advantages of the lateral position with the option of easier retrograde access to the upper urinary tract (Moraitis K et al; 2012).

The patient is placed in the lithotomy position with the ipsilateral hemi-pelvis tilted by 45°, supported by a foam wedge. The torso is twisted to the contralateral side, with the shoulders perpendicular to the operating table. The ipsilateral lower limb is slightly flexed in a ventral direction and follows the lateral rotation of the trunk, while the contralateral lower limb remains fully abducted. In this position the flank is sufficiently exposed, providing a wide choice of puncture sites and a
wide angle for handling the antegrade instruments. Percutaneous access is made close to the posterior axillary line, and the direction of the puncture needle is within the horizontal plane towards the desired calyx. Simultaneous ante- and retrograde access allows the treatment of complex unilateral upper urinary tract pathology (Papatsoris AG et al; 2008)

Another advantage is that repositioning of the patient is minimal, thus saving operative time and reducing the risk of injuring the patient. However, this position cannot be used for every patient as it requires musculoskeletal mobility and flexibility of the spine. Percutaneous access guided by fluoroscopy can be challenging. A similar position with the legs bent in a lower position was described recently (Lezrek M et al; 2011)

(Fig.27): the Barts technique (Moraitis K et al; 2012).
III-Supine positions:

(1)-The original Valadivia supine position (Fig 28):

*In 1987–88, Valdivia-Uria et al.* reported a safe percutaneous access to the kidney with the patient supine and 10 years later they reported the in vivo experience.

As the abdominal wall is punctured more laterally, away from the lumbar muscles, movements of the endoscopic instruments are less restricted. The direction of the tract preserves a low pressure in the renal pelvis, and thereby reduces the risk of fluid absorption and allows even spontaneous clearance/washout of fragments. According to anatomical CT studies, the risk of colon perforation might even be less than in the prone position, as the bowel can float free in the uncompressed abdomen and is not pressed towards or behind the kidney (*Tuttle DN et al; 2005*).

Fig. 28 the Valadivia supine position (*Tuttle DN et al; 2005*).
The main drawback of the supine position is that the flank is not fully exposed, which makes access to the posterior-medially lying upper pole more difficult and provides less availability for multiple accesses. The operating table and the patient’s hips might also restrict instrument manipulation. The absence of abdominal compression leaves the kidney more mobile, which can make puncture and dilatation of the tract more challenging (Rana AM, et al; 2008).

Some calyces are dependant and collect fragments during the disintegration of the stone. Finally, the low intrarenal pressure leaves the collecting system less expanded and therefore nephroscopy and manipulations can be more difficult (Steele D, et al 2007).

(2) The modified Valdivia supine position for simultaneous PCNL & ureteroscopy (Fig.29):

This modification was described by Valdivia et al. to allow simultaneous rigid ureteroscopy during PCNL. The difference from the original supine position is that the legs are flexed in supports, with the ipsilateral leg more elevated and the contralateral more descended, to facilitate the use of a rigid ureteroscope. Valdivia prefers the classic supine position if a flexible ureteroscope is to be used, and proposes this modification only for rigid ureteroscope (Addla SK, et al; 2008).
The modified flank roll position:

In 1993 Grasso et al. described the modified flank roll position for patients who already had a nephrostomy in situ. These authors suggested that this position is suitable when the preoperative assessment showed that the procedure might be completed retrogradely, and a percutaneous tract would only be a complementary access for flexible instruments if needed. The patient is placed in the standard dorsal lithotomy position, having the flank with the percutaneous nephrostomy tilted by 45° and padded to allow access to the nephrostomy tube. The upper extremity lies across the thorax. Both the nephrostomy site and the genitalia are prepared and draped. The limited exposure of the flank might not allow a primary puncture and manipulations with rigid nephroscopes.

The crossed-leg supine position:

This variation of the original Valdivia position was described in 2007 and consists of crossing the ipsilateral leg over the contralateral A 30° inclination of the torso is achieved by placing a cushion below the
ipsilateral flank. The arms are placed similarly to those in the original Valdivia position (Neto EA, et al; 2007).

According to these authors, crossing the legs increases the distance from the lower rib to the iliac crest, and facilitates calyceal puncture and nephrostomy tract dilatation. Also, the skin and muscles of the flank are stretched, which further helps to establish percutaneous access. The authors also suggested that this variation enables a more comfortable position for the assistant next to the surgeon (Neto EA, et al; 2007).

(5)-The Galdakao-modified Valdivia position (Fig. 30):

This position was described by Ibarluzea et al. in 2007 and renewed the attention of the urological community on supine PCNL. Other authors confirmed that the operation in this position is a safe, practical and versatile procedure, with high success rates and has important over the prone position. The main characteristic is a slight lateralisation of the Valdivia supine position, with the contralateral leg flexed. The patient is placed in an intermediate supinelateral position with a 3-L bag placed to raise the flank. The ipsilateral leg is extended and the contralateral leg is abducted and flexed, achieving a modified lithotomy position. The Galdakao-modified Valdivia position combines the surgical and anaesthesiological advantages of the original Valdivia position with the advantage of simultaneous retrograde access to the kidney. The patient needs to be draped only once and repositioning is not necessary. There is more space for manipulating the instruments than in the original supine position. The drawbacks of this modification do not differ from those known for the original supine position.
(6)-The complete supine position (Fig. 30):

PCNL in a complete supine position with no flank support was described by *Falahatkar et al. 2011* who reported this technique to be safe and feasible in all patients.

The patient is placed supine at the edge of the table, with the legs extended and the arms stretched and abducted in supports. The advantages are similar to those of other supine positions. Also, the absence of flank support prevents the cephalad sliding of the kidney, making upper-pole puncture more feasible. To further facilitate this the authors proposed using lung inflation to lower the kidneys (*Falahatkar S, et al. 2011*)

Finally, the fluoroscopic view of the kidney is not overlapped by the vertebrae, as can occur in semi-supine positions (*Falahatkar S, et al. 2011*).
(7)-The flank suspended supine position (Fig.32):

Here the patient is positioned in the supine position after insertion of a 5For 6F ureteric catheter. The shoulder and the buttock of the affected side is raised by a 3 liter water bag or air cushion. The body contour of the affected side is aligned with the edge of table. The operating table is adjusted to the jackknife position, with the tip of the lower part is slightly lowered. The leg of the affected side assumes a straightened dorsally flexed and slightly inner rotated position, while the hip of the other side is outer rotated. The knee flexed making the body of the patient assumes the 'opisthotonus position' or arching position. The patient is then immopalized at the chest and the pelvis by two adherent tapes, which cross each other at the abdomen to form a 'V' shape (Pan Tie et al; 2012).
Fig. 32: The flank suspended supine position (FSSP): (A) showing the V shaped plaster tapes crossing in front of the abdomen. (B) showing the suspended flank over the edge of the table (Pan Tie et al; 2015).

This modification allows bigger room for puncture and maneuvering of the instruments. The jackknife position can immopitalize the kidney and facilitate the puncture. Third the FSSP can lower the kidney making most of the calices easily accessible. Fourth immopalization of the chest and the pelvis with a V shaped tapes places pressure on the abdomen causing shorter percutaneous track. The FSSP is almost parallel to the horizontal plane allowing easily drainage of the stones fragments and the surgeon to operate in the sitting position (Pan Tie et al; 2015).
TECHNIQUES OF PCNL

As PCNL was used more frequently it became evident that the prone position was not optimal for all patients, particularly the morbidly obese or those with respiratory compromise. This insight, and the demand for easier and more comfortable access to the entire urinary tract to combine retrograde and antegrade endoscopic surgery, led to the introduction of alternative patient positions for PCNL (Theocharis K, et al; 2012).

Indications of PCNL:

Stone factors:
- a. Nonstaghorn calculi >2 cm.
- b. Stag horn calculi.
- c. Composition (brushite, cystine, calcium oxalate monohydrate).
- d. Impacted proximal ureteral calculi.
- e. Failure of URS and/or ESWL.

Renal anatomy factors:
- a. Lower pole calculi >1 cm.
- b. Caliceal diverticular calculi.
- c. Surgical correction of ureteropelvic junction obstruction and concurrent large stone burden. (Miller et al., 2007).

Contraindications of PCNL:

Absolute:
- a. Uncontrolled coagulopathy.
b. Active urinary tract infection.

Relative:

a. Ectopic kidney.
b. Fusion anomalies.
c. Severe dysmorphism.
d. Morbid obesity (Miller et al., 2007).

❖ Preoperative Preparation:

Urine sterility is mandatory for all elective procedures. This should be achieved by urine culture followed by sensitivity-specific antibiotics for 5 to 7 days before the procedure. Documented follow-up sterile urine is preferable but may not always be feasible (e.g., indwelling nephrostomy or urethral catheter, struvite stone). Consideration should be given for 1 to 2 days or more of preoperative intravenous antibiotics in select patients with a history of urosepsis, struvite calculi, or indwelling tubes. In patients with indwelling tubes, urine should be obtained directly from the catheter lumen, not from the drainage bag. Percutaneous entry in the setting of untreated urinary tract infection risks sepsis and death (Gupta et al., 2007) and a temporary percutaneous nephrostomy can be inserted to drain an obstructed and infected pelvicalyceal system beforehand (Wong 2009).

❖ Anaesthesia and Positioning:

Intravenous analgesia and sedation combined with local anesthetic injection may be sufficient for patients undergoing drainage
procedures. Patients having more extensive percutaneous renal surgery require spinal blockade or general anesthesia. Because patients will most likely be in the prone position, airway access is poor and endotracheal intubation is necessary if general anesthesia is being administered. In patients receiving spinal blockade, a higher level than usually utilized for lower urinary tract procedures is desirable, but not to the detriment of pulmonary function \( (Gupta \text{ et al.}, 2007) \).

Percutaneous puncture could be the most difficult step, especially when the pelvi-calyceal system is not dilated and/or the anatomy is distorted. Careful positioning of patient facilitates correct puncture of the collecting system, while at the same time protects the anaesthesised patient from inadvertent injury. The positions generally preferred for puncture are:

1- Prone oblique with affected side tilted 30 degrees up, so that the Posterior lower pole calyx is directed posteriorly on the vertical Sagittal plane (Fig. 33).

2- Completely prone, with puncture performed from posterolaterally. \( (Wong \text{ 2009}) \) (Fig. 34)
(Fig. 33) Posterior lower pole calyx in prone oblique position (Wong 2009).

(Fig. 34): Completely Prone positioning for percutaneous access. Two bolsters are placed on each side of the chest to facilitate ventilation; additional bolsters are placed under the knees and ankles. The head is carefully supported by an additional bolster (Gupta et al., 2007).
3- The modified supine position in which the patient is tilted about 30°.
(Fig. 35) (Chang, et al, 2007)

(Fig. 35): The modified supine position in which the patient is tilted about 30°.

4- Complete supine position:
a- With no towel under the patient’s flank (Fig. 36) (Falahatkar and Allahkhah, 2010).

(Fig. 36): Lateral view of complete supine position with no towel under the patient’s flank and no change in leg position. (Falahatkar and Allahkhah, 2010).
b- With a towel under the patient’s flank (Fig. 37) *(Steele and Marshall, 2007)*

(Fig. 37): a patient is placed in the supine position for percutaneous nephrolithotomy, a 3 L bag of saline is positioned beneath the flank. *(Steele and Marshall, 2007)*

❖ **Surgical Technique :**

The standard operative technique of PCNL consists of three main steps:
1. Percutaneous puncture of pelvi-calyceal system.
2. Development of track.
3. Fragmentation and/or removal of stone *(Wong, 2009)*.

1. **Percutaneous puncture of pelvi-calyceal system**

   After induction of anesthesia, cystoscopy can be performed with the patient in lithotomy or prone position with spreader bars for placement of a uretral catheter. Bladder drainage should be provided by means of an indwelling urethral catheter *(Gupta et al., 2007)*.

   Options for ureteral catheterization include a 5- or 6-Fr open-ended catheter, an occlusion balloon catheter, a dual-lumen catheter, or a ureteral access sheath. Each has its advantages and disadvantages. *Simple open-ended catheters* are generally nonobstructive, thereby preventing high intrarenal pressure. In addition, they generally are least likely to
cause ureteral injury. They may not prevent stone fragments from migrating down the ureter during the procedure, however. A **dual-lumen catheter** has the advantage of allowing simultaneous retrograde injection of more than one medium (e.g., contrast medium and/or indigo carmine), allowing simultaneous guide wire access and contrast agent or saline injection, providing drainage via one lumen and injection through the other to prevent high pressure, and preventing stone fragment migration. It does dilate the ureter, however, and may result in ureteral edema or injury requiring stent placement. An **occlusion balloon catheter** prevents fragment migration but can cause ureteral injury and high intrarenal pressure. A **ureteral access sheath** facilitates fragment passage and prevents high pressure while allowing for injection via the inner dilator but significantly dilates the ureter (thereby mandating stent placement), can cause ureteral injury, does not provide adequate remaining urethral lumen for bladder drainage, and requires a makeshift drainage apparatus at its distal end \(\text{(Gupta et al., 2007)}\).

Percutaneous puncture of the pelvi-calyceal system is done with precision under the guidance of one of the following imaging techniques:

1. Radiographic contrast medium, coloured blue with methylene blue, can be injected via a pre-inserted retrograde ureteral catheter to outline the pelvi-calyceal system. This provides an additional advantage of slight distension of the collecting system that may facilitate percutaneous puncture, and can be repeated as often as is necessary without any dose limitation. With a single stone in the renal pelvis or when the anatomy is unclear, the use of contrast material is recommended to precisely delineate the intra-renal
anatomy. In general, anterior calyces are more laterally located and posterior calyces are more medially located (mnemonic **LAMP**: Lateral-Anterior, Medial-Posterior)

2. Hydronephrotic collecting system can be punctured easily under real-time ultrasonographic guidance.

3. Intravenous injection of contrast medium produces a pyelogram for targeting the puncture. However delineation of the collecting system may not be optimal due to poor kidney excretion, and there is a dose limit due to nephrotoxicity of the contrast medium (Wong, 2009).

- **Puncture of the pelvi calyceal system according to the position:**

  **A- Percutaneous puncture of pelvi-calyceal system in prone position:**

**Subcostal Approach:**

With the C-arm in the vertical position, the collecting system is inspected and the appropriate calyx is identified. The ideal site provides the shortest tract to the calyx from below the 12th rib (Fig. 38). Examination with the C-arm at 90 degrees defines the medial vertical plane for entry into the calyx. The C-arm is then rotated approximately 30 degrees toward the surgeon. This places the axis of the C-arm in the same central posterior plane of the kidney, providing a direct end-on view of the posterior calyces. After the calyx has been identified, the overlying skin site is marked with a curved hemostat (*Kessaris and Smith, 1995; LeRoy, 1996; Niles and Smith, 1996*).
The ideal site for percutaneous puncture is one that provides the shortest tract to the calyx from below the 12th rib. In this particular case, although an intercostal approach would provide the shortest tract, it would also greatly increase the risk of injury to the pleura or lung (Gupta et al., 2007).

An 18-gauge translumbar angiography needle is advanced in the plane of the fluoroscopic beam with the C-arm in the 30 degrees position. The diamond tip prevents deflection by sharply cutting through muscle and fascia while causing minimal shearing. The appropriate direction for needle advancement is determined by obtaining a “bull's-eye sign” on the fluoroscopic screen. This effect can be observed only when the needle hub is superimposed on the needle shaft and is evident when the plane of the needle is the same as that of the x-ray beam. If the axis of the needle advancement is not parallel to the axis of the C-arm beam, a segment of the needle shaft is visible (Fig. 39) (Gupta et al., 2007).
(Fig. 39): The use of two-plane fluoroscopy to achieve accurate needle entry. With the C-arm rotated 30 degrees from the vertical position (A), the “bull's eye” sign confirms passage of the needle at the proper angle. The depth of needle penetration can be checked by intermittently rotating the C-arm to the vertical position (B) (Gupta et al., 2007).

After determination of the appropriate plane, the needle is advanced in 1 to 2 cm increments using a hemostat to minimize radiation exposure to the surgeon. The needle should approximate the avascular line of Brödel, because this provides the safest access to the posterior calyceal system. A transparenchymal route avoids the hilar vessels and seals the nephrostomy tract from urine leakage. The depth of needle penetration is monitored by rotating the C-arm back to the vertical position. With the C-arm in the vertical position, the approximation of the tip of the needle to the predetermined calyx can be seen and guided fluoroscopically. For example, the needle is too deep if it appears to be past the calyx on the fluoroscopic screen. Periodically, it is important to evaluate the correct direction of needle advancement by rotating the C-arm 30 degrees toward the surgeon and observing for the bull's-eye effect. Both the appropriate axis and the needle depth are prerequisites for a successful percutaneous access. The
needle has reached its intended target when its tip is in the desired calyx on both planes of fluoroscopy (Gupta et al., 2007).

When the needle appears to be in a calyx, the stylet is removed and the correct needle position is verified by aspiration of urine. A 0.038-inch floppy-tip J-shaped guide wire is inserted into the needle and either advanced across the UPJ or coiled within the renal pelvis. With the needle left in place, a 1 cm skin incision is made. The needle is then removed and the tract is dilated over the wire (Gupta et al., 2007).

- Subcostal approach to upper pole calyx:

  There are multiple techniques that can be done to puncture the upper pole calyx subcostally.

  (1) Displacement of the kidney caudally by placing an Amplatz sheath through a central or lower pole calyx and rotating the back of the dilator cranially, which causes caudal displacement of the kidney that can be viewed fluoroscopically. A second distinct puncture or a Y-tract is created into the upper pole. This method was successful 84% without complications (Fig. 40).

  (2) An occlusion balloon catheter can be used to apply gentle caudal traction and displace the kidney downward and below the costal margin during the initial access approach.

  (3) The needle can be advanced gradually only when the kidney is at its lowest excursion point, either incrementally during consecutive end-inspirations or while the patient is made to perform a Valsalva maneuver by the anesthesiologist (wong et al;2009).
Caudal mobilization of the kidney using an Amplatz sheath in a middle calyx presents a lower position for superior calyceal puncture (Karlin and Smith, 1989).

**Intercostal Approach:**

The risk of hydrothorax and hemothorax is increased when percutaneous access to the calyces is performed above the 12th rib. (Fig.30) (Lang and Glorioso, 1986; Irby et al, 1999). Direct percutaneous access to an upper pole calyx can be difficult by a subcostal approach, and the endourologist needs to be familiar with the intercostal approach. Many urologists favor this approach for gaining access to the upper pole and suggest that it provides direct and optimal access to most staghorn calculi, even though it carries a slight and acceptable increase in morbidity (Fuchs and Forsyth, 1990; Goljanin et al, 1998).

**Retrograde and Retrograde-assisted Percutaneous Renal Access:**

Although uncommon, some urologists may choose to obtain upper tract access by a pure retrograde method or by retrograde-assisted techniques. Retrograde nephrostomy has been shown to be a safe procedure that can be mastered with a short learning curve and minimal radiation exposure (Wong et al, 2009).
Conditions that make standard percutaneous access difficult may be overcome by utilizing a retrograde route. Cases of morbid obesity, tightly branched staghorn calculi, and a hypermobile, malrotated, or ptotic kidney may be more amenable to retrograde-based access (Conlin, 2003).

Presently, ureteroscopically assisted percutaneous access is more commonly utilized than older fluoroscopically guided retrograde access techniques (Gupta et al., 2007).

- Ureteroscopically Assisted Percutaneous Access:

  With the patient in a prone split-leg position, wire access to the collecting system is obtained by flexible cystoscopy. Under direct vision, a flexible ureteroscopy with either single or dual deflection is advanced to select the exact calyx of interest. A fluoroscopically guided percutaneous puncture is performed using the distal end of the ureteroscope as a landmark. The tip of the puncture needle is in correct position when confirmed endoscopically (Fig. 41). An antegrade guide wire can then be advanced through a ureteroscopically positioned snare or basket and withdrawn through the urethra. With this through-and-through guide wire access, standard percutaneous access, tract dilation, and percutaneous procedures of choice can be performed expeditiously (Kidd and Conlin, 2003).
(Fig. 41): Retrograde ureteroscopic visualization of the desired calyx of entry can be used to facilitate percutaneous access. *(Kidd and Conlin, 2003).*

**B- Percutaneous puncture of pelvi-calyceal system in supine position:**

The patient’s position on the operating table during complete supine PCNL can be near the edge of the table, but kept a safe distance from the metal density of the work surface to minimize interference during imaging (Fig. 42 & 43). *(Falahatkar and Allahkhah, 2010).*

(Fig. 42): Inferior view of complete supine position with no towel under the patient’s flank and no change in leg position. *(Falahatkar and Allahkhah, 2010).*
The doctor’s Valdivia classic position, The patient in supine position, and place a bag with 3 liters of water in the lumbar fossa getting the patient closer to the edge of the bed (Garcia, et al 2009)

In complete supine PCNL, the puncture site for access is the posterior axillary line, which is far from the fluoroscopy tube. Therefore, the space is open for the surgeon to work and the surgeon can perform the procedure from a more comfortable seated position (Falahatkar and Allahkhah, 2010).

The puncture is usually through a lower or mid-region calyx but sometimes through an upper-pole calyx, which often required a supracostal puncture (Steele and Marshall, 2007).

When the puncture is done and we have already arrived to the renal capsule, it is very important to observe through a radioscopy how the needle displaces the kidney to realize that we are in the correct position. Once we are in front of the calyx, this should be depressed due to the pressure of the needle (fovea sign). This sensation, visual and feeling at the same time, as Dr Valdivia says, is very important to know if
we are in the right position in front of the chosen calyx (Garcia, et al 2009) (Fig. 43)

(Fig. 43): Urine drop after needle entrance to the kidney during percutaneous nephrolithotomy (Falahatkar and Allahkhah, 2010).

**Galdakao-modified Valdivia position:**

This new position used for the resolution of complex endourological procedures allowing simultaneous percutaneous and retrograde access. The supine Valdivia position is the same, but the leg of the operated side is extended, while the contralateral one is well abducted. The patient lies supine with a 3 L saline bag under the flank, filled with air and clamped with forceps, allowing volume control by adding or subtracting air with a syringe, to find the best position. (Fig. 44) Alternatively, two distinct ‘gel’pillows define an interposed operative space on the flank, allowing the use of instruments with lower entry of the light cable. Care is taken to prevent pressure injuries by using stirrups with padding for the upper and lower extremities (Ibarluzea, et al., 2007).
Direction of the needle in the Galdakao modified Valdivia position:

It is advisable to draw the reference lines (posterior axillary line, iliac crest, and last rib) on the skin before positioning the air bag or the gel pillows below the flank. The percutaneous puncture must be made as close as possible to the posterior axillary line, without passing over it ventrally. The direction of the 18 G needle is towards the desired calyx, usually the lower one, within the horizontal plane and slightly up, a feature that might disorientate those used to the prone position (Fig. 45). The puncture should be made under combined fluoroscopic and ultrasonographic (US) guidance. The ‘freehand’ US-guided percutaneous puncture allows the needle to be directed at the most appropriate angle toward the target entry point, seeking the US beam with the needle, controlling the structures located between the skin and the kidney, and defining the third dimension not covered by fluoroscopy without rotating the C-arm. The precise entry of the needle through the tip of the renal papilla can also be controlled under direct vision, using a flexible ureteroscope previously positioned in the selected calyx. A 0.09 mm guide wire is then passed. The safest system for endourology is to have a guide exiting from both the flank skin and the urethra (Ibarluzea, et al., 2007).
(Fig. 45): Direction of the needle in the Galdakao modified Valdivia position (Ibarluzea, et al., 2007).

**Flank suspended supine position (FSSP):**

Once the patient is positioned renal puncture tract is established through the posterior axillary line under guidance of fluoroscopy or ultrasound. This step is performed with the assistant compressing the abdomen and another one injecting normal saline through the ureteric catheter to create artificial hydronephrosis to facilitate the puncture (Pan Tie et al.; 2012).

### 2. Development of track

Needle entry into the desired location of the pelvicalyceal system represents the first step of a successful percutaneous intervention (Gupta, et al., 2007). The second step is to dilate a track from the skin through the renal parenchyma into the collecting system, and to place a working sheath (Wong, 2009). The tract also must be secured and dilated to allow for the passage of nephroscopic equipment or drainage catheters. In the early experience with percutaneous techniques, dilation of existing nephrostomy tracts was carried out gradually using sequentially larger telescopic dilators over a period of 8 days. Castañeda-Zúñiga et al.
first described acute dilation of the nephrostomy tract in a single session with no untoward effects. Since then, multiple techniques have been developed that allow for safe and rapid nephrostomy tract dilation, so that percutaneous access and intrarenal surgery now can be routinely performed during the same setting.

**Guide Wire Introduction**

The main principle of acute tract dilation is that, it must always be performed over a guide wire. After needle entry into the collecting system is confirmed by return of urine after removal of the stylet, the Seldinger technique is used to advance a guide wire through the needle into the collecting system. The wire should be stiff enough to support the subsequent dilation. Passage of the wire down the ureter into the bladder should be attempted to minimize the risk of wire dislodgement during fascial dilation. In situations in which this is not possible (e.g., impacted ureteral stone, narrow UPJ), the wire should be positioned in a calyx that is distant from the initial nephrostomy tract to prevent dislodgement during dilation. In patients with complete staghorn calculi, the guide wire may coil within the punctured calyx because it cannot pass into the renal pelvis. In this case, dilation must be performed very gently because the guide wire can be easily displaced. In addition to the initial working guide wire, a second safety guide wire may also be used *(Press and Smith, 1995)*.

The safety wire is inserted immediately adjacent to the working wire and serves to protect access to the nephrostomy tract in case the working wire becomes kinked or displaced. Insertion of the safety guide wire requires the use of a double-lumen catheter or a coaxial
system to accommodate two wires. This coaxial system consists of an inner dilator tapered to the size of the guide wire and an outer sheath. After the inner dilator is removed, the external sheath allows the safe insertion of the second guide wire, ensuring its correct positioning within the ureteral lumen. Various safety guide wire introducers are available (Press and Smith, 1995).

Types of Dilators

A variety of techniques exist for acute dilation of the nephrostomy tract. The most commonly used systems include progressive fascial dilators, malleable dilators, metal coaxial dilators, and high-pressure balloon dilators. The decision of which type of dilation system is used varies among urologists on the basis of personal preference and experience. Multiple investigators have found no differences in renal parenchymal damage among the various dilation methods. It should be noted however that, when comparing balloon dilators and malleable dilators, several groups of investigators observed lower renal hemorrhage rates and lower transfusion rates in patients undergoing balloon dilation (Safak et al, 2003).

(1) Fascial Dilators.

The fascial dilator system consists of progressively larger polytetrafluoroethylene (Teflon) tubes designed to slide over a 0.038-inch guide wire. They range in size from 8 to 36 Fr and are inserted in a rotating, screw-type fashion with the entire dilation procedure performed
under fluoroscopic control. The main advantage of this system is that it is safe. The stability conferred by the firm polytet composition also makes fascial dilators ideal for dilation of fibrous tracts such as may be seen in patients with a history of retroperitoneal surgery, percutaneous surgery, or inflammatory processes of the kidney (Press and Smith, 1995). The main drawback of this system is its dependence on the integrity of the guide wire (LeRoy, 1996). In addition, despite their purported safety, caution must be exercised when introducing fascial dilators because their tips can perforate the renal pelvis medially, causing excessive blood loss or extravasation of irrigating fluid into the retroperitoneum (Gupta, et al., 2007).

(2) Malleable Dilators:

Malleable dilators were developed in 1982 by Kurt Amplatz to improve upon some of the weaknesses of the older fascial dilators and are now widely referred to as Amplatz dilators (Rusnak et al, 1982). A tapered 8-Fr angiographic catheter is initially inserted down the ureter over the working guide wire, and progressively larger polyurethane catheters are serially passed over the catheter/guide wire combination. The additional stability conferred by the tapered 8-Fr catheter facilitates the entire dilation process by preventing the guide wire from kinking and by allowing the larger dilating catheters to slide more easily. These dilating catheters range in diameter from 12 to 30 Fr in increments of 2 Fr (Gupta, et al., 2007).

Once the tract is adequately dilated, an outer sheath is passed in coaxial fashion over the polyurethane dilator. The external sheath secures access to the kidney and allows the repeated introduction and withdrawal
of endourologic equipment. The sheaths range in size from 28 to 34 Fr, and the outer diameter exceeds the inner diameter by 4 Fr; thus, the 34-Fr sheath is designed to slide over the 30-Fr dilator. The sheaths are impregnated with polytef to reduce the coefficient of friction and to minimize buckling (*Gupta, et al., 2007*).

(4) **Metal Coaxial Dilators.**

Metal coaxial dilators are made of stainless steel and are mounted together in a telescopic fashion, mimicking a collapsible radio antenna. Progressively larger dilators are added until the tract is dilated to the desired size (*Alken, 1985*). The metal telescopic dilators consist of an 8-Fr hollow guide rod that slides over a guide wire and a set of six metal tubes ranging in diameter from 9 to 24 Fr. Each dilator adapts exactly to the lumen of the next dilator. A bulge at the end of the rod represents the endpoint for the progression of the dilators, ensuring that they cannot be advanced farther. After all dilators have been advanced, their tips are in the same horizontal plane, close to the tip of the guide rod (*Gupta, et al., 2007*).

The metal coaxial dilation system is rigid and theoretically is excellent for patients with previous surgery and associated perirenal fibrous tissue. However, several notable drawbacks have limited its use. The main disadvantage is that it is difficult to control the pressure exerted during dilation. The central core of the apparatus must be held firmly while the outer dilator is advanced to avoid untoward events such as perforation of the renal pelvis and the resultant risks of extravasation and hemorrhage (*Seeman and Alken, 1995*).

(4) **Balloon Dilation Catheters:**
For the fascial, malleable, and metal coaxial dilation systems, the major risk of injury stems from the uncontrolled repetitive passage of progressively larger dilators. In an attempt to minimize the morbidity of nephrostomy tract dilation, balloon dilation catheters capable of achieving tract dilation in a single step were developed (Fig. 46) (Gupta, et al., 2007)

(Fig. 46): Balloon dilation catheter and preloaded sheath (Gupta, et al., 2007).

Before inserting the balloon catheter, a 30-Fr polytef working sheath is backloaded behind the uninflated balloon. The catheter is then inserted over the guide wire until the inflatable segment traverses the nephrostomy tract. The tip of the balloon, indicated by the radiographic marker, is advanced just inside the calyx. Passing the balloon tip beyond the calyx or stone may result in infundibular tears or urothelial injury from the impaction of the stone. Once appropriately positioned, the balloon is inflated to acutely dilate the tract. Pressures of 15 to 20 atmosphere (atm) can easily be reached with the balloon catheter. In patients with no previous renal surgery, pressures of 4 to 5 atm are usually enough to dilate a nephrostomy tract. In those who have had surgery, higher pressures are required to achieve the final dilatation. As the balloon is inflated, a characteristic “waist” appears in areas of high resistance, such as the renal capsule or a previous operative scar (Fig. 47).
With persistent inflation, the balloon expands fully and the waist disappears, allowing the backloaded sheath to be advanced into the collecting system in a rotating fashion. This sheath is advanced into the tract to the end of the balloon, not the end of the catheter. The balloon is then deflated and retrieved from the tract. The working sheath provides the access for further endourologic manipulations (*Gupta, et al., 2007*).

The balloon dilator seems to be safer, faster, and with reduced X-ray exposure of the patient and surgeon. Thus, it is regarded as the gold-standard, but it is associated with a higher cost (*Miller et al., 2007*).

(Fig. 47): During balloon dilation of the nephrostomy tract, a waist can be seen at areas of high resistance such as the renal capsule and previous operative scar. In this instance, the waist (arrow) corresponds to dilation of the renal capsule (*Gupta, et al., 2007*).
3. Fragmentation and/or removal of stone

The third step is to introduce a nephroscope via the Amplatz sheath into the pelvi-calyceal system to locate the stones (Fig. 48). The standard 26 Fr rigid rod-lens nephroscope with off-set eyepiece provides excellent optics and allows the use of strong rigid instruments to deal with the stones. Continuous irrigation with warm normal saline is set up to fill the pelvi-calyceal system with fluid, with inflow via the endoscope and outflow simply via the Amplatz sheath. This allows a very rapid flow to clear stone fragments and blood, and thus enables good endoscopic view. It dissipates the heat energy of mechanical lithotripsy and so minimises its potential injury. Last but not least, the importance of an effective irrigation system is to maintain a low pressure in the pelvi-calyceal system that reduces the risks of pyelo-renal reflux and its resultant fluid absorption and sepsis (Wong, 2009).

(Fig. 48):
A: Nephroscopy and extraction of stones in prone position (Wong et al., 2009)
B: Nephroscopy and extraction of stones in supine position (Falahatkar et al., 2010)
Smaller stones can be retrieved with rigid stone forceps directly via the Amplatz sheath. Commonly preferred instruments are tripod graspers or forceps with strong alligator jaws (Wong, 2009). Larger stones have to be fragmented first, using either one of the following energies:

1. Ultrasonic lithotripsy
2. Pneumatic lithotripsy
3. Holmium laser lithotripsy
4. Electrohydraulic lithotripsy (EHL)

And lastly inspection by flexible nephroscopy

**1. Ultrasonic lithotripsy:**

Ultrasonic energy is the most commonly used method for intracorporeal lithotripsy owing to its demonstrated safety and efficacy. The piezoelectric effect creates vibrational ultrasonic energy which is transmitted down the shaft of the probe. These probes are always rigid, therefore rigid nephroscopy is required and its use is limited to calices which can only be safely reached without undue torquing of the kidney. Although solid probes are available, hollow ultrasonic probes are preferred because of the ability to suction simultaneously. They range from 3 to 12 Fr in size, with the hollow designs being larger in diameter. Under direct vision, the surgeon gently presses the tip of the probe against the stone. As the surgeon activates the probe, the assistant or activation pedal modulates the suction, thereby balancing visibility by hydrodistending the system with evacuation of broken fragments. Stone graspers are used intermittently to remove fragments less than 1 cm (Pietrow et al., 2003).
2. Pneumatic lithotripsy:

Another major energy source is the pneumatic lithotrite, or Swiss Lithoclast. This device has a generator, hand piece, and foot pedal. When activated, compressed air propels a metal projectile inside the hand piece into the base of the probe producing a “jackhammer” effect. Pressures of up to 3 atm are generated, and this ballistic energy is transmitted along the probe into the stone. (Kuo et al., 2004).

Advantages of ballistic lithotripsy include relatively inexpensive equipment with reusable components and a high margin of safety because very little heat is generated at the probe tip. Disadvantages include the inability to remove fragments simultaneously, and stone retropulsion. In an effort to improve simultaneous fragment removal, ballistic lithotripsy was combined with a suction device that can be used only with rigid probes (Delvecchio et al, 2000).

3. Holmium laser lithotripsy:

The Holmium: YAG laser generates a beam with a wavelength of 2100 nm and pulse duration of 250 µs. This wavelength is highly absorbed by water, thus the laser fiber must be placed directly on the stone. Fibers range in size from 200 to 1000 microns, and the power generated by the machine is controlled by modulating the energy (Joules) and frequency (Hertz) of each pulse. The benefits of using Holmium laser are that very hard stones can be broken, and that flexible nephroscopy can be used with these energy sources. However, a significant downside compared to ultrasonic lithotrities is that suctioning cannot be performed simultaneously. However, one recent report used an innovative suctioning device together with the Holmium laser (Cuellar and Averch 2004).
4. Electro-hydraulic lithotripsy (EHL):

EHL utilizes electrical energy that overcomes the insulative gap of an electrode to produce a spark and an ensuing cavitation bubble (Yang and Hong, 1996). Symmetrical collapse of the cavitation bubble results in a secondary shockwave or high-speed microjets if the bubble collapses asymmetrically. Both the secondary shockwave and microjets are responsible for stone fragmentation (Willscher et al, 1988; Denstedt and Clayman, 1990). An advantage of EHL is its low capital cost compared with laser units. EHL probes are a disposable component and depending on stone hardness, more than one probe may be required to achieve complete stone fragmentation. The probes are more flexible than laser fibers. The most important disadvantage of EHL is that some stones are resistant to fragmentation and that high peak pressures are generated at a distance from the probe tip, producing a narrow margin of safety (Vorreuther, 1993).

- Drainage after Percutaneous Nephrolithotomy:

At the end of the operation, a percutaneous nephrostomy catheter is inserted along the track and left in place for one to two days. This temporary catheter nephrostomy provides monitoring for haemorrhage and diverts urine in case drainage down the ureter is not functioning well due to temporary obstruction by inflammatory swelling or blood clot (Wong, 2009), and maintains renal access if second look nephroscopy is required, and tamponades any bleeding points. There are multiple choices in nephrostomy drainage, and the final choice is dictated by surgeon
experience and discretion. Self-retaining tubes (balloon-Foley, Malecot, Cope loop) are preferred over simple, non self-retaining tubes such as red rubber Robinson catheters or modified chest tubes because the latter can be easily dislodged. Patient discomfort is greatest with large supracostal nephrostomy drainage tubes (Kim et al 2005).

Standard versus tubeless PCNL:

External drainage of the pelvicalyceal system after percutaneous procedures of the upper urinary tract (i.e., percutaneous nephrolithotomy) has been routine practice among endourologists. (Wickham et al, 1984; Bellman et al, 1997; Delaney and Wake, 1998; Goh and Wolf, 1999) This technique has translated into the modality of “tubeless percutaneous renal surgery” in selected patients at some institutions (Limb and Bellman, 2002). In addition, use of hemostatic sealants at the renal parenchymal defect after tubeless percutaneous procedures (i.e., nephrolithotomy) has shown some benefit in limiting postoperative urine extravasation and aiding in hemostasis (Mikhail et al, 2003; Lee et al, 2004; Noller et al, 2004). Nevertheless, postoperative drainage with a nephrostomy tube after percutaneous renal surgery remains a safe and standard practice (Gupta et al., 2007).

❖ Post-operative Care

The patient is only left with a wound of the size of the working sheath that is no more than 1 cm. However, the patient may still have some pain albeit moderate, and nausea is not uncommon. It is advisable on the first day post operation to limit oral intake to fluids, give
intravenous fluid infusion, prescribe appropriate analgesic as required, and to continue antibiotic therapy (Wong, 2009).

Twelve to 48 hours after the percutaneous procedure, ante grade nephrostograms are typically performed. Complete scout radiographs should be performed to exclude residual stone fragments. Contrast should delineate upper tract anatomy and drain freely into the bladder. Hopefully there are no stones noted and there is free drainage into the bladder. In these situations the nephrostomy may be clamped and removed after a few hours or removed immediately after the study. If there are fragments large enough to be of clinical concern, the surgeon has the option of recommending shock-wave lithotripsy or second-look nephroscopy (Park et al., 2006).
RECENT ADVANCES IN PERCUTANEOUS NEPHROLITHOTOMY

The continuous innovations in technology, instrumentations, and techniques allow urologists to perform percutaneous nephrolithotomy (PCNL) with increasing efficacy. Although recent advances have facilitated the procedure, some steps are still challenging (Erem K et al; 2014).

Percutaneous nephrolithotomy (PCNL) is a well set, well known, and widely accepted minimally invasive surgical procedure for stone removal within the urological procedures. As with many minimally invasive procedures, the main purpose of PCNL is the complete removal of the renal calculi, reducing mortality and morbidity without deteriorating quality of life (Kalogeropolou C et al; 2009).

However, this technique is directly competing with other minimally invasive techniques such as retrograde intrarenal surgery (RIRS) and laparoscopic procedures. The indications for RIRS have expanded, and it became a viable alternative to PCNL in select cases. However, PCNL is still the gold standard for high-volume renal calculi (>2 cm), and data demonstrating utilisation of RIRS for >1 cm renal stones are still underwhelming. Nevertheless, excessive efforts have been made to reduce the morbidity and improve the efficiency of PCNL so as to make it more competitive (Li Zc et al; 2012).
In accordance with the developing technology, PCNL requires better instruments for complete stone removal, more precise stone targeting, and access to the kidney and relevant calices. The newer developments have mainly focused on imaging techniques, as well as the fusion of multiple imaging procedures, tracking and navigation systems during access to the stone, miniaturisation of the instruments, and robotic systems.1-7 Furthermore, the debate continues over the use of the prone or supine position, tube or tubeless PCNL, and the efficiency of ‘microperc’(Rodrigus P et al;2013).

(A)Imaging:

Computed tomography (CT) is mandatory for preoperative planning and appropriate percutaneous access. It shows the anatomy of kidney calices and the relation of the stone to the pelvicalyceal system, the kidney position, and its relation to other abdominal structures (Jessen JP et al; 2013).

Angiographic CT can also be used for detailed images of blood vessels and calyceal anatomy. Technological advances have also enabled the acquisition of three-dimensional (3D) images through ultrasound (US), providing volumetric measurements and 360-degree analyses of anatomic structures(Jessen JP et al; 2013).

After using the benefits of cone beam CT (CBCT) in neurosurgical operations, the application has been extended to percutaneous surgery. CBCT is a novel imaging modality that combines the versatility of conventional C-arm with the functionality of cross-
sectional imaging to provide high-resolution, 3D, CT-like images (Roy OP et al; 2012)

As a result of a recent study, the authors concluded that CBCT could help for better percutaneous access using the advantages of improved imaging, which allows surgeons to have similar real-time access via high quality CT images. The intraoperative availability of images may reduce the need for postoperative imaging and subsequent adjunctive procedures for clearance of residual fragments (Roy OP et al; 2012).

1-Multimodal imaging:

Several studies presented the combination of different imaging techniques. Among these, Li et al. 2012; combined preoperative magnetic resonance imaging (MRI) with augmented intraoperative USG images, and found valuable results due to the additional advantages of high resolution, multi-planar, and 3D images (Yaniv Z et al; 2009).

The Interactive Closest Points algorithm was used as a rigid registry process through the manual selection of pairs of points in both images from the cranial pole, caudal pole, and kidney hilum (Leroy A et al; 2008)

A respiratory gating method was also used to minimise the impact of kidney deformation by using US to obtain only images at the same stages of the respiration cycles (Yaniv Z et al; 2009).

In another study, an automatic rigid registration method was used to combine CT and US images. Image contours were highlighted by using processing algorithms to improve cross-correlation of image intensity.
Wein et al. 2014 presented a fully automatic image-based algorithm for registering 3D freehand USG sweeps with CT images. Target distance error ranged between 3.5-8.1 mm in these studies.

Imaging is not only necessary to plan pelvicalyceal access, but also to evaluate treatment success and complications after PCNL. Previous studies aimed to identify possible preoperative radiological findings that predict prognostic factors. Several authors mentioned the necessity of reliable prediction models (Wein et al; 2014).

Thomas et al. 2011 developed the Guy’s stone score to grade PCNL complexity based on radiological findings. Lately staghorn morphometry, S.T.O.N.E. nephrolithometry, and a nephrolithometric nomogram have been developed to estimate PCNL success prior to surgery.

2-Staghorn Morphometry

Staghorn calculi sometimes require several renal access procedures to obtain complete clearance. Staghorn morphometry is a new prognostic tool to predict the position of access and stages for PCNL, which requires 3D CT urography assessment with volume-rendering software (Matlaga BR et al ;2011)

Recently, a new classification of staghorn stones into three types has been proposed based on the volume of distribution of stone and the surface area. Type 1 staghorn stones have a total stone volume of <5,000 mm3 with <5% of unfavourable calyceal stone percentile volume, whereas type 3 staghorn stones have a total volume of >20,000 mm3 with >10% of unfavourable calyceal stone percentile volume. The type 2 staghorn stone is in between. Based on statistical models, they found that
a type 1 staghorn stone would require one access in one stage, type 2 stones would require one access in more than one stage, or multiple accesses in one stage, and type 3 stones would require multiple accesses and stages\textit{(Thomas K et al;2011)}. 

3-\textit{S.T.O.N.E. Nephrolithometry}

In this scoring method, five variables from preoperative non-contrast enhanced CT were included; stone size, tract length, obstruction, number of involved calices, and essence or stone density. Stone-free patients had statistically significant lower scores than the patients with residual stones (p=0.002). Additionally, the score was correlated with the estimated blood loss (p=0.005), operative time (p=0.001), and length of hospital stay (p=0.001) \textit{(Okhunov Z et al ;2013)}. 

4-\textit{Nephrolithometric Nomogram}

A nomogram was constituted to predict the stone-free rate using preoperative parameters, including case volume, prior treatment, stone burden and location, staghorn stones, and number of stones. \textit{(Mishra S et al.;2013)}.

A high total score was significant for a higher chance of stone-free rate, while low score had a lower chance of stone-free rate. Stone burden was the best predictor of treatment outcome. In addition, nephrolithometric nomogram showed consistent but lower performance in the lower stone-free rate ranges \textit{(Mishra S et al.;2013)}. 
(B)-Instruments:

The evolution of devices from their prototypes has increased the instrumentation options for urologists. Improved lithotripsy devices, digital nephroscopes, stone retrieval and occlusion devices, and haemostatic or adhesive agents for tubeless procedure can be valuable tools for successful PCNL. New lithotripsy devices, including a combination of ultrasonic-pneumatic device, dual ultrasonic lithotripter, and pneumatic stone breaker, have the potential to enhance the efficiency of stone fragmentation (Antonelli JA et al;2014).

Micro PCNL (Microperc)

Endoscopic access technique has been introduced in recent years using micro-optics, which are inserted either within the needle or the working sheath. ‘Microperc’ is a recently described technique in which percutaneous renal access and lithotripsy are performed in a single step using a 16 gauge micro-puncture needle. The main aim of this innovation is to reduce the tract size with the intention of less morbidity. Bader et al.2011 reported a modified needle of 1.6 mm in diameter that integrates 0.9 and 0.6 mm micro-optical system. The authors concluded that the micro-optical needle appears to be helpful for confirming percutaneous access before dilatation of the tract, thus decreasing tract size, need for imaging, and multiple accesses. Desai et al.2011 further modified this concept and completed PCNL through the ‘all seeing needle’.
(C)-Access:

(1)-Endoscopically guided PCNL:

*Grasso et al. 1995* reported first endoscopy-assisted percutaneous renal access as an alternative technique for successful access in a few patients in whom other methods failed. Later, the technique was developed as a primary access method by insertion of the needle into the collecting system under the guidance of both fluoroscopy and direct vision of flexible ureteroscope. The guidewire can be passed into the access sheath, and easily delivered via the urethral end of the access sheath. The direct visual confirmation has the advantage of a successful access in a short time with no requirement of multiple attempts.

(2)-Robotics:

Most urological procedures are amenable for robot-assisted surgery. Different types of robotic systems are under development. These include image-guided robots that, in addition to the direct visual feedback, use medical images for guiding the intervention (*Cinquin P. et al; 2011*).

Recently, one centre presented three different types of medical robots. The first system (PAKY-RCM) consists of an orientation module between a needle driver and a robotic 7-degree free arm, enabling the positioning of the needle and completion of its insertion using rotational movements. Additionally, the system regulates the strength during the access. The surgeon controls all movements of the robot via a joystick under the guidance of fluoroscopic images (*Lazarus J et al; 2011*).
The AcuBot robot includes previous robotic modules, but adds a bridge-like structure over the table, and a linear pre-positioning stage. This attaches to CT or fluoroscopy table of the imager. The mounted needle driver in the module is supported by a passive arm. It has 6 degrees of freedom configured for decoupled positioning, orientation, and instrument insertion ((Lazarus J et al;2011).

The newest robot (MrBot) is introduced as a fully-actuated MRI robot for image-guided access for percutaneous interventions. The robot is customised for needle insertion and designed to be compatible with the highest field strength. It is constructed with a pneumatic stepper motor using nonmagnetic and dielectric materials. This system, with 6 degrees of freedom, has a great potential for PCNL (Nicolau S et al;2013).

Lately, advances of US-guided robotic systems have been reported. The typical approach resorts to a surgical needle attached to a robotic arm that is driven automatically or controlled by the surgeon in 3D or 2D imaging volume(Nicolau S et al;2013).

A locator apparatus that stabilises the needle during the access was tested in a study. The authors achieved a mean access time of 225 seconds, which is much quicker than the average access time reported for traditional technique (approximately 12 minutes) (Teber D et al; 2009).

Although medical robotic systems have certain benefits, supporting technology is still struggling to overcome some important problems in difficult initial setups, expensive costs, mechanical problems, absence of tactile feedback, and not fully developed motion tracking systems (Rodrigues PL et al; 2013).
(3)-**Tracking and Surgery Navigation:**

Navigation software and augmented reality systems have recently been introduced as computer-assisted navigation systems combining imaging and tracking systems. Most of them work by obtaining the target anatomic area from preoperative data, using image segmentation algorithms or computer graphics (direct volume or surface rendering). Then, the image processed data are superimposed and registered onto a real-time intraoperative video (augmented reality) or static preoperative volume data (navigation software). The surgical tools are commonly updated using a motion tracking system. *(Rodrigues PL et al; 2013)*.

Recently, *Rassweiler et al. 2014* reported iPad-assisted percutaneous access. All anatomic structures were identified and marked in preoperative CT images. Augmented virtual reality of preoperative CT 3D images could display all anatomical details of the kidney. There was no limitation of USG such as shadows caused by ribs, and the advantage of freehand needle placement without holding the US probe. The iPad was used as a camera to take a picture of the operating field. Then compressed data were transferred to a server located in a control room via Wi-Fi. The server operated the algorithm to identify the position and orientation of the navigation, and to overlay it accordingly with preoperative marked CT images, which were sent back to the iPad. The exact overlays of optical markers, which must always be visible on the iPad screen, were rigidly registered for motion tracking system.
PATIENTS AND METHODS

This study was conducted on 60 patients with renal stone disease from March 2013 to October 2016 in urology department, Benha University Hospital, and were divided randomly into 3 groups: group (A): 20 patients underwent percutaneous nephrolithotripsy in flank suspended supine position (FSSP), group (B): 20 patients underwent percutaneous nephrolithotripsy in standard supine position, group (C): 20 patients underwent percutaneous nephrolithotripsy in the prone position.

Exclusion criteria:

- Renal anomalies.
- Bleeding diathesis.

All patients were evaluated by:

I- Complete history taking including:

- Age of the patient.
- Complaint: right or left flank pain.
- History of previous operations, chronic urinary tract infection, chronic systemic disease and/or blood dyscryiasis.

II- Examination: both general and local

A- General examination: as vital signs, bony deformity, chest and heart examination, and body built by body mass index (BMI) to determine obesity and its degree from the following formula:

Weight kg / Height m$^2$.

"0": Acceptable (20-24.9 kg/m$^2$).
"I": Overweight (25-29.9 kg/m²).
"II": Obese (30-39.9 kg/m²).
"III": Morbid obese (>40 kg/m²).

**B- Local examination**: as regard, scars of prior operations, incisional hernia, abdominal or flank swelling, ascites and organomegally.

**III- Investigations:**

The patients were subjected to routine laboratory and radiological investigations including:

**A- Laboratory investigations:**

- Complete urine analysis with culture and sensitivity test when needed.
- Serum creatinine levels.
- Complete blood picture.
- Bleeding and coagulation time.
- Liver function tests (bilirubin, prothrombin time and activity, SGPT and SGOT).
- Fasting blood sugar.

**B- Radiological investigations:**

- Plain Urinary Tract (PUT) (Fig. 49).
- Abdomino-pelvic ultrasound.
- Non contrast spiral CT abdomen and pelvis with coronal reconstructive images (Fig. 50).
Fig. 49: A digital PUT showing a right upper third ureteric stone with a left renal stone with left inserted DJ.

Fig. 50: Showing (A): a non-contrast pelvi abdominal CT cross section showing a left renal pelvic stone with left DJ stent and a stone upper third right ureter (B): the soft tissue subtraction of the same patient.
IV- Preoperative requirements:

1- Informed consent:

It was written by all our patients in which they were informed about the complications of PCNL and conversion to open surgery may be necessary when the procedure can not properly or safely completed or if significant complications occur during the procedure.

2- Patient preparation:

The day before surgery the patients were subjected to:

a- One gm parenteral cephalosporin was given with induction of anaesthesia.

b- The patient was typed and cross matched for 2 units of blood.

3- Instrumentations and equipments specific to the procedure:

Which were prepared and checked before the operation. They include Instrumentations for ureteric catheter insertion (Fig. 51) and instrumentations for PCNL (Fig. 52).

(Fig. 51): Instrumentations for ureteric catheter insertion.
**V- Anesthesia:**

- General anesthesia was performed to all patients according to Standard technique.

**VI- Technique:**

In the 3 groups, the patients were in the lithotomy position for ureteric catheter insertion, which was fixed to a urethral catheter (Fig. 53&54).

(Fig. 52): Instrumentation for PCNL.

(Fig. 53): Ureteric catheter insertion

(Fig. 54): Ureteric catheter insertion under image
Then the patients were divided into 3 groups, 20 patients turned in flank suspended supine position (FSSP) (group A), another 20 patients in supine position (group B), the remaining 20 patients turned in prone position (group C).

**Group (A): Flank suspended supine position (FSSP) PCNL:**

The patients were placed in the supine position with the shoulder and the buttock raised by a 3 liter bag of water suspending the flank of the affected side. The body contour was aligned to the edge of the table. The operating table was adjusted to the jackknife position with the tip of the lower part of the table slightly lowered. The leg of the affected side of the patient a straightened dorsally flexed and slightly inner rotated, the knee of the other side is flexed. The patients were then immobilized at the chest and the pelvis with two adherent tapes which crossed each other at the abdomen to form a 'V' shape (fig.55).

(Fig.55): The FSSP in (A) it shows the suspended flank after raising the shoulder and the bittock by a 3 liter bag of water while (B) shows the immopalized patient at the pelvis and the chest by 2 adhesive taoes crossing in front of the abdomen forming a V shape.
The patients were then sterilized by povidone iodine 10% solution followed by toweling of the patient, then by a sterilized marker pen 3 lines were drawn on the anterior, middle and posterior axillary lines (fig.56).

(fig.56): it shows the patient was toweled and putting our 3 marks

Then marking the site of the stone by a mark, followed by retrograde urography by fluoroscopic imaging and selection of the proper calyx to reach the stone (fig.57).

(fig.57): Retrograde urography followed by selection of the proper calyx.

Puncture the skin along the posterior axillary line under guidance of the fluoroscopy this step was done with one assistant injecting normal saline through the ureteral catheter to create artificial hydronephrosis and
another assistant pressing on the anterior abdominal wall of the affected side to immobilize the kidney during puncture, till reaching the pelvi-calyceal system and aspiration of urine.

Insertion of J tip guide wire to be passed through the ureter or coiled to a far calyx and insertion of safety guide wire, then dilatation of the tract by Alkene's dilators or Teflon dilators then application of Amplatz sheath over the last dilator (Fig.58).

(fig.58): it shows after successful insertion of the Amplatz sheath.

Then using nephroscopy and destruction of the large stones by pneumatic lithotripsy & extraction of smaller ones & fragments by stone forceps, then nephrostomy tube was fixed and antegrade urography was done (fig.59).
(fig.59): (A) shows the antegrade urography at the end of the procedure while (B) showing the inserted nephrostomy tube.

**Group (B): Supine PCNL:**

The patient remains in the supine position with the side of the interest at the edge of the table with a small cushion was placed under the flank to elevate it 15-20 degrees (Fig. 60).

(Fig. 60): Supine position of the patient with the side of interest at the edge of the table.

After sterilization & toweling as before, puncture the skin along the midaxillary line 0 degree (tangential) with the operating table or
slightly upwards, till reaching the pelvicalyceal system usually through the lower or the middle calyx (fig. 60).

After gaining urine, a J tip guide wire was inserted through the punctured needle to pass through the ureter or coiled to a far calyx and insertion of safety guide wire, then incision of the skin and fascia with scalpel to ease the dilatation.

Tract dilatation by Alkene's dilators or Teflon dilators till application of Amplatz sheath over the last dilator (Fig. 61).

(fig. 60): Retrograde and puncture needle

(fig. 61): A&B showing dilatation by Teflon dilator.
Then using nephroscopy to visualize the stone, large stones were fragmented using pneumatic lithotripsy, and smaller ones extracted using stone forceps.

**Group (C): prone PCNL:**

The patient was turned prone with putting a bridge or towel under his chest & pelvis leaving the abdomen free for respiration, then sterilization of the skin by povidone-iodine 10% solution, then toweling the patient (Fig. 62).

(Fig. 61): Prone position with a bridge under the chest and the pelvis leaving the abdomen free for respiration.

(Fig. 62): Sterilization and toweling in prone position.
Then marking the site of the stone by a mark, then retrograde urography was done using fluoroscopic image & selection of the proper calyx to gain access to the stone.

Puncture the skin along the posterior axillary line 30 degrees with the operating table, till reaching the pelvi-calyceal system with aspiration of urine (Fig. 63).

(Fig. 63): A. Puncture needle entry at the posterior axillary line subcostally.

. Successful puncture of the pelvicalyceal system with urine return.

Insertion of J tip guide wire to be passed through the ureter or coiled to a far calyx and insertion of safety guide wire then dilatation of the tract by Alkene's dilators or Teflon dilators then application of Amplatz sheath over the last dilator.

Then using nephroscopy and destruction of the large stones by pneumatic lithotripsy & extraction of smaller ones & fragments by stone forceps, then nephrostomy tube was fixed and antegrade urography was done.
In all 3 groups, nephrostomy tube was clamped the day of surgery for tamponad and opening it at the morning. Stone clearance was determined by a combination of fluoroscopy and rigid nephroscopy at the end of the procedure & sometimes with a PUT, U/S or CT postoperative if there was not confidence in the intra-operative assessment.

If the patient was stone free, the nephrostomy tubes removed after 1 day postoperative & the ureteric and the urethral catheters removed after 2 days further, but when there were residual stones, a second look PCNL after 1 week was done.

We performed (3) case of staghorn stone in FSSP position, (1) cases of staghorn stone in prone position, no staghorn stones were performed in the supine position. The procedure in morbidly obese patients is easier in FSSP position & supine position than prone one that we performed the procedure in (2) cases of morbid obesity in FSSP position (1) in the supine position & position and (1) cases in prone position.

The preoperative data (patient's characters and stones' characters) of both groups as regard to sex, age, BMI, previous renal surgery, stone side, stone size, stone number, stone site and stone radio-opacity are recorded and tabulated. Also, the intra-operative data of both groups as regard to calyceal puncture, operative time, stone free rate, blood loss and intra-operative morbidity are recorded and tabulated. Finally, post-operative morbidity, and the need auxillary treatment or re- treatment of the 3 groups are also recorded and tabulated.
Results

From table (1) to table (3): comparison between studied groups regarding personal data:

Table(1): Sex of the patients in the 3 groups:

<table>
<thead>
<tr>
<th></th>
<th>Group A FSSP</th>
<th>Group B supine</th>
<th>Group C prone</th>
<th>X^2 test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11 (55%)</td>
<td>12 (60%)</td>
<td>15 (75%)</td>
<td>1.87</td>
<td>0.393</td>
</tr>
<tr>
<td>Female</td>
<td>9 (45%)</td>
<td>8 (40%)</td>
<td>5 (25%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.(64): Sex of the patients in the 3 groups
Table(2): Showing the age of the patients in the 3 groups:

<table>
<thead>
<tr>
<th></th>
<th>Group A FSSP N</th>
<th>Group B supine N</th>
<th>Group C prone N</th>
<th>X² test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age /y Mean ±SD</td>
<td>39.05±14.93</td>
<td>42.35±14.31</td>
<td>41.15±15.18</td>
<td>Stt=0.254</td>
<td>0.667</td>
</tr>
</tbody>
</table>

Table(3): Showing the BMI in the 3 groups:

<table>
<thead>
<tr>
<th></th>
<th>Group A FSSP N</th>
<th>Group B supine N</th>
<th>Group C prone N</th>
<th>X² test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI Mean ±SD</td>
<td>28.81±6.16</td>
<td>25.68±6.74</td>
<td>27.94±6.65</td>
<td>Stt=1.23</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Fig.(65): showing the age and the BMI in the 3 groups.
Tables from 1 to 3 show the demographic data of the studied cases (total number was 60 patients divided into 3 groups A, B, and C 20 patients in each group. Mean age in group A was (39.05±14.93) ranging from 65 to 17 years old, in group B the mean age was (42.35±14.31) ranging from 69 to 23 years old while group C the mean age was (41.15±15.18) ranging from 70 to 19 years old. The mean body mass index (BMI) by Kg/sq.m in group A was (28.81±6.16) ranging from 18 to 40, in group B was (25.68±6.74) ranging from 19 to 39.65, and in group C the mean BMI was (27.94±6.65) ranging from 18 to 36.5 kg/sq.m. There were 38 males and 22 females divided into the 3 groups, in group A there were 11 males (55%) and 9 females (45%), group B there were 12 males (60%) and 8 females (40%), while in group C there were 15 males (75%) and 5 females (25%).

**From table (4) to table(7): Comparison between the studied groups according to the stone characters:**

Table (4): comparing the 3 groups according to the side of the stone:

<table>
<thead>
<tr>
<th>Side</th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>$X^2$ test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rt</td>
<td>13(65%)</td>
<td>14(70%)</td>
<td>9(45%)</td>
<td>2.92</td>
<td>0.233</td>
</tr>
<tr>
<td>Lt</td>
<td>7(35%)</td>
<td>6(30%)</td>
<td>11(55%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table (5): comparing the 3 groups according to the number of the stones:

<table>
<thead>
<tr>
<th>Number</th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>$X^2$ test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>11(55%)</td>
<td>13(65%)</td>
<td>16 (80%)</td>
<td>2.85</td>
<td>0.241</td>
</tr>
<tr>
<td>Multiple</td>
<td>9 (45%)</td>
<td>7 (35%)</td>
<td>4 (20%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table (6): comparing the 3 groups according to the size of the stone:

<table>
<thead>
<tr>
<th></th>
<th>Group A FSSP</th>
<th>Group B Supine</th>
<th>Group C Prone</th>
<th>St t test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size/cm Mean ±SD</td>
<td>2.82±0.91</td>
<td>2.71±0.79</td>
<td>2.57±0.59</td>
<td>0.526</td>
<td>0.594</td>
</tr>
</tbody>
</table>

Fig(66): showing the side, the number, and the size in the 3 groups

Table (7): comparing the 3 groups according to the site of the stones:

<table>
<thead>
<tr>
<th>Site of stone:</th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>FET</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>3(15%)</td>
<td>0(0%)</td>
<td>1(5.3%)</td>
<td>7.63</td>
<td>0.447</td>
</tr>
<tr>
<td>Middle</td>
<td>4(20%)</td>
<td>6(30%)</td>
<td>7(36.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>8(40%)</td>
<td>9(45%)</td>
<td>6(31.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td>5(25%)</td>
<td>5(25%)</td>
<td>3(15.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi-site</td>
<td>0(0.%)</td>
<td>0(0%)</td>
<td>2(10.5%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tables from 4 to 7 are comparing the studied groups according to the stone characters; there were 35 right renal stones and 24 left renal stones divided in to 3 groups. Group A 13 right renal stone cases (65%) and 7 left renal stones cases(35%), group B had 14 right renal stones patients(70%) and 6 left renal stones patients (30%),as for group C there were 9 right renal stones patients (45%) and 11 left renal stones cases (55%).According to the stone multiplicity in group A there were 11 cases of single renal stones (55%) and 9(45%) cases of multiple renal stones, in group B there were 13 single renal stones (65%) and 7 cases (35%) of multiple renal stones as in group C there were 16 (80%) single renal stones and 4 (20%) multiple renal stones.as for the size of the stones in cm in group A the mean size was (2.82± 0.9) ranging from 4.5cm to 1.5 cm, group B the mean size was (2.7±0.59) ranging from (4cm to 1.5cm) while in group C the mean size was (2.57 ±0.59) ranging from 1.5cm to 3.9cm.As for the stones locations in group A there were 3(15%) upper calceal stones,4(20%) middle ,8 (40%)lower, and 5 (25%) renal pelvic stones, in group B there were no upper calceal stones, 6 cases (30%) of
middle calceal stones 9 (45%) cases of lower calceal stones and 5 cases (25%) of renal pelvic stones, while in group C there were 1 case (5.3%) of upper calceal stones 7(36.8%) of middle calceal stones, 6 (31.6) of lower and 3 cases of multisite renal stones (10.5%).

**Intra operative data were tabulated in the 3 groups from table (8) to table (11):**

Table (8): showing the puncture site:

<table>
<thead>
<tr>
<th></th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>FET</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Puncture site:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>4(20%)</td>
<td>6(30%)</td>
<td>4(20%)</td>
<td>0.769</td>
<td>0.799</td>
</tr>
<tr>
<td>Lower</td>
<td>16(80%)</td>
<td>14(70%)</td>
<td>16(80%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.(68): comparing the puncture site between the 3 groups.
Table (9): showing operative time in the 3 groups:

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>St test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operative time (min)</strong></td>
<td>61.65±15.14</td>
<td>75.95±18.11</td>
<td>78.4±9.7</td>
<td>7.54</td>
<td>0.001**</td>
</tr>
<tr>
<td>Mean ±SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.(69): showing the operative time in the 3 groups.

Table(9) & figure (69) the mean operative time by *minutes* of the operative time of the 3 groups (which is defined from uretral catheterization to the placement of nephrostomy tube). In group A the mean operative time was (61.65±15.14), in group B the mean time was (75.95±18.11), while in group C the mean operative time was (78.4±9.7) minutes. Patients who underwent FSSP PCNL had the least operative time in comparison to the patients in group B who underwent supine PCNL and C who underwent prone PCNL (which had the longer operative time mainly due to changing of the patients position) with a significant statistical difference between the 3 groups.
Table (10) showing the intraoperative morbidity in the 3 groups:

<table>
<thead>
<tr>
<th>Intra-operative morbidity</th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>X^2 test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1(5%)</td>
<td>2(10%)</td>
<td>3(15%)</td>
<td>^2.03</td>
<td>0.505</td>
</tr>
<tr>
<td>No</td>
<td>19(95%)</td>
<td>18(90%)</td>
<td>17(85%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As in table (10) which is showing the intraoperative morbidity, in group A patients who underwent FSSP PCNL there was 1 patient who had intraoperative morbidity(5%) the patient lost significant amount of blood that necessitated one unit of blood transfusion , in group B patients 2 patients (10%) had intraoperative morbidity on patient had significant blood loss which necessitated one unite of blood transfusion, and the other patient we lost the nephrostomy tract as bothe guide wires fell , so we left the nephrostomy tube as a drain and the patient had a 2\textsuperscript{nd} look PCNL, while in group C patients 3 patients (15%) had intraoperative morbidity 2 patients had significant blood loss which they had one unit of blood transfusion each, while the 3rd patient had significant bleeding during dilatation of the tract, so we left a nephrostomy tube as a tamponed and the patient underwent 2\textsuperscript{nd} look PCNL later. There was no significant statistical difference.
Table (11) showing the intraoperative blood loss which needed blood transfusion in the 3 groups:

<table>
<thead>
<tr>
<th>Blood loss</th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>FET</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>1(10%)</td>
<td>2(15%)</td>
<td>2(15%)</td>
<td>0.424</td>
<td>1.0</td>
</tr>
<tr>
<td>Absent</td>
<td>19(90%)</td>
<td>18(85%)</td>
<td>18(85%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.(70): showing the blood loss which needed blood transfusion in the 3 groups
The post-operative data were tabulated from table (12) to table (15):

Table (12): showing the postoperative morbidity in the 3 groups:

<table>
<thead>
<tr>
<th>Post-operative morbidity</th>
<th>Group A N(%)</th>
<th>Group B N(%)</th>
<th>Group C N(%)</th>
<th>FET</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>2(10%)</td>
<td>3(15%)</td>
<td>2(10%)</td>
<td>0.454</td>
<td>1.0</td>
</tr>
<tr>
<td>No</td>
<td>18(90%)</td>
<td>17(85%)</td>
<td>18(90%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.(71): showing comparison between the 3 groups regarding the intra-operative & postoperative morbidity.
Table 12 showing the patients in group A "FSSP" in which 2 patients (10%) had postoperative morbidity, one patient had postoperative fever which was relieved by anti-pyritics and another patient his nephrostomy tube was slipped but was passed under conservative treatment, in group B patients 3 patients (15%) had post-operative morbidity 2 of them had postoperative fever which was relieved by anti-pyritic and another patient who had perinephric collection upon which he had blood transfusion pre and post-operative, fluids, antibiotics, anti-pyritic and a JJ stent was placed which was removed on month later, and in group C patients 2 patients (10%) had postoperative morbidity one patient had postoperative fever and the other had postoperative UTI both patients received antibiotics, anti pyritics and fluids.

Table (13): showing comparison between the studied groups according to the patients who needed re-treatment in the form of second look PCNL:

<table>
<thead>
<tr>
<th></th>
<th>Group A FSSP N(%)</th>
<th>Group B Supine N(%)</th>
<th>Group C Prone N(%)</th>
<th>X² test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Re tt with pcnl</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1 (5%)</td>
<td>2 (10%)</td>
<td>1 (5%)</td>
<td>^0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>No</td>
<td>19 (95%)</td>
<td>18 (90%)</td>
<td>19 (95%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. (72): showing the comparison between the three groups.

Table (14): comparing the 3 groups according to the needed auxiliary treatment in the form of uretroscopy and ESWL:

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>X^2 test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSSP N(%)</td>
<td>Supine N(%)</td>
<td>Prone N(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Auxillary ttt</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eswl</td>
<td>1(5%)</td>
<td>2(10%)</td>
<td>2(10%)</td>
<td>^0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>UrS</td>
<td>-</td>
<td>-</td>
<td>1(5%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig.(73): comparing the 3 groups according to the need of auxiliary treatment.

Tables 13 & 14 comparing the patients in the 3 groups in regards to the patients who needed re-treatment in the form of 2\textsuperscript{nd} look PCNL and the need of auxiliary treatment in the form of ESWL & URS. In group A patients who underwent FSSP PCNL one patient needed 2\textsuperscript{nd} look PCNL (5\%) while another patient needed auxiliary treatment (5\%) in the form of ESWL, in group B patients "supine" 2 patients(10\%) underwent 2\textsuperscript{nd} look PCNL and another 2 patients needed auxiliary treatment in the form of ESWL(10\%), and in group C patients 1 patient (5\%) needed 2\textsuperscript{nd} look PCNL ,while 3 patients needed auxiliary treatment 2 of them(10\%) needed ESWL, and another 1(5\%) needed uretroscopy treatment there was no statistical difference.
Table(15): Comparing the stone free rate between the 3 groups:

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>X² test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSSP N(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>1(5%)</td>
<td>4(20%)</td>
<td>3(15%)</td>
<td>^2.03</td>
<td>0.505</td>
</tr>
<tr>
<td>No</td>
<td>19(95%)</td>
<td>16(80%)</td>
<td>17(85%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.(74): comparing the 3 groups according to the stone free rate

In regards to the stone free rate shown in table 15 & figure 74 one patient (5%) in group A had residual stone, while 4 patients (20%) in group B had residual stones, while in group C 3 patients had residual (15%), all these patients needed no 2nd look PCNL or auxillary treatment.
Data management

The clinical data were recorded on a report form. These data were tabulated and analyzed using the computer program SPSS (Statistical package for social science) version 16 to obtain:

Descriptive data

Descriptive statistics were calculated for the data in the form of:

1. Mean and standard deviation ($\pm SD$) for quantitative data.

2. Frequency and distribution for qualitative data.

Analytical statistics

In the statistical comparison between the different groups, the significance of difference was tested using one of the following tests:

1- ANOVA test (F value): Used to compare mean of more than two groups of quantitative data.

Inter-group comparison of categorical data was performed by using chi square test ($X^2$-value) and fisher exact test (FET).

\[
x^2 = \sum \frac{(observed - expected)^2}{Expected}
\]

\[
Expected = \frac{col.total \times row.total}{Grand \ total}
\]

A $P$ value $<0.05$ was considered statistically significant (S) while $>0.05$ statistically insignificant $P$ value $<0.01$ was considered highly significant (HS) in all analyses.