DIURESIS RENOGRAPHY:
AS A CLINICAL STUDY FOR A
DILATED UPPER URINARY TRACT

THESIS
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قالوا سبحانه: "إلا إما إعلمتنا إنك أنت العليم الحكيم صدق الله العظيم" 

آية 35 سورة البقرة
DEDICATION

to my sweat heart

-Mohamed
- Ghada
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"In the Name of Allah, Most Gracious Most Compassionate"

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INTRODUCTION AND AIM OF THE WORK
INTRODUCTION

AND AIM OF THE WORK

The diagnosis and management of upper urinary tract obstruction continue to be important problems in both pediatric and adult urology. The clinician is frequently confronted with a dilated collecting system and must determine whether this system is obstructed or whether the dilatation is a consequence of muscular atony or structural dysmorphism (Thrall, 1988).

The distinction between significant mechanical obstruction and dilatation not associated with obstruction is fundamental and critical to patient management. Uncorrected obstruction can lead to renal parenchymal atrophy and an increased likelihood of intercurrent problems, such as infection. Severe, prolonged and uncorrected obstruction can ultimately lead to complete loss of renal function (Hinman, 1970).

The sequence of pathophysiologic events leading to renal atrophy is complex and by no means completely understood. It is currently believed that there is a cyclical process where in obstruction initially leads to increased pressure within the collecting structures. This pressure is transmitted via the luminal structure to the renal parenchymal resulting in reduction in parenchymal blood flow. The subsequent reduction in urine formation temporarily
relieves the increased pressure while leaving the kidney with a lower functional capacity. The pressure then gradually increases again and the cycle is repeated with progressive loss of function.

The changes due to obstruction can be arrested and, to a certain extent, reversed following surgical intervention (Walker et al., 1980). On the other hand, surgical intervention is frequently not indicated or may even be contraindicated in many cases of dilatation unassociated with obstruction. Moreover significant residual dilatation is almost uniformly present following surgical correction of mechanically obstructed system (Roberts et al., 1970).

Conventional contrast urography and conventional radionuclide renography are unreliable for differentiating obstructive from non obstructive hydroureteronephrosis because of overlap in findings between the conditions (Wax and Mc Donald, 1966). Dilatation, delayed opacification and delayed washout are hallmarks of obstruction but may also be seen secondary to virtually any cause of collecting system dilatation.

The aim of this work is to evaluate diuresis renography as a rapid, simple, non invasive technique in assessment of dilated upper urinary tract whether obstructed and in need for operation or not obstructed and operation is not necessary.
REVIEW OF LITERATURE
FUNCTIONAL ANATOMY
OF THE UPPER URINARY TRACT
A. Gross Anatomy

a. Anatomy of Renal Pelvis and Calyces

Numerous variations of calyceal and pelvic anatomy are possible. In some instances the renal pelvis may lie entirely within the renal sinus, whereas in other circumstances the calyceal branches are sufficiently long that the entire pelvis is extra-renal. It should be realized that there is a tendency for variations in renal pelvic and calyceal anatomy to be symmetric bilaterally, so that greater clinical suspicion is warranted in instances in which a unilateral variant is found. Despite the foregoing variations, the inter-relationship of hilar structures remains relatively constant, with the renal vein situated anteriorly and the renal pelvis posteriorly. The main renal artery occupies a position in-between but gives off major anterior and posterior divisional branches that flank the upper portion of the renal pelvis (Olsson, 1986).

If the renal pelvis is partially extra-renal, it lies along the lateral border of the psoas muscle and on the quadrates lumborum muscle. The left renal pelvis lies at the level of the first or second lumbar vertebra. The right pelvis is little lower. The renal pelvis tapers inferomedially to form the ureter (Tanagho, 1984).
The renal calyces drain the renal papillae and are in immediate apposition. The total number of calyces is usually 8 but can range from 4 to 12. A single calyx may drain one papilla, whereas a composite calyx may drain multiple papillae. The polar calyces demonstrate the greatest variation in size and shape and are generally compound. The calyces drain into the infundibulae, which are the primary divisions of the renal pelvis and are usually 2 - 3 in number. The infundibulae or primary divisions then empty into the renal pelvis (Fig. 1) (Spirnak and Resnick, 1983).

The apical segment of the kidney has one major calyx which lies in the mid frontal plane and usually receives two minor calyces (medial and lateral). The basilar segment has a single major calyx in the median plane and receives two minor calyces (anterior and posterior). There are usually three major calyces in the anterior segment that enter the renal pelvis at about 20 degrees angle to the mid frontal plane. The posterior segment also has three major calyces joining the renal pelvis at 75 degrees with the mid frontal plane (Straffon, 1986).

The major calyces fuse with each other to form a funnel shaped pelvis which tapers gradually as it passes inferomedially to become continuous with the ureter. The pelvis may be intra-renal or extra-renal, this refers to the extent to which it is covered with parenchymal tissues anteriorly and posteriorly. Brodel (1901), had classified the
Fig. (1) Renal pelvis and its primary and secondary divisions (Spina and Resnick, 1983).
renal pelvis into "true" and "divided" types. However, Wikham and Miller (1983), suggested that the divided pelvis only refers to the configuration seen when there are two major calyces separated by parenchyma, thus giving the impression of a divided pelvis. The capacity of the normal pelvicalyceal system is about 5 - 15 ml in average. Occasionally, there is no actual pelvis because there has not been much dilatation at this end of the ureteric bud and the calyces open directly into the ureter (Tanagho, 1971).

b. Anatomy of the Ureter

The renal pelvis tapers down into a muscular tube, the ureter, on each side. This tube extends through the retroperitoneum such that its peristaltic contractions can deliver urine from the kidney to the urinary bladder. The average ureter is about 30 cm in length and may be divided into approximately equal abdominal and pelvic portions. Each portion, in turn, may be further classified, somewhat artificially, into two divisions. The abdominal ureter consists of lumber and iliac divisions, each approximating 8 cm in length, traversing the lumber and iliac fossae, respectively. The pelvic ureter is divided into the longer parietal and shorter intravesical divisions (Olsson, 1986).

The abdominal ureter leaves the renal pelvis opposite the lower pole of the kidney and assumes a vertical course downward and medially on the anterior surface of the psoas muscle, which separates it from the transverse processes.
The genitofemoral nerve is the only structure between the ureter and the psoas muscle (Olsson, 1986).

The abdominal ureter is well encompassed within an extension of Gerota's facial space. There is a cleavage plane between the parietal peritoneum and the anterior leaf of Gerota's fascia (Olsson, 1986).

The right ureter lies along the right border of the inferior vena cava. Four sets of vessels intervene between it and the peritoneum, these are the right colic, the testicular or ovarian the ileocolic, and the superior mesenteric vessels in the root of the mesentery. While the left ureter is separated from the peritoneum anteriorly by the upper left colic, the testicular or ovarian and two or more lower left colic vessels (Sturdy, 1974).

As the ureter crosses the iliac vessels it lies immediately above the sacroiliac joint. At this point, the ureters are only 2 inches apart. While the ureters are at their most widely separated point at the ischeal spine (Paulson and Weinertb, 1978).

The pelvic ureter on each side is approximately 15 cm in length. The longer parietal division continues in its close relationship with the peritoneum, crossing the pelvic brim just lateral to the bifurcation of common iliac arteries. It descends posterolaterally between the hypogastric artery and the peritoneum and is separated by
the hypogastric artery from the pelvic musculature and nerves. As it approaches the bladder base, the superior vesical artery crosses above the ureteral course, which then becomes medially directed once again (approximately at the level of the ischial spine) to reach the urinary bladder (Olsson, 1986).

In males the terminal part of the intrapelvic ureter is crossed by the vas deferens, overlaps the seminal vesicle, and surrounded by a plexus of veins. While in females it passes below the broad ligament and is crossed by the uterine vessels. The terminal 2.5 cm of the ureter is close to the lateral fornix of the vagina. The left ureter is more related to the fornix of the vagina than the right one (Sturdy, 1974).

The ureter then penetrates the bladder wall obliquely. The angle of vesical insertion varies from 90 to 135 degrees. In elderly males, the ureterovesical angle is accentuated due to elevation of the trigone secondary to prostatic enlargement. This may lead to difficulty in ureteric catheterization (Lich and Howerton, 1970).

The intravesical ureter is about 1.5 cm long and is divided into an intramural segment totally surrounded by the bladder wall and a submucosal segment (about 0.3 cm long) directly under the bladder mucosa (Tanagho et al., 1968).

According to the anatomic studies performed by
Tanagho and Pugh (1963), ureterotrigonal complex is formed of mesodermal component which arise from the wolffian duct and endodermal component; the vesical detrusor muscle. The mesodermal component is made up of 2 parts that are innervated by the sympathetic nervous system (Fig. 2).

1. The Ureter and Superficial Trigone

As the ureter approach the vesical wall, its irregular helical muscle fibers are reoriented into the longitudinal plane. The intravesical ureteral segment is thus composed of longitudinal muscle fibers only and therefore cannot undergo peristalsis. As the smooth muscle fibers approach the ureteral orifice, those that form the roof of the ureter swing to either side to join those that form its floor. They then spread out and join equivalent muscle bundles from the other ureter and also continue caudally, thus forming the superficial trigone. The trigone passes over the neck of the bladder, converges at the internal to proceed downwards into the urethra in the midline posteriorly, ending at the verumontanum in male and just inside the external urethral orifice in female. Thus, the ureterotrigonal complex is one structure. Above the ureteral orifice, it is tubular; below that point, it is flat.

2. Waldeyer's Sheath and Deep Trigone

Beginning at a point 2-3 cm above the bladder, an external layer of longitudinal smooth muscle surrounds the
Fig. (2) Normal uretero trigonal complex (Tanagho and Pugh, 1963).
ureter. This muscular sheath passes through the vesical wall, to which it is connected by a few detrusor fibers. As it enters the vesical lumen, its roof fibers diverge to join its floor fibers, which then spread out, joining muscle bundles from the contralateral ureter and forming the deep trigone, which ends at the bladder neck (Tanagho, 1984).

The vesical detrusor muscle completely surrounds the intramural ureter, lies behind the submucosal ureter as well as behind the trigone. So, the trigone seems to be superimposed over the detrusor, which at that level is composed of two layers: circular layer immediately behind the deep trigone and outer longitudinal muscular coat which is very well developed and forms a complete sheet behind the deep trigone. The vesical detrusor muscle is innervated by parasympathetic nerves (S 2 - 4) (Tanagho, 1986).

The ureter isn't of uniform caliber, but rather displays three points of physiologic narrowing at the ureteropelvic junction, crossing iliac vessels and ureterovesical junction. The internal diameter of the ureter tends to be smallest at the ureterovesical junction. This fact is important to the new field of ureteroscopic surgery. In prostatic hypertrophy, elevation of the bladder base leads to significant angulation between the parietal and intramural segments of the pelvic ureter (hockey stick sign of urographic examination). Such angulation con-
stitutes another zone of ureteral narrowing (Fig. 3) (Olsson, 1986).

*Fig. (3) Variable ureteral caliber (Olsson, 1986).*
B. Microscopic Anatomy

The wall of the upper urinary tract (calyces, pelvis and ureter), basically consists of an outer connective tissue adventitia, an inner transitional epithelial mucosa and a smooth muscle layer in-between. Since the conductive function of the upper urinary tract is mainly dependent on the muscle layer, emphasis on this layer will be the theme in this description.

a. The Musculature of the Calyces and Pelvis

Narath (1940), gave full account on the anatomy of the renal calyx. He described the following muscles in relation to renal calyx (Fig. 4).

1. Musculus Levator Fornicis

On contraction, this muscle has a pulling effect on the fornix.

2. Musculus Sphincter Fornicis

This muscle acts as a sphincter closing the neck of the calyx against the space below the fornix around the papilla.

3. Musculus Longitudinalis Calycis

Bundles of this muscle extend also into the wall of the pelvis. When this muscle contracts, it will shorten the length of the neck of the calyx.
Fig. (4) Diagram showing arrangement of muscle fibres in the calyceal system (Narath, 1940).
4. Musculus Sphincter Calycis

This is a circular muscle sphincter around the neck of the calyx.

The muscle coat of the calyces and pelvis has classically been described as consisting of an inner longitudinal, intermediate circular and outer longitudinal layer of smooth muscle (Satani, 1919). However, it has been demonstrated that the musculature of the pelvis and calyces is a densely woven spiral network of smooth muscle fibers traveling longitudinally, obliquely and circularly. When this network contracts, there is a squeezing effect on the pelvis as a whole. This gentle squeeze, as indicated by the very low contraction pressure recorded in the renal pelvis, probably is dampened by the somewhat flaccid pelvic wall (Davis and Zimskind, 1963).

b. Microscopic Anatomy of the Ureter

The wall of the human ureter is composed of three layers, an external adventitia, a smooth muscle coat and an inner mucous membrane.

1. Adventitia

The outer layer is a loose connective tissue sheath which surrounds the ureter entirely, blending with its muscular coat and merging into the surrounding retroperitoneal tissue (Notley, 1982). This layer is continuous with renal capsule within the renal sinus proximally and continues dis-
tally to become thicker and at the lower end of the ureter it becomes fibromuscular and forms a sleeve around the terminal 1.5 - 2 inches (Waldeyer's sheath) (Olsson, 1986).

With the electron microscopy, this layer is composed of a dense bundles of collagen fibers running in all directions, the majority following the long axis of the ureter, supported by numerous fibrocytes. In the adventitia, numerous blood vessels are present, the majority of which run longitudinally and many accompanied by bundles of non-myelinated nerve fibers (Notely, 1982).

2. Mucosa

The mucous membrane of the ureter is composed of transitional epithelium, 4 - 6 layers thick, lacks a basement membrane and rests upon a relatively thick lamina (Velardo, 1981). The first layer of the mucosa characteristically consists of large polygonal cells. The second and third layers of ureteral mucosa consists of 2 - 3 strata of cells which vary in size and shape and are embedded in a slimy cement substance. It seems that this substance is responsible for the ability of the transitional epithelial cells to slip over each other. The deepest layer of ureteral mucosa consists of high cuboidal, almost columnar cells. Different basal areas of ureteral mucosa display a fairly consistent type of cell group characteristically high cuboidal whereas others appear to be low columnar (Velardo, 1981).
The transitional epithelial lining of the ureter rests upon the lamina propria which is continuous with the renal interstitial tissue and contains both elastic and collagenous fibers (Velardo, 1981).

With electron microscopy, the transitional epithelium is formed from 3 - 5 cells deep with deeply enfolded basement membrane about 25 μm thick while the lamina propria is 350 - 700 μm in thickness and composed of large numbers of collagen fibers arranged in bundles and interspaced with fibrocytes and their processes. Scattered randomly through the lamina propria are small blood vessels and non-myelinated nerve fibers (Notely, 1982).

3. The Muscle Coat

The muscle coat of the ureter consists of a layer of smooth muscle bundles. The muscle bundles are circular and longitudinal in arrangement, but vary in location and predominance depending on the level of the collecting system. Circular fibers are predominant around the bases of the renal papillae, longitudinal fibers then become intermingled with the circular fibers along the course of the renal pelvis and the ureter; longitudinal fibers finally predominate in its intravesical portion (Olsson, 1986).

Tanagho (1971), described a "helical" arrangement for the muscle bundles of the ureter and he explained this arrangement on embryological basis. He stated that early in
development, the mesenchymal cells are circularly oriented around the growing ureteric bud and the final arrangement depends upon the degree and direction of growth in either longitudinal or transverse axis. If it is the former (lengthening), the fibers will assume more longitudinal orientation (Fig. 5c). If it is the latter (broadening), the fibers will retain most of their circular orientation (Fig. 5b). Growth in both directions, which is usually the case, will result in fibers with mixed orientation with predominance of one or the other orientation at certain location (Fig. 6). As a result each muscle bundle becomes one long irregular helix (Fig. 7). The combination of several muscle bundles constitute the unique arrangement of the ureteral musculature (Fig. 8).

Tanagho (1971), stated that such a helical arrangement is the most efficient for providing the ureteral peristaltic wave.

According to previous explanation, the renal pelvis will have a preponderance of circularly oriented fibers as it grows mainly a long a transverse axis. The pelviureteric region has this arrangement to a lesser degree but there are still more circular fibers. The growth of the ureter is mainly longitudinal, therefore, it has an equal mixture of fiber orientation. The intravesical ureter has a pure longitudinal arrangement of muscle fibers. This explanation
Fig. (5) Diagrammatic representation of effect of lengthening and widening on the orientation of the ureteral musculature. A. Initial early intra-uterine phase with musculature mainly circular. B. Widening of this ureter will accentuate the circular orientation. C. Lengthening will lead to more longitudinal orientation (Tanagho, 1974).

Fig. (6) Diagrammatic representation of the effect of widening and lengthening that takes place at the cranial end of the ureteral bud resulting in the normal funneled ureteropelvic junction (Tanagho, 1974).
Fig. (7) A. Diagrammatic representation of the course of two muscle bundles in the ureteral wall assuming irregular helical pattern. B. Three muscle bundles with their irregular helical course: the result is that at any one level there is a mixture of muscle fibers with variable orientation (Tanagho, 1974).
Fig. (8) Diagrammatic illustration showing the effect of contraction of this mixture of muscle fibers during a peristaltic wave. There is shortening, narrowing and twisting of the ureteral wall (Tanagho, 1974).
has been supported by Allen (1973); Hanna et al. (1976) & Velardo (1981).

With electron microscope, the muscular coat of the human ureter is approximately 750 μm in thickness through which are scattered small blood vessels and bundles of non-myelinated nerve fibers (Notley, 1982).

Ureteral Innervation

The ureteral nerves arise from both abdominal and pelvic sources and are arranged into superior, middle and inferior groups.

1. Superior Ureteric Nerves

Arise from the lower part of the renal plexus and supply the upper part of the ureter. These ureteric nerves are connected with the testicular or ovarian nerves.

2. Middle Ureteric Nerves

Arise from the side of the superior hypogastric plexus and from the upper part of the homolateral hypogastric nerve. They are often connected with branches passing to the vas deferens.

3. The Inferior Ureteric Nerves

Supplying the lower end of the ureter come from the termination of the hypogastric nerve and from the upper part of inferior plexus. These ureteric nerves are connected
with filaments which supply the vas deferens, seminal vesicles and urinary bladder.

These nerves form a rich network of nerve fibers in the adventitia of the ureter, known as "ground plexus of Engelmann" and from this network nerve fibers pass into the tunica muscularis as motor fibers and into the mucosa as sensory fibers (Notly, 1971).

The referred pain of ureteral colic is transmitted by the ilio-hypogastric (L₁ or T₁₂ and L₁), ilioinguinal (T₁₂ and L₁) and external spermatic branch of genitofemoral nerve (L₁ and L₂) (Campbell, 1978). El Badawi and Schenk (1973), revealed that the ureterovesical junction has a dual sympathetic and parasympathetic innervation.

Blood Supply of Renal Pelvis and Ureter

The blood supply of the ureter is derived from several sources, but unlike the gut, it receives no regular segmental blood supply. The renal pelvis and the upper ureter are supplied by branches of the renal artery or arteries. The lower ureter receives branches from the inferior and superior vesical arteries and in-between these extremes numerous variable vessels reach the ureter from the gonadal and iliac arteries. All these vessels make longitudinal anastomosis with each other in the adventitia of the ureter. The veins of the ureter drain into the renal, gonadal and internal iliac veins. The lymphatic vessels run
Fig. (9) Ureteric arteries, schematic (Olsson, 1988).
back alongside the arteries, from the abdominal portion into
the para-aortic lymph nodes and from the pelvic portion into
the nodes alongside the internal iliac arteries on the pel-
vic side wall (Fig. 9) (Notely, 1982).

RADIOLOGIC ANATOMY
OF THE UPPER URINARY TRACT

A. Pelvicalyceal System

The normal renal pelvis is triangular or pyramidal. The base is inside the renal sinus and usually parallels to long axis of the kidney. The triangle bends downwards so that its apex points downwards and medially to join the ureter. This bending requires that both borders of the pelvis be curved in a medial direction, the upper medial border being convex, the lower lateral border being concave. The capacity of the normal varies widely, usually averaging from 5 to 15 ml (Emmett and Witten, 1971).

Arising from the pelvis are divisions known as the major calyces. These may vary in number from two to four from these major calyces, minor calyces are branched. The usual number of minor calyces is 6, 7, or 8 although the number may vary from 4 to 12, depending on the number of renal pyramids or papillae present. They tend to arrange themselves into two distinct rows (one row in the anterior half of the kidney and one in the posterior half).
The shape of the normal renal pelvis varies widely. Among the factors which may have a part in determining the shape of the pelvis is its position in relation to the renal sinus. An intra-renal type of pelvis which lies almost completely within the renal sinus is usually rather short and small, whereas a typical extra-renal type of pelvis is likely to be large and associated with long major calyces. Among the more common variety is the square type of pelvis. Oval and globular pelvis are not uncommon.

Incomplete filling of a normal pelvis and calyces is also capable of producing unusual configurations which may be considered as pathologic lesions, with better filling of the pyelogram will usually show normal conditions (Emmett and Witten, 1971).

Calyces may be divided into two segments; namely, major and minor. In the typical normal case, the major calyx is the larger. It begins at the periphery of the pelvis and extends to its junctions with the minor calyces. Each major calyx may be divided into three parts; the base which is adjacent to the pelvis; the isthmus or infundibulum, which is long tubular portion and the apex or terminal portion, from which one or more minor calyces project. The form and size of the major calyces are subjected to wide variations (Friedland et al., 1983).

The minor calyces arise from the terminal portion
(apex) of a major calyx. Each minor calyx consists of two parts, the calyx proper, which is a short tubular projection beginning at the apex of the major calyx, and the fornix, which is the portion that surrounds the conical renal papilla. The number of minor calyces which arise from each major calyx is extremely variable, and there may be more fornices than minor calyces.

The tendency to variation in the size, shape and number of the major and minor calyces is extremely marked. This wide variation is chiefly responsible for the difficulty to recognize the many types of normal urograms (Emmett and Witten, 1971).

B. Radiologic Anatomy of the Ureter

Visualization of the ureter is an extremely important part of excretory urography and no urogram should be considered completely satisfactory if ureteral visualization has not been accomplished. The ureter descends parallel to the midline on the anterior surface of the psoas muscle. The ureters usually overlie the transverse processes of the vertebrae however 18% of normal ureters, almost always on the right side overlie or are medial to the pedicles of the spine at the L5 and S1 levels. The right ureter often approaches the midline particularly in young adults. No, significant sex difference is apparent (Scoldino and Pablinskas, 1972).
When viewed laterally, the upper ureter is seen to be dorsal to the plane of the anterior longitudinal ligament of the spine until the level of L 4–5; where it becomes anterior just before it enters the bony pelvis. To obtain a true appreciation of this relationship, the roentgenogram must be exposed while the patient is lying either on his back or on the side of interest (Pollack, 1971).

Although the pelvic portion of the ureter is relatively fixed, the abdominal part is quite mobile. This degree of ureteral mobility accounts for the rather wide latitude given in defining the range of normal for abdominal ureter (Pollack, 1971).

An interesting variant in the course of the ureter is the deviation sometimes produced by hypertrophy of the psoas muscle. The hypertrophied muscle can displace the upper ureter laterally below the renal pelvis (Haines and Kyaw, 1971). The ureters then turn medially, in their lumbar segments, with varying degrees of acuteness and descend along the anteromedial surface of the psoas and are often closer to the midline than usual, especially at the level of L5–S1 vertebrae and below, (Bree et al., 1976). This lower medial displacement caused by psoas muscle hypertrophy may simulate nodal masses or retroperitoneal fibrosis (Friedland et al., 1983). The abdominal ureters lie lateral to the aorta and the major aortic lymph node chains. Thus aneurysm of the aorta and enlarged lymph nodes tend to displace the ureters
laterally (Friedland et al., 1983). The ureters may also be displaced by developmental variations in the cardinal vein system as seen in the retrocaval ureter where the right ureter usually crosses medial to the pedicles of the first four lumbar vertebrae. Even when the ureters continue downwards more or less parallel to the vertebral bodies, they are variable in position and are not necessarily identical in position on both sides (Friedland et al., 1983).

The gonadal vein on the right side crosses in front of the ureter at the level of L4 where it may create an extrinsic pressure defect, particularly in females (ovarian vein syndrome).

The normal areas of narrowing in the ureter are the ureteropelvic junction, the pelvic brim and the ureterovesical junction. It is impossible to assess the exact diameter of normal ureter because of its wide limits of variations. It may be as high as 8 mm or more. The diagnosis of dilatation secondary to obstruction should be validated by demonstrating the point of obstruction (Emmett and Witten, 1971).

The entire ureter is almost never visualized on any single film. The intermittent contractions of this structures produce zones of contractions which temporarily affect the lumen and strip it of contrast material.

A diagnosis of ureteral stricture should not be made
without consistent evidence of localized narrowing on multiple films. In almost all cases one should expect to see dilatation proximal to the area of narrowing and diminished filling below. On the other hand, if the entire ureter is visualized on a single film, the suspicion of obstruction or ureteral atony should be raised. While total ureteral visualization may be coincidental on any film, its persistence on several films, especially if it is unilateral, is particularly an assurance that the ureter is abnormal. The ureteral fullness accompanying diuresis will disappear at the conclusion of the study, whereas that with obstruction or atony remains as "standing column" for longer period of time. In evaluating a low ureteral obstruction on the juxtavesical or intramural ureter, it is important to have the patient empty his urinary bladder before obtaining the final film, since a contrast filled bladder will obscure the morphology of the distal ureter (Pollack, 1971).

The ureter enters the bony pelvis by crossing the common iliac at the origin of external iliac artery. The artery may have an oblique posterior indentation. From a position anterior to the lower half of sacroiliac joint, the ureter follows the inner margin of the iliac bone in an arc that is convex posteriorly and laterally. The ureters lie medial to the iliac vessels and the major lymph node chains. Large nodes may displace the ureters medially. At the level of the ischeal spine it turns anteriorly and medially to
reach the base of the bladder, where the ureteric orifices are about 2 cm apart.

An interesting phenomenon sometimes observed, is the spurting of urine from the ureteral orifice into the bladder. This has been termed the "ureteral jet" phenomenon. It is remotely possible, however, that under certain circumstances, it might be confused with an ectopic insertion of the ureter (Pollack, 1971).
PHYSIOLOGY OF THE UPPER URINARY TRACT
(CALYCES, PELVIS AND URETER)

The function of the upper urinary tract (calyces, pelvis and ureter) is to transport urine from the kidney to the urinary bladder. At flow rates within normal the transport of urine is accomplished by coordinated contractile activity of smooth muscles of the calyces, pelvis and ureter (Weiss, 1986).

A. Calyceal Motility

Two phases are encountered and described in the motion of renal calyx; a collecting phase and an emptying phase.

a. The Collecting Phase

During the collecting phase the levator fornicis is relaxed. The fornix sinks downwards. The sphincter fornicis is relaxed, assisted by the upper part of the longitudinalis which is contracted, forcing in this way the formation of a goblet, at the end of which the closed sphincter calycis prevents a backflow of urine from the pelvis into the calyx. The formation of a goblet would involve a vacuum below the papillae which naturally is not possible. But a negative pressure will be created which acts as a suction on the canaliculli of the papilla. Through this suction and the secretory pressure, the urine is brought to the calyx. The formation of the goblet is not a sudden change,
rather it is created slowly in accordance with the amount of urine produced (Narth, 1940).

b. The Emptying Phase

As the formed goblet is filled with urine, the sphincter calycis opens to let the urine into the renal pelvis. The sphincter fornix closes, the upper part of the longitudinal is relaxes, thus allowing the formation of a cup below the papilla. By contraction of the levator fornix, this cup is pulled tighter to the papilla to prevent backflow of urine into the caliculi. At the same time the lower part of the longitudinalis contracts assisting the relaxation of the sphincter calycis in reversing the process of goblet formation (Narth, 1940).

Gosling and Constantinou (1976), studied the sequence of calyceal and renal pelvic contractions and they observed that the contractile wave is propagated from the calyces towards the UPJ, some of the waves fade whereas others result in ureteral contraction. It has been suggested that the relatively long refractory period of the pelvis is responsible for the non-propagation of all calyceal contractions into the ureter.

Gosling and Constantinou (1976), had noted also that not all the calyces act at the same time.

B. Physiology of Ureteropelvic Junction

At normal urine flows, the frequency of calyceal and
renal pelvic contractions is greater than that in the upper ureter, and there is a relative block of electrical activity at the UPJ (Morita et al., 1981). At these flows, the renal pelvis fills, and the renal pelvic pressure rises, urine is extruded into the upper ureter, which is initially in a collapsed state. Ureteral contractile pressure that move the bolus of urine are higher than renal pelvic pressures, and a closed UPJ may be protective of the kidney in dissipating back-pressure from the ureter. As flow rate increases, there is cessation of the block at the UPJ and development of a 1:1 correspondence between pacemaker and ureteral contractions (Constantinou and Hrynczuk, 1976).

With ureteropelvic junction obstruction, there may be areas of narrowing or valve like processes (Maizels and Stephens, 1980). In other instances there is no gross narrowing at the UPJ, and abnormal propagation of peristaltic impulse is a causative factor in the obstruction, in these instances, there appears to be a functional obstruction at the UPJ, since a large caliber catheter can readily be passed through the UPJ even though urine transport is inadequate.

The functional abnormality occurs at UPJ may be related to many factors such as, an alteration in the configuration of muscle bundles at the UPJ, may be decrease in the musculature of the UPJ or may be disruption of intercellular relationships at the UPJ itself. It appears possible
that, at least in some instances, disruption of cell to cell propagation of peristaltic activity results in the impairment of urine transport across the ureteropelvic junction (Weiss, 1986).

C. Physiology of the Ureter

The function of the ureter is to transport urine from the kidney to the bladder. Under normal conditions, ureteral peristalsis originates with electrical activity at pacemaker sites located in the proximal portion of the urinary collecting system (Weiss et al., 1967; Gosling and Dixon, 1974 & Constantinou, 1974). The electrical activity is then propagated distally and gives rise to the mechanical event of peristalsis, ureteral contraction, which propels the bolus of urine distally. An efficient propulsion of the urinary bolus is dependent on the ureter's ability to completely coapt its walls (Woodburne and Lapides, 1972).

Lapides (1948), stated that the normal adequate stimulus for initiation and maintenance of ureteral peristalsis is the stretching of its smooth muscles by the urine content in the lumen.

Whitaker (1982), stated that the essential feature of normal peristalsis is bolus formation and this is only achieved by occlusion of the ureteral lumen.

a. Ureteral Peristalsis

These are worm-like movements which can be seen at
operation if the ureter is gently pinched between a forceps.
Ureteral peristalsis were studied by Tarttner (1932), who
found that it consists of two components: The first is a
longitudinal contraction which shortens the ureter and nar-
rows it but does not obliterate its lumen. The second is a
circular contraction which momentarily obliterates the lumen
in successive segments of the ureter as the wave advances.

The ureteric contractions occur at a rate between one
and ten per minute. The duration of the peristaltic wave
was found to be from two to nine seconds.

The resting pressure in the ureter was found to be
9 cm water. The amplitude, represents the maximum pressure at
the peak of ureteral contraction wave, was found to be from
12 - 33 cm water with higher values, in the lower ureter which
is usually between 20 - 40 cm water (Weinberg and Maletta,
1961).

Lapides (1948), found that a suction wave follows the
peristaltic wave; at the same time a force is exerted on the
fluid in front of a wave. He also stated that the tonus and
rhythmic contractions of the intact ureter are entirely in-
dependent of central nervous system and all its ganglia; the
normal adequate stimulus for the initiation and maintenance
of the ureteral peristalsis is the stretching of the smooth
muscle fibers by urine excreted from the kidney.

Tanagho (1974), stated that the main function of the
ureter is the transport of urine by its rhythmic peristaltic activity. Its irregular helical muscular arrangement makes it possible to initiate a wave of contraction which occludes its lumen above a bolus of urine. The latter is progressively propagated toward the urinary bladder. Contraction of the longitudinal segments of the helical fibers shortens the ureter while the transverse segments narrow the lumen and the oblique segments produce twisting. Djurhuus (1977), considered that in addition to a myogenic transmission of an impulse normal peristalsis requires distention of the ureter by a urine bolus. The conduction of electrical activity and the probable mechanism of ureteral muscle contraction have been reviewed by Weiss (1979). He believed that the autonomic nervous system has a modulating effect on ureteric function. While Murray et al. (1958), stated that transplantation, which removes extrinsic innervation, does not interfere with ureteric function, nor does the interposition of a piece of bowel between the pelvis and distal ureter (Struthers and Scott, 1974).

Hutch (1972), stated that urine reaching the lower ureter would gather in the extravesical segment because the intravesical segment is constantly closed. With the rise in pressure resulting from peristaltic wave, this accumulated urine is propelled through the intravesical ureter into the bladder with the characteristic jets. Following each jet,
the intravesical ureter closes tightly due to the tone of the deep trigone while awaiting the next jet.

The mechanics of urinary transport within the ureter have been recently described by Griffiths and Notshaele (1983). They stated that, at normal flow rates, as the renal pelvis fills, there is a rise in renal pelvic pressure and urine is extruded into the upper ureter, which is initially in a collapsed state. Contraction waves originate in the most proximal portion of the ureter and move the urine in front of it in a distal direction. The urine that had previously entered the ureter is formed into a bolus. In order to propel the bolus of urine efficiently, the contraction wave must completely coapt the ureteral walls and the pressure generated by this contraction wave provides the primary component of what is recorded by intra-luminal pressure measurements. The bolus that is pushed in front of the contraction wave lies almost entirely in a passive, non contracting part of the ureter (Weinberg, 1974). To enter the bladder the urine traverses the UVJ, which when functioning properly, assures one-way transport of urine. The bolus is forced into the bladder by the advancing contraction wave, which dissipates at the ureterovesical junction.

As with any tubular structure, the ureter can transport a set maximum amount of fluid per unit time. Under normal flows, in which bolus formation occurs, the amount of urine transported per unit time is significantly
less than the maximum transport capacity of the ureter. At extremely high flows, as are employed in the standard perfusion studies (Whitaker, 1973), the ureteral walls do not coapt, and a continuous column of fluid is transported rather than a series of boluses. When transport becomes inadequate, stasis of urine occurs with resultant ureteral dilatation. Inadequate transport can result either from too much fluid entering the ureter per unit time or from too little fluid exiting the ureter per unit time. One must consider both input and output when predicting whether or not ureteral dilatation will occur. For example, a minor degree of obstruction to outflow will cause more dilatation at high-flow rates than at low-flow rates. Even a normal non-obstructed ureter will impede urine transport if the rate of flow is great enough (Griffiths, 1983 & Weiss, 1986).

Electrical Activity

The primary event in ureteral peristalsis is the conduction of electrical activity or action potential along the ureter. The electrical properties of all excitable tissues depend on the distribution of ions on both the inside and the outside of the cell membrane and on the relative permeability of cell membrane to these ions.

b. Resting Potential

In the non excited or resting state, the electrical potential difference across the cell membrane is refereed to
as the resting membrane potential (RMP). The RMP is determined primarily by the distribution of potassium ions (K⁺) across the cell membrane and by the permeability of the membrane to potassium (Washizu, 1966; Hendrickx et al., 1975).

The RMP in the ureter is between -33 to -77 mv, the inside of the cell being negative with respect to the outside. Although the RMP is primarily related to K⁺, other ions probably also contribute (Weiss, 1986). One such ion, is sodium (Na⁺) (Kuriyama, 1963). In the resting state, the sodium concentration on the outside of the cell membrane is greater than on the inside. An active mechanism capable of extruding sodium from within the cell against a concentration and electrochemical grading is required. The distribution of chloride ions (Cl⁻) across the cell membrane and the relative permeability of the membrane to chloride may be factors in the maintenance of the RMP in the ureter (Washizu, 1966 & Kuriyama, 1963).

c. Action Potential

The resting membrane potential of the ureteral cell remains stable until it is excited by stimulus whether it is electrical, mechanical (stretch), or chemical or by conduction of electrical activity (action potential) from an already excited adjacent cell. When the ureteral cell is excited, depolarization will occur making the inside of the cell less negative. If a sufficient area of the cell
membrane is depolarized rapidly enough to reach an arbitrary level of MP referred to as the threshold potential (TP), an action potential develops. The membrane becomes less permeable to K⁺ and more permeable to Na⁺ and Ca⁺⁺ which move inward across the cell membrane and provide the ionic mechanism for the development of the upstroke of the action potential. After reaching the peak of its action potential, the membrane maintains a depolarized state, plateau of the action potential, for a period of time before the membrane potential of the activated cell returns to its resting level (repolarization). The plateau appears to be related to a persisting inward Na⁺ current and repolarization of the membrane probably is related to a decrease in the membrane permeability to Na⁺ and Ca⁺⁺ and renewed increased in permeability to potassium (Weiss, 1986).

Dixon and Gosling (1973), have provided the morphologic evidence of specialized pacemaker cells in the proximal portion of the urinary collecting system. The transmembrane resting potential of the pacemaker cells does not remain constant but rather undergoes a slow spontaneous depolarization. If the spontaneously changing membrane potential reaches the threshold level, the upstroke of an action potential occurs. The ionic mechanism for a pacemaker potential has not been fully determined. Several changes in ionic currents have been postulated which include:
(42)

(1) decrease in the outward K⁺ current,
(2) an increase in the inward Na⁺ current,
(3) a decrease in the pump extrusion of Na⁺ or;
(4) an increased extrusion of Ca²⁺ with resultant decrease in K⁺ permeability.

(Noble and Tsien, 1968 & Weiss, 1986)

Although the primary pacemaker for ureteral peristalsis is located in the proximal portion of the collecting system, other areas of the ureter may act as latent pacemakers (Weiss, 1986). The ureter acts as a functional syncitium (Bozler, 1938). Under normal conditions electrical activity arises proximally and is conducted distally from one muscle cell to another across areas of close cellular opposition. Conduction velocity in the ureter is 2–6 cm/sec (Kuriyam et al., 1967). Whether the action potential is conducted down via nerves or muscles is a controversial issue (Gosling et al., 1983).

Ureteral Contractile Activity

The mechanical event, ureteral peristalsis, follows an electrical event to which it is related.

The exact mechanism of ureteral contraction is unknown. However, there is a wise reason to believe that it is in part similar to that involved in the contraction of the other muscles (Weiss, 1978). The contraction event in most muscle tissues is dependent on the concentration of
free sarcoplasmic Ca\(^{++}\) in the region of the contractile proteins, actin and myosin. Any process that results in an increase in Ca\(^{++}\) favours the development of a contraction; any process that results in a decrease in Ca\(^{++}\) favours relaxation.

The calcium involved in the ureteral contraction is derived from two main sources. The inward movement of extracellular Ca\(^{++}\) into the cell during the upstroke of the action potential provides a significant source of sarcoplasmic calcium. In addition calcium is released from more tightly bound storage sites presumably from the endoplasmic reticulum, mitochondria and membrane binding sites in response to an excitatory impulse. This dual source of calcium in the ureter has been provided by (Vereecken and co-workers, 1975).

Relaxation results from a decrease in the concentration of free sarcoplasmic Ca\(^{++}\) in the region of the contractile proteins. The decrease in the sarcoplasmic Ca\(^{++}\) can result from uptake of Ca\(^{++}\) into intracellular storage sites or from extrusion of Ca\(^{++}\) from the cell (Fig. 10) (Weiss, 1979).

A conclusion could be reached that Ca\(^{++}\) is necessary for excitation contraction coupling during contractile machinery. In the absence of Ca\(^{++}\), the ureter loses its ability to contract in response to electrical stimuli. Also
Fig. (10) Schematic representation of calcium movements during contraction and relaxation (Weiss, 1978).

agents that interfere with the movement of Ca\(^{++}\) in the ureteral cell such as lithium (Li\(^{+++}\)), manganese (Mn\(^{++}\)) and calcium antagonists like verapamil and (D-600) inhibit ureteral contraction.

In skeletal muscles, during relaxation, the troponin that is attached to the tropomyosin is inactive and the tropomyosin prevents the interaction between actin and myosin (Fig. 11a). With activation, there is an increase in the sarcoplasmic Ca\(^{++}\) concentration. The Ca\(^{++}\) binds to the troponin, producing a conformational change that results in the displacement of tropomyosin, thus allowing for the interaction of actin and myosin and the development of a contraction (Fig. 11b).

In smooth muscles the most widely accepted theory suggests that phosphorylation of myosin is involved in the contractile process, and that a troponin-like system does not constitute the primary regulatory mechanism (Weiss, 1986).

With excitation, there is a transient increase in the sarcoplasmic Ca\(^{++}\) concentration. At this higher concentration, Ca\(^{++}\) forms an active complex with calcium binding protein calmodulin (Watterson et al., 1976). Calmodulin without Ca\(^{++}\) is inactive. The calcium calmodulin complex activates a calmodulin dependent enzyme, myosin light chain kinase (Fig. 12). The activated myosin light chain kinase,
Fig. (12) Schematic representation of contractile process in smooth muscle. Calmodulin is activated by $Ca^{++}$. The activated calcium-calmodulin complex activates the enzyme myosin light-chain kinase, which phosphorylates the light chain of myosin. Phosphorylation of myosin light-chain kinase decreases the rate of activation of the enzyme by the calcium-calmodulin complex (Weiss, 1986).
in turn, catalyses the phosphorylation of myosin (Fig. 13). Phosphorylation of the myosin light chain allows activation by actin of myosin Mg\(^{++}\) ATPase activity leading to hydrolysis of ATP and the development of contraction (Fig. 14). With low Ca\(^{++}\) concentration, the myosin light chain kinase is not active since calmodulin requires Ca\(^{++}\) to activate the enzyme. This prevents activation of the contractile apparatus.

Furthermore a phosphatase dephosphorylates the myosin light chain thus preventing actin activation of myosin ATPase activity and relaxation results (Weiss, 1986).

Second Messengers and Ureteral Functions:

Many of the pharmacologic agents that influence the ureteric function do not cross the cell membrane and thus their actions appear to be mediated by second messengers. These second messengers include cyclic adenosine 3 - 5 monophosphate (CAMP), cyclic guanosine 3 - 5 monophosphate (cGMP), Ca\(^{++}\), inositol, 1, 4, 5 triphosphate and diacylglycerol.

The second messenger cAMP, mediates the relaxing effects of \(\beta\)-adrenergic agonists such as isoproterenol, in the ureter and in a variety of other smooth muscles (Weiss et al., 1977). Although some relaxation can occur independent of change in cyclic nucleotide levels, relaxation induced by
**Fig. (13)** Schematic representation of the contractile process in smooth muscle. The activated enzyme, myosin light-chain kinase, catalyzes the phosphorylation of myosin. Myosin must be phosphorylated in order for action to activate myosin ATPase (Weiss, 1986).

**Fig. (14)** Schematic representation of the contractile process in smooth muscle. Action causes ATPase activity of phosphorylated myosin. This allows interaction of actin and myosin with the development of a contraction (Weiss, 1986).
β-adrenergic agonists is associated with increase in cAMP levels.

The β-adrenergic agonists combine with a receptor on the outer surface of the cell membrane, and the agonist receptor complex, in turn, activates the enzyme adenylate cyclase on the inner surface of the cell membrane with the subsequent conversion of ATP to cAMP (Fig. 15).

All agents that increase cAMP levels cause relaxation of urinary tract smooth muscles by phosphorylation of the enzyme cAMP-dependent protein kinase which catalyses the phosphorylation of proteins which apparently leads to the uptake of Ca** into intracellular storage sites with a resultant decrease in free sarcoplasmic Ca** and the development of relaxation. Cyclic AMP may be increased within the cell either by increasing synthesis through activation of the enzyme adenylate cyclase or by decreasing degradation by inhibiting phosphodiesterase enzyme activity. Weiss et al. (1977), have demonstrated both adenylate cyclase and phosphodiesterase activities in the ureter.

D. Physiology of the Ureterovesical Junction

The ureterovesical junction is an imaginary valve that permits free efflux of urine only. Under normal conditions and at normal flow rates, the contraction wave, which occludes the ureteral lumen, propogates distally with the urine bolus in front of it, when the bolus reaches the UVJ,
Fig. (15) Schematic representation of the role of cyclic AMP in β-adrenergic agonist-induced relaxation of smooth muscle. Agonist combines with receptor on the outer side of the cell membrane. The receptor-agonist complex, in turn, activates the enzyme adenylate cyclase (a.c.) on the inner surface of the cell membrane, which in the presence of magnesium (Mg++) and guanosine triphosphate (GTP) results in the conversion of adenosine triphosphate (ATP) to cAMP. Cyclic AMP is postulated to cause an increased uptake of Ca++ into intracellular storage sites with a resultant decrease in Ca++ in the region of the contractile proteins, resulting in relaxation. Cyclic AMP also may have other actions not shown that inhibit the contractile process. The enzyme phosphodiesterase (PDE) degrades cAMP to 5'AMP (Weiss, 1981).
the pressure within the bolus must exceed intravesical pressure to pass across the UVJ. Under these conditions, in which the contraction wave is able to coapt the ureteral wall and move the urinary bolus distally, the pressure generated by the contraction wave exceeds the pressure within the urinary bolus. Inefficient transfer of urinary bolus across the UVJ may occur under certain circumstance such as, an obstruction at UVJ, when intravesical pressure is excessive, or when flow rates are so high as to exceed the transport capacity of the normal UVJ. Under these conditions, the pressure within the bolus increases and may exceed the pressure in the contraction wave. This results in an inability of the contraction wave to completely occlude the ureter, so only fraction of the bolus passes across the UVJ into the bladder (Weiss, 1986). Also, if the ureter is wide and weakly contracting, even in normal UVJ, retrograde flow of urine from the bolus will occur (Griffiths, 1983).

The exact mechanism of closure of ureterovesical junction and the way in which reflux is prevented is a matter of controversy.

a. Flap-Valve Theory

This theory states that the "valve" is a purely passive mechanical function which depends on the obliquity of the intravesical ureter. Also, the relatively long course of the intravesical segment may play a role in the ef-
iciency of the valve (Gruber, 1929), while Hutch (1961), had emphasised that the easy compressibility of this part of the ureter which is supported posteriorly by a thick and powerful portion of the bladder musculature during its intravesical course plays a great part in efficiency of UVJ. Another important factor is the ratio between the length and diameter of the intravesical ureter.

b. Trigonal - Muscle Theory

Using a microdissection technique Tanagho and Pugh (1963), postulated that the essential factor in the ureterovesical "valve" is the ureteric muscle, which together with waldayer's sheath and the two layers of muscle in the trigone, forms a complex system which allows free efflux of urine but at the same time, prevents reflux.
FACTORS AFFECTING URETERAL FUNCTION

1. Urine Flow Rate

The response of the ureter to an increase in the urine output may be either, an increase in the peristaltic frequency or in the volume of each urine bolus or both (Weiss, 1979). The initial response of the ureter is to increase frequency. Maximum frequency rate increases and then further increases in urine transport occur by means of increases in bolus volume (Constantinou et al., 1974). At relatively low flow rates, small increases in flow result in large increases in peristaltic frequency. At higher flow rates, relatively large increases in flow result in only small increases in peristaltic frequency. As flow rate continues to increase, several of the boluses coalesce, and finally the ureter becomes filled with a column of fluid and dilates. At these high flow rates, urine transport is through an open tube (Weiss, 1986). Also, a large urine volume excretion may be accompanied by a high intra-ureteral pressure and no visible peristalsis. Kill (1957), has suggested that the ureter can accommodate to high urine flow rates in three ways:

(a) Increase in the volume of ureteral cone (the segment of the ureter filled with urine during pelvic diastole).
(b) Greater shortening during contraction may occurs. So, the pressure peak with the bolus is higher suggesting that the contractile force is raised.
(54)

(c) Reduction in frequency of contraction at high rates of urine flow. It is well known that the response to rapid stretching is arised in frequency; but sustained stretching has an inhibitory effect, possibly because of alteration of permeability characteristics of the membrane (Kill, 1957).

2. Bladder Filling and Neurogenic Vesical Dysfunction

Ureteral dilatation can result either from an increase in urine flow rate or from a decrease in urine output from the ureter. The relationship between ureteral intraluminal pressure and intravesical pressure is so important in determining the efficacy of urine passage across the U.V.J. into the bladder (Weiss and Biancani, 1983). In the normal ureter the intraluminal pressure exceeds the intravesical pressure resulting in passage of urine from the ureter into the bladder. In the dilated ureter which is poorly contractile or in normal ureter under extreme flow rates, the ureter does not coapt its walls to form boluses and the baseline pressure in the column of urine within the ureter must exceed the intravesical pressure (Weiss, 1986).

Also, the intravesical pressure is so important in determining the efficacy of urine transport from the ureter into the bladder. During filling phase, the normal bladder maintains the low intravesical pressure. This is character due to sympathetic inhibitory effect and vesico-elastic properties of the bladder wall. This pressure gradient be-
between the intraluminal ureteral pressure and low intravesical pressure maintain urine efflux into the bladder and prevent ureteral dilatation (Weiss, 1986).

In the non compliant bladder or neurogenic bladder dysfunction, small volume of urine will cause a rise in intravesical pressure which will alter the urine efflux and the ureter can not empty itself. Initially, the frequency of peristalsis of the ureter increases to overcome the high intravesical pressure. Ultimately, stasis occurs with the development of ureteral dilatation (McGuire et al., 1981).

The mechanism of the influence of the full bladder on ureteral peristalsis have been postulated to be due to increased compression of the intramural ureter and the progressive stretching of the trigone, which in turn leads to closure of intravesical ureter and especially increases resistance to flow through the ureterovesical junction (Tanagho and Meyers, 1971a).

3. Obstruction

The effect of obstruction on ureteral function depends on duration, degree of obstruction, the rate of urine flow and on the presence or absence of infection.

A. Early Effect

Early following onset of obstruction, there is a back-up of urine within the upper urinary tract, also, the kidney continues to produce urine, these will cause arise in
the intraluminal pressure and consequently increase in ureteral dimensions i.e. length and diameter. The ureter responds early by transient increase in frequency and amplitude of peristaltic contractility to bypass obstruction (Rose and Gillenwater, 1973 and 1978). With time, as the ureter fills with urine and the peristaltic contraction waves unable to coapt ureteral wall to form boluses. Then, urine transport through conduit dependent upon hydrostatic pressure generated by the kidney (Rose and Gillenwater, 1973).

Within few hours after obstruction the intraluminal baseline ureteral pressure reaches the peak and then declines to a level slightly higher than normal baseline pressure. This reduction of intraluminal pressure can be attributed to many factors such as a reduction in renal blood flow with resultant reduction in glomerular filtration rate and in intratubular hydrostatic pressure. Fluid reabsorption into the venous and lymphatic systems and a decrease in wall tension may play a role in reduction of baseline intraluminal ureteral pressure (Weiss, 1986).

B. Persistent Obstruction

As obstruction persists, there is a gradual increase in ureteral length and diameter to considerable dimensions. This occurs even though ureteral pressure remains at a relatively low and constant level. A continued small amount of urine production is required for the continuing increase in
the intraluminal volume (Biancani et al., 1973). Such changes account for the relatively low intrapelvic pressures clinically observed in massively dilated, chronically obstructed upper urinary tract (Struthers, 1969).

A combination of weakened nature of contractions and the fact that the dimensions of the conduit are increased makes it difficult for chronically obstructed ureter to coapt its walls. Failure of complete coaptation impairs the ability of the ureter to constrict its lumen effectively. So, the transporting function of chronically obstructed ureter will be impaired (Struthers, 1969).

The effect of dimensional changes on urine transport can be understood from the La Place equation.

\[ \text{Pressure} = \text{tension} \times \frac{\text{Wall thickness}}{\text{Radius}} \]

An increase in ureteral diameter would decrease intraluminal pressure. Furthermore, the equation provides a possible explanation for the improved function resulting from ureteral tapering (Weiss, 1979).

Most likely, decent contractile ability will be retained if the outcome of obstruction is muscle hypertrophy within the conduit wall, while if scar formation and collagen replacement of smooth muscles occur, the contractile capacity will be lost (Hanna, 1976).
4. Effects of Calculi on Ureteral Function

Obstruction is one of the most deleterious factors affecting renal structure and function. When calculi cause acute obstruction of the ureter, there is an initial backup of urine which is associated with an increase in baseline resting ureteral intraluminal pressure and in ureteral length and diameter. The increase in intraluminal pressure is dependent on the continued production of urine by the kidney which in turn, freely passes beyond the site of obstruction. The increased intraluminal pressure and increase in urine volume proximal to obstruction result in the increase in ureteral dimensions. As the intraluminal pressure continues to increase, contractions rapidly cease and urine transport becomes dependent solely on the hydrostatic forces generated by the kidney (Rose and Gillenwater, 1973). After a few hours of obstruction, intraluminal pressure is observed to decline at a time in which the dimensional changes remain stable (Biancani et al., 1976).

The decrease in the intraluminal pressure can be attributed to changes in intrarenal haemodynamics such as reduction in renal blood flow, which brings about a concomitant reduction in glomerular filtration rate and intratubular hydrostatic pressure (Vaughan et al., 1971). In addition, there is an increased reabsorption of urine into the venous and lymphatic channels, which also adds to
the reduction in the intraluminal ureteral pressure (Rose and Gillenwater, 1973).

Subsequently as obstruction persists, there is gradual increase in ureteral dimensions, although intraluminal pressure remains constant at its lowered level which is slightly higher than the normal baseline pressure. A continued urine production, although small, is required to account for this increase in intraureteral volume.

However, the ureter must coapt its walls, in order to generate a satisfactory intraluminal pressure and to provide efficient urine transport. So, factors that affect the spontaneous passage of calculi include:

1. The size and shape of the stone (Veno et al., 1977).
2. Intrinsic areas of narrowing within the ureter.
3. Ureteral peristalsis.
4. Hydrostatic pressure of the column of urine proximal to the calculus (Sivula and Lehtonen, 1967).
5. Edema, inflammation and spasm of the ureter at the site at which the stone is lodged.

The most useful factors in facilitating stone passage are an increase in hydrostatic pressure proximal to a calculus and relaxation of the ureter in the region of the stone (Weiss, 1979).

5. Pregnancy

Hydroureteronephrosis of pregnancy begins in the
second trimester and subsides within the first month after delivery. It is most severe on the right side and the ureteral dilatation does not occur below the pelvic brim. There is an increasing bulk of evidence that favours a mechanical rather than a hormonal genesis (Roberts, 1976).

(a) Normal ureteral contractile pressures have been recorded in pregnant women and would suggest that hormonally induced atony is not the prime factor in the observed dilatation (Roberts, 1976).

(b) Roberts (1976), has emphasized that women with pelvic kidneys do not suffer hydroureter of pregnancy as their ureters do not cross the pelvic brim.

(c) Elevated intraureteral pressure in pregnant monkeys return to normal when the uterus is elevated from the ureters at laparotomy (Roberts, 1976).

(d) Elevated base-line ureteral pressures consistent with obstruction have been recorded above the pelvic brim in pregnant women. These high pressures decreased when positional changes permit the uterus to fall away from the ureters (Sala and Rubi, 1967).

(e) Large ovarian or uterine tumours can produce a pyelographic picture similar to that of hydroureter of pregnancy (Boyarsky and Labay, 1981).

(f) Roberts (1976), reported that slowly released progestin administered by implantation in monkeys, failed to produce ureteral changes similar to those produced during pregnancy.
(g) Hydronephrosis of pregnancy is only observed in dipeds. Quadripeds do not suffer from hydronephrosis of pregnancy as their gravid uterus hangs away from the ureter (Roberts, 1976).

Observed hormonal effects on ureteral function have been used to implicate a hormonal mechanism in the ureteral dilatation of pregnancy. Several studies have shown an inhibitory effect of progesterone on ureteral function (Hundley et al., 1942 & Kumar, 1962). Progesterone has been noted to increase the degree of ureteral dilatation during pregnancy and to retard the rate of disappearance of hydroureter in postpartum women. Marchant (1972), has failed to induce changes in ureteral activity in women by the administration of estrogens, progesterone or a mixture of these drugs. Although mechanical obstruction appears to be the primary factor in the development of hydronephrosis of pregnancy, there is some evidence to suggest that a combination of hormonal and mechanical obstructive factor is involved (Fainstat, 1963).

6. Vesicoureteral Reflux

Factors that have been implicated in the development of vesicoureteral reflux include:
(a) anatomic and functional abnormalities at the ureterovesical junction;
(b) inordinately high intravesical pressures and
(c) impaired ureteral function.  

(Tanagho et al., 1968)

Although an abnormality of the ureterovesical junction is the primary etiologic factor in most cases of reflux, there is an evidence to suggest that decreased ureteral peristaltic activity may be a contributory factor. This may explain why a normal ureter may not reflux even when reimplemented into a bladder without a submucosal tunnel (Debroyne et al., 1978), or why defunctionalized refluxing ureter may cease to reflux when a proximal diversion is taken down (Weiss, 1979). The observation that vesicoureteral reflux may temporarily cease following electrical stimulation further supports this possibility (Melick et al., 1966).

Even the mildest forms of vesicoureteral reflux are associated with a decreased frequency of ureteral peristalsis (Weiss and Biancani, 1983). Although this may offer further evidence that decreased peristaltic activity is a possible etiologic factor in the development of reflux, an alternative interpretation is that the decreased peristaltic activity is due to reflux.

Ross et al. (1972), reported the following changes with vesicoureteral reflux:

(a) The base-line intraureteral pressure rose concomitantly with increase in bladder pressure.
(b) The effective amplitude of contraction was diminished and sometimes eliminated, but in some instances there was an initial temporary rise followed by diminution.

c) The rate of ureteral contractions was increased in most instances, but in some patients the contractions ceased.

d) The rhythm was altered and usually became irregular.

The diminished ureteral function associated with reflux is considered as a contributory factor in failure of antireflux procedures applied in poorly functioning dilated ureters (Weiss, 1979).

Simultaneous occurrence of reflux and obstruction has been reported (Weiss and Lytton, 1974). Although this might, at first appear to be contradictory, the two entities can occur together and depend to some degree on the pressure proximal and distal to a site of partial obstruction. It would appear that obstruction is the primary factor leading to renal deterioration in these cases, and reflux occurs in certain instances when the pressure distal to obstruction site exceeds pressure proximal to it.

Also, reflux and infection are commonly associated together. In these cases, both reflux and infection can influence the ureteral function.

7. Gravity

Schick and Tanagho (1973), have observed the effect of gravity on ureteral peristalsis in the intact animal
using fluoroscopic image intensifier. When the animal is placed in the head-down position, the frequency of peristaltic activity increased and the volume of urine bolus carried by each peristaltic wave decreased. Work done by the ureter increased markedly, yet its efficiency (urine volume transported) was poor. Schick and Tanagho (1973), have also noted cessation of peristaltic activity after 3 hours (maximum 4 – 4½) if urine is transported against gravity. So, Schick and Tanagho (1973), concluded that gravity aids the transport of urine from the renal pelvis to the bladder and when the ureter loses this facilitatory effect of gravity, it suffers from a functional obstruction adversely affecting the entire collecting system.

Tanagho and Meyers (1971b), have directly observed the ureteral peristaltic activity in the opened abdomen of dogs. They have demonstrated that when the experimental animal is placed in the head-down position, urinary stasis occurred and peristaltic activity ceased after about an hour. Once the animal is returned to the supine position, the peristaltic activity is resumed immediately and the wave are effective.

8. Infection

Infection within the upper urinary tract may impair urine transport (Weiss, 1986).

Grana et al. (1965), investigated the effect of
chronic infection on ureteral peristalsis in the dog and illustrated marked abolition of ureteral activity. The primary histologic change in the infected ureter is the destruction of the muscular tissue. Ureteral dilatation without obstruction has been present in every infected ureter. Based on their findings, Grana et al. (1965), found that, it has been reasonable to assume that long term chronic infection plays an important role in the development of dilated ureter.

Teague and Boyarsky (1968), showed that the instillation of living or killed coliform bacilli or E. coli endotoxin into the renal pelvis of dogs resulted in marked suppression of ureteral activity. Continuous tracing of peristaltic pressure and cinefluorography showed suppression of activity for 30 min to 2 hours. Both irregularity of rhythm and suppression of activity were demonstrated. Ureteral pressure, urine cultures and cinefluorography after 48 hours and one week, showed no residual effect. So Teague and Boyarsky (1968), suggested that a reaction to some component of E. coli by the ureter rather than an established infection is the likeliest explanation of the peristaltic changes. Boyarsky and Labay (1972), found that changes in ureteral peristalsis may occur within fifteen minutes after local, intravenous or intra-arterial administration of bacteria or E. coli endotoxin.

Ross et al. (1972), have demonstrated irregular con-
tractions often with a decreased amplitude in humans with infection. In the more severe cases absence of activity was noted.

Kass and co-workers (1976), reported 4 patients who during the early course of a well documented acute pyelonephritis, were observed to have otherwise unexplained hydronephrosis and hydroureter. The urinary tract infection and the hydronephrosis cleared after adequate treatment.

So, there is a considerable evidence that infection may impair urine transport although Struthers (1976), failed to confirm the inhibitory effect of *E. coli* and its endotoxin on ureteral peristalsis in dog. Boyarsky et al. (1978), stated that it is necessary to distinguish ureteral dilatation and hydronephrosis which occur secondary to post-infectious strictures from depressed peristalsis caused by infection, prior to establishment of cicatricular changes in the ureter secondary to infection.
THE PATHOPHYSIOLOGY OF URINARY TRACT OBSTRUCTION

Obstructive uropathy with resultant hydrenephrosis is the eventual outcome of most urologic diseases. The effects of urinary tract obstruction on renal function and structure, that is, obstructive nephropathy, has been studied at the level of whole kidney function using clearance techniques, at the level of the individual nephron using micropuncture, and at the cellular level using tissue slices and membrane preparations (Klahr, 1983).

Hydrodynamics in the Obstructed Urinary Tract

The effects of urinary tract obstruction on hydrodynamics will depend on the rate of urine flow at the time of obstruction, with very high pressures being generated during diuretic states, and will also depend on the level of obstruction, with higher pressures being generated by obstruction at higher levels in the urinary tract, particularly above the level of the bladder. Whether obstruction is unilateral or bilateral and partial or complete is also important (Rose and Gillenwater, 1973).

Immediately after acute ureteral obstruction, both the base line and peak intraluminal pressures are increased, and one hour after obstruction, baseline and peak pressures are similar and three to five times greater than pressures prior to obstruction (Whitaker, 1975). At this point coa-
ureteral ligation or after relief of acute obstruction, intraluminal hydrostatic pressure is normal, but glomerular filtration pressure and renal blood flow are reduced (Harris and Yarger, 1974; Dal Canton et al., 1979). These findings indicate that glomerular filtration rate is depressed by factors other than high intraluminal hydrostatic pressure opposing filtration pressure, this fall in glomerular filtration rate involves renal vasoconstriction associated with prolonged obstruction (Moody et al., 1975).

The escape of urine across walls of the collecting system is a third mechanism by which the urinary tract may be decompressed with prolonged obstruction. There is evidence that complete obstruction of the urinary tract does not completely abolish glomerular filtration. Direct micropuncture of glomeruli and proximal tubules indicates the presence of significant filtration (Dal Canton et al., 1977).

If there is persistence of filtration, then reabsorption of the filtrate must also occur (Dal Canton et al., 1980).

In addition to renal tubular reabsorption, it has been suggested that urine may be reabsorbed directly across the walls of the renal pelvis through the lymphatics (pyelolymphatic reflux) or renal venous system (pyelovenous reflux). Also, urine may escape through ruptured fornices
into the renal sinus and perirenal spaces (pyelosinus and pyelointerstitial) (Holmes et al., 1977).

Changes in Intrarenal Pressure, Glomerular Filtration, and Renal Hemodynamics

A. During Obstruction

a. Acute Obstruction

After either unilateral or bilateral ureteral obstruction, renal blood flow increases significantly (15 - 25 per cent) in the first (1) to (2) hours. This decrease in renal vascular resistance immediately after complete ureteral obstruction is probably secondary to the synthesis and release of vasodilator prostaglandins. With persisting unilateral or bilateral ureteral obstruction, renal blood flow progressively decrease to 40 to 50 per cent of normal by 24 hours (Moody et al., 1975; Moody et al., 1977). Glomerular filtration rate is more markedly reduced than renal blood flow. Glomerular filtration rate is 20 to 30 per cent of normal in both unilateral and bilateral obstruction after 24 hours (Dal Canton et al., 1979 and 1980).

1. Acute Unilateral Obstruction

After acute unilateral obstruction, there is an immediate increase intrapelvic and proximal tubular hydrostatic pressure, the severity of which depends upon the rate of urine flow prior to obstruction and the degree of ureteral muscular contraction (Gillenwater, 1986).
Despite this increase in intratubular pressure, the glomerular filtration rate is 80% of normal because of an increase in glomerular capillary hydrostatic and glomerular plasma flow, secondary to afferent arteriolar dilatation and decreased renal vascular resistance (Dal Canton et al., 1977).

As unilateral obstruction persists, progressive vasoconstriction and a decrease in nephron filtration rate develop within about 4 hours, and by 24 hours glomerular filtration is 30 per cent of normal due to a decrease in glomerular capillary pressure and plasma flow associated with an increase in renal vascular resistance, presumably at the level of the afferent arteriole. Proximal intratubular pressure is now normal rather than increased as during the first few hours of obstruction (Moody et al., 1975).

2. Acute Bilateral Obstruction

During acute bilateral ureteral obstruction, proximal tubular hydrostatic pressure increases to a higher level than after unilateral obstruction, and in sharp contrast to unilateral obstruction, intrarenal pressure remains twice normal after 24 hours. Renal blood flow increases for the first few hours after obstruction and then decreases to 40 to 50 per cent of normal similar to unilateral obstruction. Glomerular filtration rate after 24 hours is reduced to about 30 per cent of normal in bilateral obstruction, as it is in unilateral obstruction, but the decrease in glomerular
filtration rate in bilateral obstruction is due to a persistent increase in proximal tubular hydrostatic pressure while glomerular capillary pressure and plasma flow are normal (Dal Canton et al., 1980).

b. Chronic Obstruction

During chronic complete ureteral obstruction renal blood flow progressively decreases. After 24 hours renal blood flow is 40 to 50 per cent of normal in both unilateral and bilateral obstruction. Prolonged unilateral ureteral obstruction is associated with a further decrease in blood flow to 30 per cent at 6 days, 20 per cent at 2 weeks and 12 per cent at 8 weeks (Vaughan et al., 1970).

Glomerular filtration rate decreases progressively during complete ureteral obstruction (Gillenwater, 1986).

Ureteral pressures also decreases within 24 hours to about 50 per cent of the peak levels, and ureteral pressure continues to decline gradually over the next 8 weeks despite continuation of the obstruction (Vaughan et al., 1970).

During chronic partial ureteral obstruction, glomerular filtration rate may remain unchanged or decrease depending on the severity and duration of obstruction and the extracellular fluid volume status. Maintenance of normal nephron filtration rates appears to depend on an increase in glomerular capillary hydrostatic pressure, which results from a more marked increase in efferent compared to
afferent arteriolar vascular resistance and which may also be associated with a decrease in glomerular capillary ultrafiltration coefficient (Humes et al., 1980). Decreased nephron filtration rates in chronic partial obstruction have been associated with mild persistent increase in proximal pressure (Wilson, 1972). Nephron loss, which may be more marked in deep compared to superficial nephrons, also contributes to decreased glomerular filtration rate with chronic partial obstruction (Wilson, 1974).

B. Relief of Obstruction

Following relief of 24 hours duration of unilateral obstruction, intratubular pressure is normal, but glomerular filtration rate remains reduced and renal vascular resistance increased, with a gradual return to normal after approximately one week (Dal Canton et al., 1979). Following relief of 24 hours of bilateral obstruction, intratubular pressure decreases from elevated levels to normal, but glomerular capillary pressure and plasma flow also decrease due to afferent arteriolar vasoconstriction, resulting in a persistent decrease in glomerular filtration rate (Dal Canton et al., 1980).

After relief of chronic partial unilateral urinary obstruction, there is no increase in absolute sodium and water excretion from the hydropnephrotic kidney, although decreased concentrating ability and increased fractional excretion of sodium are observed (Gillenwater et al., 1975),
presumably due to altered function in the deep nephrons and collecting ducts. The results indicate that other factors such as volume expansion or further reduction in functioning nephron mass with uremia are necessary to bring about an increase in salt and water excretion (post-obstructive diuresis) following relief of obstruction. With hypotonic saline loading, there was a disproportionate diuresis from the hydronephrotic kidney (Wilson, 1974), which was associated with reduced reabsorption in the distal nephron, indicating that volume expansion may be a significant factor in post-obstructive diuresis even in absence of uremia.

Mild post-obstructive diuresis developed after relief of chronic partial ureteral obstruction of a solitary hydronephrotic kidney. In contrast to the marked post-obstructive diuresis seen after relief of acute complete bilateral ureteral obstruction, the modest increase in urine flow and sodium excretion that occurred after relief of chronic partial obstruction was due entirely to an increase in glomerular filtration rate after release of obstruction, and there was no increase in fractional sodium excretion. Surface nephron glomerular filtration rate increased by only 20 per cent, and tubular reabsorption did not change significantly after relief of obstruction, where as whole kidney glomerular filtration rate doubled, suggesting that there was greater improvement in function of deep nephrons (Wilson, 1988).
After relief of complete obstruction, a marked and sometimes prolonged diuresis may follow the relief of severe obstruction of both kidneys or of a solitary kidney. This diuresis is characterized by massive losses of water, sodium, and other solutes. If not replaced, such losses obviously could lead to severe hypovolaemia and life-threatening electrolyte imbalance. However, a brisk diuresis following relief of urinary tract obstruction may also be physiologically appropriate or even iatrogenic rather than an indicator of tubular malfunction. Many factors influence the urinary flow rate following relief of obstruction, and the appropriateness of fluid replacement in a given case will depend on which mechanisms are important in that patient (Witte et al., 1964).

The mechanisms responsible for post-obstruction diuresis may be physiologic or consequences of abnormal tubular function:

(a) Saline diuresis: When obstruction of urinary tract is bilateral and prolonged, renal insufficiency occurs, so that continued intake of fluid and electrolytes results in expansion of the extracellular fluid volume. In this situation, fluid volume expansion activates natriuretic forces that will become manifest when obstruction is relieved and glomerular filtration rate increases. Also, this hypotonic expansion will suppress vasopressin secretion and water diuresis would be superimposed
(Chander et al., 1973).

(b) Osmotic diuresis due to retained urea: During the period of urinary tract obstruction, there is a progressive azotemia with accumulation of urea and other poorly reabsorbable solutes. After relief of obstruction, the high concentration of urea and similar solutes in glomerular filtration will result in an osmotic diuresis (Peterson et al., 1975).

(c) Osmotic diuresis due to excessive infusion of intravenous solutions.

(d) Recovery of glomerular filtration: The rate and degree of recovery of glomerular filtration after relief of obstruction is important in determining the occurrence of marked post-obstructive diuresis. In the reported cases of striking post-obstructive diuresis, glomerular filtration rate has been relatively high, 30 to 70 per cent of normal, thus delivering a large load of solute and water to tubules with impaired reabsorptive capacity (Mc Dougal and Persky, 1975).

(e) Diuresis due to defect in tubular reabsorption of sodium: Following the relief of unilateral obstruction in experimental animals, fractional reabsorption of sodium is decreased, but not sodium excretion is usually similar or less than that of the unobstructed kidney because glomerular filtration rate is low. In contrast to the kidney after relief of bilateral obstruction, proximal, tubular reabsorption is decreased and
natriuresis with subsequently diuresis is more prominent in cases with bilateral obstruction than that with unilateral obstruction (Harris and Yarger, 1975).

(f) Diuresis due to impaired water reabsorption from the collecting ducts.

The recovery of glomerular filtration after relief of obstruction is a problem of major clinical importance. The potential for recovery of glomerular filtration rate will seriously affect decisions regarding treatment of obstructive uropathy. The factors that determine the extent to which the decrease in glomerular filtration rate is reversible have been studied systematically in dogs by measuring the rate and degree of return of renal function after varying periods of complete unilateral ureteral obstruction. The maximum glomerular filtration rate attained after the release of obstruction of 7 days duration was about two-thirds of glomerular filtration rate before obstruction. If the obstruction was 28 days duration, the glomerular filtration rate returned to only a fifth of the original rate (Vaughan and Gillenwater, 1971).

In general the recovery of renal functions after release of obstruction is related mainly to severity of renal injury, the duration of obstruction and presence or absence of infection (Gillenwater, 1986).
INVESTIGATIONS OF THE DILATED
UPPER URINARY TRACT

One of the major problems in any discussion of the investigation and management of obstructive uropathy is the difficulty in precisely defining what the term means. Impedance to urine flow, urinary tract dilatation, reduction in flow rate, increased intrarenal pressures and functional impairment all play a part in the genesis of the syndrome. Attempts to produce a working definition tend to place emphasis on whichever of these aspects the definer has an interest in and to ignore the others. "Impedance to flow resulting in abnormal back pressure on the kidney" or "narrowing such that the proximal pressure must be raised to transmit the usual flow through it" are two such examples (O'Reilly, 1982).

Following the onset of the obstruction, urine accumulates proximal to the affected site leading to increased pelvic or ureteric dimensions and an initial pressure rises. The maintenance of this pressure depends on the continued production of urine which, however, has no free exit route beyond the obstruction. Thus, within a short time, the pressure peaks and declines due to falling blood flow and glomerular filtration, leak of urine into venous and lymphatic channels and change in wall tension. The viscoelastic properties of the ureter will then allow further in-
crease in the dimensions of the upper tract to occur even though the pressure has fallen to and remains normal (Ash and Gilday, 1980).

With these points in mind, the task of the surgeon or physician dealing with urinary tract obstruction is directed towards diagnosing and removing the obstruction, preserving renal function and hopefully reversing any damage which has occurred. In acute obstruction, all these may be possible. In chronic situation, selection and timing for surgery are far from straight forward, and are complicated by decisions regarding which kidney to operate on first in bilateral disease, the persisting effects of previous obstruction or surgery in recurrent disease, and the distinction between patients with true obstruction and those with similar urographic appearance from non-obstructive dilatation or vesicoureteric reflux (O'Reilly, 1982).

The procedures which may be used to arrive at the appropriate management decision will be discussed. Like many modern investigative options, informed and wise usage should result in maximum information, while ill informed and blanket usage will be expensive and counter-productive. Their use needs to be tailored in the light of the physiological consideration and to the existing clinical situation (O'Reilly, 1982).

The problem of the dilated non-refluxing upper uri-
nary tracts frequently meets the urologists throughout the every day practice. Sometimes it is difficult to decide that the system is obstructed or not and whether to send the patient home or to take him to the operation theatre. Dilatation usually accompanies obstruction but there is no doubt that dilatation can be present with no obstruction. The problem is more evident in those patients who had been submitted to previous surgical procedures for correction of obstruction or extraction of obstructing stone and still have dilated systems. Whether this dilatation is due to reobstruction or it is merely residual dilatation (Whitaker, 1973b).

Such condition is more encountered in those patients who submitted to ureterolithotomy, ureteral reimplantation, pyeloplasty, ureterointestinal anastomosis after total cystectomy and lastly dilated system due to non-refluxing megaureter.

Diagnosis of obstruction in dilated upper urinary tracts still depends upon conventional methods for diagnosis (i.e. IVU and retrograde pyelography). Although demonstration of the anatomy of renal pelvis and ureter by IVU may sometimes be all what is needed, but current surgical decisions often require informations about the status of urine transport.

Before discussing the available modalities for diag-
nosing obstruction, the symptomatology of the patient should be considered. Patients presenting with loin pain, renal colic or symptoms suggesting infection should be thoroughly investigated for a possible obstructing factor.

1. Plain Radiograph

The plain film of the abdomen is an integrated part of every roentgenographic study of the ureter. Although the normal ureter produces no detectable image in the plain film, the presence of calcification may delineate a dilated ureter. Al-Ghorab (1968), described a condition which will be shown in the plain film as punctate discrete calcifications in the course of the ureter which was called ureteritis calcinosa. A dense radio-opaque calcific shadow along the course of the ureter resembling a stone may be present in cases of bilharzial pseudocalculation (Al-Ghorab, 1962 & Maged and Soliman, 1968).

The presence of multiple small rounded calculi in the ureter is suggestive of the presence of a distal obstruction.

Soft tissue shadow of a markedly dilated ureter may be seen as an elongated more or less linear mass (Friedenberg and Bottizer, 1981).

Therefore, it is important to obtain and examine the plain film prior to any contrast examination, which may
obscure any calcification along the ureter (Pfister and Newhouse, 1978).

2. Intravenous Urography

The intravenous urogram is by far the most commonly employed examination of the ureter. Iodinated contrast material injected intravenously is concentrated and excreted by the kidneys; the opacified urine then serves to outline the ureteral lumen. Once injected intravenously, these compounds are filtered from the plasma at the renal glomeruli. They are neither secreted nor reabsorbed from the renal tubules to any significant degree; the reabsorption of water from glomerular filtrate concentrates the compounds sufficiently to render the urine radio-opaque (Pfister and Newhouse, 1978).

Under normal circumstances, the ureters begin to carry opacified urine approximately three minutes after injection and remain transiently opacified to some degree for hours; maximum contrast density and maximum ureteral filling due to the associated diuresis are produced within five to ten minutes after injection.

Osmotic diuresis produced by contrast may, if sufficiently great, overwhelm the normal peristaltic activity of the ureter and cause the organ to act like a fixed distended conduit. This phenomenon, known as "columning" suggests an element of ureteral obstruction when contrast doses are low
but not uncommonly appears as a normal finding when large
doses are used. Delayed films may be necessary in any con-
dition in which diminished urine flow or increased ureteral
volume slows the opacification of the ureter, films obtained
as long as 24 hours or more after contrast injection may be
required. Sometimes, one may resort to infusion urography
for visualization in advanced hydronephrotic cases (Pfister
and Newhouse, 1978).

Ureteral compression at the height of the pelvic brim
will cause temporary obstruction and produce optimal filling
of pelvicalyceal system and proximal two-thirds of the
ureter. The release of compression just prior to the
20 min. supine and prone projections will usually provide
excellent uretrogams (Friedenberg and Bottizer, 1981).

Dilatation of the ureter of varying degrees may be
seen in the IVU. However, it is very important to notice
that IVU will only give a static-still anatomic picture and
also not differentiate between tense obstructed and flobby
non obstructed systems. The degree of obstruction cannot be
depicted from the static pictures of the IVU (Whitaker,
1973b).

The criteria for significant renal obstruction on an
IVU included moderate to severe hydroureteronephrosis with
calicectasis, delayed appearance of contrast material in the
affected collecting system compared to the non-affected
side, decreased density of the contrast agent in the affected collecting system due to either dilution by retained non-opaque urine and/or diminished renal concentrating ability and delayed drainage from the ureter into the bladder (with the bladder empty and in the absence of reflux) (Peters et al., 1989).

3. Furosemide Intravenous Urography

The furosemide intravenous urography naturally is based on the presumption that the kidney in question is able to excrete contrast medium. The renal pelvis varies in size according to the state of activity and the diuretic load. The pelvis can during low urine output be confined to the anatomical pelvis which extends to the pelvi-ureteric junction or may even extend as far as down to the bladder during high urine output (Djurhuus et al., 1985).

Diuresis urography was performed in the hydrated patient. Forty milligrams of furosemide was injected intravenously 20 minutes after the contrast. Five radiological features are examined: (1) Size of renal pelvis before and after furosemide. (2) Size of the calices before and after furosemide. (3) Contrast dilution within the renal pelvis after furosemide. (4) The occurrence of pain during examination.

The only reliable and consistent feature was found to
be the change in size of the renal pelvis. This was measured by outlining the pelvis on a table with a pressure sensitive surface linked on line to a computer (Whitefield et al., 1981).

Whitefield et al. (1977), considered that a 20% increase in the area of the renal pelvis, as determined by planimetry, 15 minutes after diuresis is interpreted as an obstructed pattern. The test particularly valuable in PUJ obstruction.

There are disadvantages to urography in the diagnosis of obstruction: The radiation dose is appreciable, in patients with poor renal function there may be insufficient definition of the collecting system after contrast; where previous surgery has caused peri-pelvic fibrosis, so the compliance of the pelvis may be reduced and the criteria used for diagnosing obstruction become unreliable (Whitefield et al., 1981).

4. Retrograde Pyelography and Ureterogram

It is well known that the passage of ureteric catheter does not exclude functional obstruction although it may, to a certain extent, rule out organic obstruction. Moreover, failure of passage of the catheter may occur in the absence of obstruction.

Retrograde examination of the ureter must be interpreted somewhat differently from IVU. Direct injection of
contrast usually distends the pelvicalyceal system and the ureter to its maximum and often obliterates peristalsis. The true anatomy and physiology of the ureter are more accurately demonstrated in the drainage films. Washout of contrast from the ureter and collecting system in the drainage films is produced both by collapse of the opacified structure after cessation of injection pressure and by continued flow of non-opacified urine from the kidney. So, persistence of large amounts of contrast in this film can, therefore, be produced both by low urine flow rates or large ureteral volumes. Persistence of contrast in delayed films should not, therefore, be assumed always to represent obstruction (Pfister and Newhouse, 1978).

Advantages of Intravenous Urography Over Retrograde Pyelography

Clark (1985), mentioned the following advantages:-

(1) It demonstrates the function of the kidney;
(2) it demonstrates its parenchymal outline on the end of injection film;
(3) it demonstrates an undistorted outline of its collecting system on the later film;
(4) cystoscopy is not needed, and
(5) there is no danger of introducing infection into the kidney.

Drawbacks of Retrograde Pyelography

(1) The obvious disadvantage of retrograde pyelography is
that it necessitates cystoscopy which may produce pain, dysuria, frequency and haematuria. These symptoms are the result of trauma, infection or both (Greene, 1978).

(2) Oedema which may aggravate the obstruction and converts the slowly draining ureter into completely obstructed one (Mitchell, 1981).

(3) Post-pyelography reaction which is followed by pain, haematuria, fever, chills, sweating, dysurea and frequency. This may be due to irritation of contrast medium, from infection or from over distention of the renal pelvis and calyces (Greene, 1978).

(4) Pyelonephritis: so, it must be performed extremely cautiously.

(5) Pyelo-renal back flow: there are five types of back flow; pyelosinus, pyelolymphatic, pyelotubular, pyelovenous and pyelointerstitial (Woodruff et al., 1973).

Retrograde studies of the upper urinary tract for a possible obstruction are to a certain extent unreliable as they are:

(1) can be misinterpreted giving a false diagnosis of obstruction,

(2) passage of the catheter can not exclude functional obstruction,

(3) the catheter may, sometimes, not pass while there is no obstruction.
(4) the test is an invasive one carrying a risk of ascending infection and perforation.

5. Antegrade Pyeloureterography

The ureter may be opacified by direct injection of contrast into the renal pelvis, which may be accomplished either via an indwelling nephrostomy tube or by direct needle puncture. This mode opacifies the ureter as densely and completely as the retrograde ureterogram.

Antegrade pyeloureterography has some advantages. It does not require general anaesthesia, does not injure the ureterovesical orifice or produce ascending infection. Injection of contrast material into the renal pelvis permits fluoroscopic observation of ureteral peristalsis without retrograde flow or the presence of a ureteral catheter. It is particularly useful in evaluating complex reconstructive surgical alteration (Pfister and Newhouse, 1978).

In addition, perfusion of the ureteral lumen at known flow rates, together with simultaneous measurement of renal pelvis and bladder pressures, permits accurate measurement of resistance to urine flow. These measurements are frequently of great value in patients with dilated ureters of obscure etiology and in whom the results of ureteral surgery must be evaluated (Pfister and Newhouse, 1978).

The technique may sometimes be difficult and has its complications such as fever which may occur as a result of
over distention of an infected system, retroperitoneal haemorrhage is always a possibility.

Whitaker (1973), has criticized the significance of informations obtained by antegrade pyeloureterography. He stated that the information forthcoming is often only anatomical. Dynamic information particularly in reference to small degree of obstruction is often not forthcoming. Of course, if no contrast medium flows through the site of suspected obstruction under any circumstances clearly, an obstruction is present and conversely, if the first few milliliters of medium run straight through, then an obstruction is unlikely (Whitaker, 1973).

6. Cineradiography

Cineradiography, also called cinefluoroscopy or, simply, cine, is a valuable diagnostic instrument in the study of ureteral function. Leadbetter, (1981), has revised the subject. The value of cineradiography is its ability to view a dynamic actions of organs such as ureter. Prior to the introduction of cine, only momentary segments of the dynamic state were recorded by standard techniques. Anatomic defects were clear but physiologic abnormalities were either unrecognized or visualized fleetingly on the fluoroscopic screen. Cineradiography allows the recordings to be obtained on a film or a tape which makes the information available for repeated analysis and study.
Technique

For the cine intravenous urogram, a drop infusion of the dye should be used. This accomplishes:
(1) increased density and visualization, and
(2) diuresis creating more peristalsis.

When the dye begins to appear, recordings are made at intervals as the bolus of dye is followed from the renal pelvis along the length of the ureter to the bladder. In an area of abnormality a more prolonged study of the involved segment should be obtained.

Indications:
The main indication of cineradiography are:
1. Hydroureter of Any Aetiology

Non-refluxing hydroureters may best be observed and more easily demonstrated by filling the ureter via a nephrostomy tube or through a retrograde ureteric catheter. There may be surprising effective peristalsis, even in the presence of rather marked hydroureter. More characteristically is either completely absent or altered so that there appears to be a “rocking” motion. This motion is best described as a wave of peristalsis which travels for a short distance and then reverses to produce a retrograde peristalsis, creating the appearance of the dye rocking back and forth. The point at which the retrograde peristalsis begins may be the point of an intrinsic obstruction such as stone, stricture or tumour, the site of an aperistaltic segment or
simply the result of the uncoordinated peristaltic motion of a very wide ureter.

2. Evaluation of Ureteral Function

A. Preoperative

Information relative to the effectiveness or ineffec-
tiveness of peristalsis is often necessary to decide whether reconstruc-
tive surgery should be performed or a period of urinary diversion is more desirable or even that surgery is not indicated at all.

B. Post-Operative

It may be helpful in deciding whether ureteral func-
tion has recovered sufficiently to remove a nephrostomy tube or ureteral splint or whether function is very bad that perhaps a nephrostomy should be left.

3. Classification of Undiagnosed Ureteral Obstruction

An aperistaltic ureteral segment is an obstructive lesion that is not visualized by standard intravenous urograms. Such a segment can occur anywhere along the ureter, but most commonly at UPJ or UVJ and a catheter can be easily passed through it. This entity can be definitely diagnosed by cinecharacteristically, ureteral peristalsis begins above such a segment but when it reaches the area of a peristalsis only a small portion of dye will pass through it, the remainder will go upwards in a retrograde fashion and may produce the previously described rocking.
However, Weiss (1979), stated that cineradiography of the ureter is of limited value in assessing function. One can observe the movement of fluid within the ureter but cannot qualitatively assess urine transport or the functional capacity of the ureteral wall.

7. Ultrasonography

Renal ultrasound is an excellent screening examination for suspected urinary tract obstruction. Its usefulness is based on the ability to detect hydronephrosis (Amis et al., 1982).

In hydronephrosis, ultrasound provides excellent anatomic informations and enables one to grade the degree of dilatation and in some cases the site of obstruction can be shown when a distended bladder is used as a transonic window to image the distal ureter. The ultrasonic features of hydronephrosis are mainly changes in central sinus echo complex which become separated by echo free spaces, and the dilated pelvis itself can be recognised as an echo free zone medially these changes reflect the degree of dilatation of the pelvi-calyceal system (Ellenbogen et al., 1978).

The degree of hydronephrosis was graded on a scale of 0 - 3 as follow:
Grade [0] Central collecting system echoes compact and homogeneous.
Grade [1] Slight separation of the collecting system echoes
with a central ovoid or fusiform sonolucency.

Grade [2] Further separation of the collecting system echoes
with a rounded sonolucency seen centrally.

Grade [3] Major portion of the kidney replaced by a
sonolucent sac.

(Ellenbogen et al., 1978)

Joseph et al. (1981), put a criteria according to
which hydronephrosis can be graded ultrasonically:

(1) **Normal**: No separation of central sinus echo complex.

(2) **Mild hydronephrosis**: Slight separation of central sinus
    echo complex.

(3) **Moderate hydronephrosis**: Further separation of central
    sinus echo complex and the appearance of multiple
    communicating echo free areas, separated by echogenic septa
    representing renal parenchyma.

(4) **Severe hydronephrosis**: Huge sonolucent sac with marked
    thinning of renal parenchyma.

Indications for ultrasound examination in obstructive
uropathy have included azotemia, previous reaction to con-
trast media, pregnancy and oligouria.

While accuracy of the examination in detecting
hydronephrosis may approaches 100 per cent, it should be ac-
cepted that many causes of urinary tract dilatation are non
obstructive in origin. Similarly, obstruction without
hydronephrosis, although infrequent, exists. Ultrasonog-
raphy may be associated with false positive or false nega-
tive renal sonograms. So, renal sonography suggesting hydronephrosis should be followed with additional diagnostic studies to confirm or exclude obstruction (Amis et al., 1982).

Pfister (1978), stated that B-mode ultrasound has a definite place in the diagnosis of some ureteral diseases. Although the normal ureter is not visualized, a dilated ureter is particularly well suited to be detected by this method since the interface between the walls and the fluid filled lumen reflects the sound waves well. Wacksman (1984), reported 7 cases in which a dilated ureter below the renal pelvis could be diagnosed. However, the poor resolution of the obtained images and the limitation of each image to structures within one plane render these studies inferior to contrast examination (Pfister, 1978).

Moreover, it is obvious that ultrasound can diagnose a dilated system but can not differentiate obstructed from non-obstructed renal units.

An additional information that can be obtained from sonographic examination of dilated kidneys is the parenchymal thickness of the kidney under investigation.

Diuresis Sonography

Engelman et al. (1981), added a new dimension to use of ultrasonography in the diagnosis of obstruction. They tried to use ultrasonography in a dynamic fashion in the
diagnosis of UPJO using what they called (Diuresis sonography). They stated that sonographic surface and volume measurements of the renal pelvis is sometimes difficult, firstly because of the irregular form and secondary, because of the often poor cranial outline behind the eleventh and twelfth ribs in pronounced hydrenephrosis. In contrast they found that reproduction of maximal depth and width of the renal pelvis is superior with sonography.

Engelman et al. (1981), found that furosemide diuresis does not lead to any measurable changes in non-dilated or intra-renal pelvis. If the pelvis is extra-renal, as in cases with PUJO, a degree of dilatation will occur depending on the degree of obstruction and the function of the kidney. Also, no measurable increase in diameter in normal kidney or if the kidney not respond to furosemide diuresis. As a rule width increase more than depth. Engelman et al., have considered an increase in diameter of 30% or more as a clear indication of obstruction (Fig. 16).

The diuretic ultrasound provides a safe, non invasive tool for the assessment of clinically significant obstructed renal unit. With the almost universal availability of ultrasound, this test provides for rapid, dynamic screening assessments of the obstructed renal unit without the necessity of contrast media or x-ray exposure. Its particular advantages would be seen in the pregnant women, those in
renal failure or those allergic to contrast media also in prenatal or post-natal period (Goldberg et al., 1988).

Goldberg et al. (1988), stated that the use of a 50 per cent increase in unit size compares favourably with the 22 per cent increase in renal diameter used as a standard for evaluation of dilated upper urinary tract.

An obvious disadvantage of this test is that unlike diuretic renogram, ultrasound provides no quantitative information regarding renal function (O'Reilly et al., 1979).

Critical to accurate assessment is consistent measurement of the same part of the renal pelvis at each examination. Although hydronephrosis is more apparent in the long axis view, measurements in this plane have been found to be impractical due to the complex shape of the collecting system. Lastly, the diuretic ultrasound allows, a simple, inexpensive, minimally invasive alternative for the demonstration of clinically significant upper urinary tract obstruction, and has a place as a useful adjunct to the urologic and radiologic armamentarium (Goldberg et al., 1988).

8. Computerised Tomography

A CT image is produced in three steps. During first step, multiple x-ray exposures or views of an object are obtained. The second step involves a computer-aided reconstruction of the image, and the third step entails dis-
Fig. (16) Diuresis sonography. Increase of width and depth in transverse scan after frusemide diuresis (Engelman et al., 1981).

NORMAL CURVES

Fig. (17) Diagram showing enhancement of the CT number over cortical and medullary regions of interest after injection of contrast in a control. The arrow over the cortical curve shows the maximum cortical rise and that over the medullary curve shows the maximum medullary rise. The maximum rate of increase in CT number before the maximum medullary rise was reached is the steepest medullary slope (Neal et al., 1985).
playing the image in various shades of gray (Mc Cullough, 1977).

The role of CT in ureteral pathology is limited as only transverse sections of the abdomen can be taken. Dilated ureters even without contrast within their lumen, may be seen as structures distinct from other retroperitoneal organs but, the normal ureter can hardly be detected and the radiation dose is considerable (Pfister and Newhouse, 1978). The effect of ureteral obstruction can be easily detected as a hydronephrotic kidney. It is important to determine the cause of blockage. When the cause of obstruction is unclear on a conventional urogram, CT may explain the reason for it in up to 90 per cent of cases (Bosniak et al., 1981).

Bosniak et al. (1981), concluded that while computerised tomography is not the first step in work up of hydronephrosis, it may be essential to arrive at the correct diagnosis. In time, this imaging modality may replace more invasive procedures such as retrograde pyelography in studying some patients with ureteral obstruction of unclear aetiology. However, the costs of this examination should be taken into consideration before considering it as a routine one.

Dynamic computed tomography involves rapid sequence CT after injection of contrast medium. [The maximum enhancement of a medullary region of interest and its rate of
enhancement were derived]. A sequence of scans may be taken to follow contrast medium through cortex and medulla (Brennan et al., 1979). By defining a region of interest over part of the cortex and part of the medulla it is possible to record the CT number sequentially, thereby obtaining data relating to the renal handling of the contrast medium. Neal et al. (1985), thought that such data should permit measurement of the transit of contrast medium through the kidney and so give an objective measurement of the presence of obstructive nephropathy.

Typical curves over the cortex and medulla are shown in the figure. Three parameters were derived from these curves. The maximum cortical rise was the maximum rise in CT number measured over the cortical region of interest immediately after the initial steeprise. The maximum medullary rise was the maximum CT number reached in the first 90s after injection of contrast. The steepest medullary slope was the steepest rate of increase in CT number measured over the medullary region of interest (Fig. 17) (Neal et al., 1985).

The original hypothesis was that, if obstruction results in a decrease in renal transit time, the rate of appearance in the medulla of injected contrast medium when measured by means of Dynamic CT would be a good estimate of renal transit time and would, therefore, predict the presence of obstruction. Many pitfalls in Dynamic CT do not
support this hypothesis.

Firstly, technical reasons.

Secondly, the steepest medullary slope is probably not related solely to transit of contrast medium through the kidney. For example, medullary blood flow and concentrating ability of the nephron will also affect the steepest medullary slope. Both of these factors may be impaired by chronic obstruction (Neal et al., 1985).

9. Urodynamic Methods

Obstruction is a situation in which difficulty is encountered in getting urine through the system. When analysed a little more scientifically, this implies that any particular degree of obstruction requires a certain pressure to force urine through the system at the usual or even at a reduced flow rate. Thus in an unobstructed system there are normal pressure and flow but in an obstructed system either the pressure is abnormally high or the flow rate is reduced or a combination of both is present. So, an accurate diagnosis of obstruction entails the measurement of pressure and flow (Whitekar, 1973a, b).

A. Retrograde Pressure Measurement

Studies of ureteric and pelvic pressure changes as measured through retrogradely passed catheter. The objection of this method is that the catheter itself, however small, must present a potential or real obstruction, and indeed it is illogical to assure the resistance of an
orifice or a tube with a foreign body lying in its lumen (Whitaker, 1973a).

B. Direct Measurement of Upper Tract Pressure

The definition of obstruction dictates that at times there will be an abnormally high pressure above the suspected site. So, it is logical to attempt to measure this pressure. This can be easily done at the time of surgery by direct puncture of renal pelvis or ureter, or later via a nephrostomy tube. Such static and isolated pressure recordings are of limited value and if the patient is dehydrated, as in the operating theatre, they will not reflect the normal dynamic state (Whitaker, 1973a). However, continuous recording of pressure over a number of hours can be meaningful and is useful after pyeloplasty to ensure that the pressure is satisfactory before removing the nephrostomy.

C. Pressure During Diuresis

Measurement of intrapelvic pressure during steady maximal diuresis has been tried by Whitaker (1973), in children with dilated ureters. However, he found that the test is lengthy and uncomfortable for children and the results are difficult to interpret. A high rise in pressure, certainly suggests the presence of obstruction. However, little or no rise will not exclude obstruction particularly in failing kidneys. It is difficult to be sure when the diuresis has reached its maximum and even then whether there
is a steady state of flow through the site of the suspected obstruction. Information about the flow rate is lacking.

D. Pressure/Flow Studies (Whitaker Test)

The studies of Johnston (1969), & Backlund and Reuterskiold (1979), using perfusion and pressure measurement in the renal pelvis and ureter led the way to the evolution of the Whitaker test.

The principle of the test, as described by Whitaker (1973a, b), is to perfuse the upper urinary tract at a constant high flow rate (10 ml/min) with a saline or contrast from above downwards. This is done through a tube, a cannula or a needle and simultaneously measuring the pressure difference between the renal pelvis and the bladder. The high flow rate will stress the system maximally to unmask any present obstruction. The recorded pressure is that needed to drive the fluid at this high constant flow rate through the suspected site of obstruction. A system which will tolerate such a high flow without a considerable increase in pressure is an unobstructed system (Wolk and Whitaker, 1982).

Technique

Whitaker (1973a, b), has first described the test and its uses. Whitaker (1976 to 1979a, b and c & 1981), has further emphasised the uses of the test. All-Over these years there was no change in the technique.
The test should be performed in an x-ray room with full screening facilities. The basic requirements for the test are shown in fig. (18). The pressure transducer can be replaced by a simple water manometer as suggested by Pfister et al. (1982). A urethral catheter (12 - 14 F Foley's catheter) is inserted and allowed to drain until measurement of the pressures are commended when it is attached to the transducer.

The assess to the upper tract above the suspected site of obstruction can be made by either a nephrostomy tube or percutaneous puncture (Tube or Needle).

The procedure is done in the prone position. Local anaesthesia is usually sufficient, however, sedation may be needed - heavy sedation is better avoided as the patient's co-operation is usually needed. General anaesthesia may be essential in young children.

Contrast medium is injected intravenously, the dose varying according to the age and size of the patient. In adults between 70 and 100 ml of 76 % urografin is the usual dose. The opacified pelvi-calyceal system provides a target on the image intensifier which can be aimed at with the needle. In a grossly dilated system intravenous contrast injection may be unnecessary as direct antegrade injection of the dye into the pelvi-calyceal system is easy (Coolsaet et al., 1980).
Perfusion and Pressure Measurement

Before starting the puncture, the pressure measuring apparatus is calibrated (Fig. 18).

After the puncture, the perfusion of 30% urograffin or saline is commenced at a rate of 10 ml/min with the recording apparatus running. An immediate sudden rise of pressure indicate that the cannula is not lying freely in the pelvi-calyceal system and readjustment is necessary. Although, Whitaker considered the flow rate of 10 ml/min to be within the physiological range, Hanna (1981), stated that this rate is clearly unphysiologic and overstress of the system may invalidate the results.

A normal or low pressure at this flow rate excludes obstruction. If the pressure at this fast flow rate (10 ml/min) is high, a lower flow rate, 5 or 2 ml/min can be used to determine what flow the upper tract can tolerate.

In equivocal results, Pfister et al. (1982), suggested an increase of the flow rate to 15 - 20 ml/min.

According to Whitaker (1978), the whole study usually takes around 30 - 45 minutes. The patient is kept in hospital for at least 12 hours after the test with regular monitoring of the blood pressure, pulse and urine output.

Analysis of the Results

Whitaker (1979b), analysed the results of 170 P/F
Fig. (18) A schema for simplified percutaneous ureteral urodynamic study is depicted. Disposable water manometers are interfaced with a single 22-gauge renal needle and bladder catheter (Pfister, 1982).
studies and he considered a relative pressure of up to 12 - 15 cm H₂O as normal at a flow rate of 10 ml/min giving a low flat curve (Fig. 19c). Values of 22 - 40 cm H₂O indicate moderate obstruction giving a high curve (Fig. 19b). Values more than 40 cm H₂O are indicative of severe obstruction giving rising curve (Fig. 19a).

Values between 15 and 22 cm H₂O are considered equivocal or they may indicate some degree of mild obstruction. The criteria given by Jaffe and Middleton (1980); Pfister et al. (1982), are similar to those of Whitaker.

Limitations and Complications

The Whitaker’s test is definitely invasive as it requires kidney puncture and general anaesthesia in children (Whitaker, 1973a). The invasive nature of the test makes it not readily applicable to equivocal cases when repeated follow up may be indicated. The second criticism to the test is its inability to give an idea about parenchymal function (Whitefield and Britton, 1981). The pressure flow study has also no value in predicting the outcome of surgery in hydronephrosis (Djurhuus and associates, 1982 & 1985).

Fortunately, the test has a few complication, Whitaker (1979b), reported the following complications in a series of 170 studies:

(1) Transient haematuria: is to be expected but always resolve spontaneously.

(2) Clot colic: occurred in one case only in the series.
Fig. (19) Three broad categories of pressure results. Rising curve marked obstruction, high curve-moderate obstruction and low curve-absence of obstruction (Pfister, 1982).
(108)

(3) Extravasation: may occur either during or after the procedure.

(4) Urinary infection.

(5) Peritonism but resolve spontaneously.

Gram-negative septicaemia may be encountered (Whitefield and Britton, 1981), subcapsular haematoma, intra-abdominal bleeding and peripelvic urinoma may be encountered by this procedure (Jaffe and Middleton, 1980).

Also, it is important to consider the potential sources of error inherent in the Whitaker test. When an obstruction is present the intrapelvic pressure will not increase until after the collecting system is filled completely. Thus, there exists the potential for a falsely low pressure recording. If there is leakage of fluid outside the collecting system or if the study is terminated before the pelvi-calyceal system is filled completely. In addition, Kass and associates (1984), have observed instances where in the perfusion pressures were low and flow rates of 10 c.c. per minute but became abnormally elevated only when the flow was increased above this rate. Therefore, one must consider the intrinsic urine output of the kidney, since it contributes an unknown volume to the total amount of fluid being perfused, and the potential for false positive studies should be considered whenever the urine output of the kidney being studied is high. Another source of error exists when the urethral catheter fails to drain the bladder effec-
tively, resulting in an increase in the intravesical pressure, which may impair secondarily upper tract drainage. Perfusing the kidney with dilute contrast medium under fluoroscopic control allows the identification of many of these potential sources of error but it does have the disadvantage of additional radiation exposure (Kass et al., 1985 & Kass and Majd, 1985).

E. Constant Pressure Perfusion Study

Whitaker test offers a dynamic means of evaluating equivocal upper urinary tract obstruction. The upper urinary tract is perfused at a constant flow rate while renal pelvic and bladder pressures (gradient across suspected obstruction) are recorded. The results are obtained and categorized as shown previously. Woodbury et al. (1989), have introduced a new technique in evaluating equivocal upper urinary tract obstruction. In an effort to define a more physiological method to determine obstruction in the upper urinary tract, the technique of constant pressure perfusion was studied in the animal models. In contrast to the constant flow technique of Whitaker, constant pressure perfusion is independent of upper tract compliance, uses low fixed pressures (7 to 12 cm water) in the renal pelvis and measures flow rates from the upper tracts (Vela-Navarrete, 1982).

The constant pressure perfusion and constant flow tests correlate well in general, but Woodbury and as-
sociates (1989), noted several potential advantages of constant pressure perfusion technique over constant flow technique of Whitaker. The constant pressure perfusion technique is physiological in that it potentially measures the renal pelvic pressure versus flow out relationship in the normal pressure ranges. High flow rates are not necessary and, therefore, renal pelvic pressure measurements are not only physiological but they tend to be more accurate. Also, constant pressure perfusion may reduce peristaltic artifact. As suggested by Ripley and Somerville (1982), with constant pressure perfusion flow ceases when renal pelvic pressure equals infusion pressure, thereby limiting stretch as a stimulus for smooth muscle contraction. However, with constant flow, flow into the renal pelvis is maintained despite changes of intrarenal pressure. This may stimulate peristaltic waves and wide fluctuations of renal pelvic pressures, which are difficult to correlate with flow. Up till now this test does not introduced to the clinical situation and the technique was performed in that a single kidney model and this offers great limitation (Woodbury et al., 1989).
RADIOISOTOPIC RENOGRAM

In recent years, radionuclide studies have become an essential tool in the armamentarium of clinical test required by urologist and nephrologist. Indeed these procedures have drastically changed the method of investigations of patients with diseases of urinary system. The successful application of this methodology is based upon the use gamma-camera and selection of the most appropriate radiopharmaceuticals for each individual clinical condition to be studied (Testa, 1990).

Radiopharmaceuticals

The information provided by any renal radiopharmaceutical depends on the way in which it is handled by the kidney. Renal agents may be categorized as to their predominant mechanism of uptake or excretion as follows:

A. Glomerular Filtration: technetium diethylene-triamine penta-acetic acid (Tc-DTPA).

B. Tubular Secretion: Radioiodine orthoiodohippuric acid (I-131 Hippuran).

C. Parenchymal (tubular binding): Technetium dimercaptosuccinic acid (Tc-DMSA), Technetium glucoheptonate (Tc-GHA), Technetium iron ascorbate (Tc-Fe Asc), Technetium iron ascorbate DTPA (Tc-Fe Asc DTPA) (Velchik, 1985).

The carrier molecule portion of the radiopharmaceutical (DTPA, Hippuran, DMSA and so forth) determines the in
vivo biodistribution of the agent, whereas the radioactive tracer determines the imaging characteristics. Both have a major impact on the type of diagnostic information derived from the study (Velchik, 1985).

A. Agent Excreted by Glomerular Filtration

A very large number of substances is excreted by this route. To be useful for measurement of glomerular filtration rate (GFR) a compound must:

(a) Be readily filterable through the membranes of glomerular capillaries.
(b) Not to be bound to plasma protein.
(c) Not be fractionated during the process of ultrafiltration.
(d) Be physiologically inert and not metabolized.
(e) Be neither secreted nor absorbed by the renal tubules.
(f) Have no effect upon renal function.
(g) Be measurable accurately in plasma and urine using routine laboratory procedures.

Many substances such as creatinine, although excreted by glomerular filtration, are to some extent reabsorbed by the tubules and therefore unsuitable for measurement of glomerular filtration rate. Inulin is regarded as the reference compound and no substance can be accepted for measurement of GFR unless it has been validated by comparison with this standard.
(113)

Inulin itself is difficult to administer and difficult to measure and is therefore unsuitable for routine clinical use (Merrick, 1984).

"\(^{99}\)Tc-DTPA is similar to inulin in that it is filtered but not reabsorbed or secreted (Arnold et al., 1978). So, the excretion is virtually completely by glomerular filtration without tubular reabsorption. So, little "\(^{99}\)Tc-DTPA is protein bound that it can be used for accurate measurement of GFR (Braren, 1979).

Peak kidney concentration (Transit time, or TT) occurs approximately (3 to 5 minutes) after injection (Tauxe and Dubovsky, 1979).

Vogel and Matin (1981), stated that less than 10 percent of injected dose remains in blood 2 hours after injection; only 2.5 percent remains in each kidney at 4 hours. It is also an excellent agent for excretory studies but is inferior to "\(^{99}\)Tc GHA and "\(^{99}\)Tc DMSA for cortical evaluation (Freeman and Lutzker, 1984).

The best agent for measurement of GFR is \(^{125}\)I sodium isothalamate. The rate of excretion of this compound is identical to that of inulin; it has a long half-life with very little release of free iodine even up to 60 days. \(^{125}\)I can readily be measured in plasma or urine (Merrick, 1984).
B. Agents excreted by Tubular Excretion

The reference substance in this group is the sodium salt of para-aminohipuric acid (PAH). The extraction ratio is between 80% and 90%, compared with that of a filtered substance which is approximately 20%. As the clearance is less than 100% it cannot be used to measure renal blood flow. PAH clearance is commonly referred to as "effective renal plasma flow".

The only commonly employed radiopharmaceutical in this group is sodium orthoiodohippurate (OIH) which may be labelled with $^{131}$I, $^{123}$I, or $^{125}$I. It is commonly referred to by a proprietary name, Hippuran. The extraction ratio of OIH is lower than that of PAH, probably because there is some back diffusion in the distal tubules. Both PAH clearance and OIH clearance are described as (effective renal plasma flow [ERPF]), although the later is 10% to 20% lower than the former. It is preferable to avoid the ambiguous term ERPF and to specify whether PAH clearance or OIH clearance is being measured (Blaurox and Freeman, 1980; Blaurox et al., 1982).

The high extraction efficiency becomes a significant advantage in patients with renal failure in whom it is possible to obtain an adequate study with hippuran but not only intravenous urography or even the other renal radiopharmaceuticals (Freeman and Lutzker, 1984). Similarly, its high extraction efficiency makes it the optimal agent for renogram (Time-activity curve) analysis although any of the
renal agents may be utilized. It is very sensitive to small changes in renal function and very minimal degrees of renal function. Peak kidney concentration occurs 2 to 4 minutes after injection. Iodine 131 has a relatively long $T_1/2$ (8 days) (Blaufax and Freeman, 1980).

C. Substances Bound by the Kidney

A large number of substances are known which are bound to the renal cortex, principally the proximal tubules. The best agent in this group is technetium dimercaptosuccinic acid ($^{99m}$Tc DMSA), Technetium monomercaptosuccinic acid ($^{99m}$Tc MMSA) and a number of other compounds are almost identical in properties but are not licensed and are not commercially available in kit form (Merrick, 1984).

In contrast to the excreted agents the extraction ratio is very low, less than 10%. Approximately one quarter of the administered activity is fixed by each kidney, one quarter is excreted and the remainder distributed at a fairly uniform low concentration throughout the body. In the presence of renal failure, there is significant uptake visible in the liver and bone marrow, but when renal function is normal no organ other than the kidneys (and at early times the bladder) is visualised. Uptake in kidneys does not reach a plateau until 12 - 15 hours after intravenous injection. However, in normal subjects the kidneys are visualized as clearly 90 minutes after injection as at any later time optimal parenchymal imaging are obtained at 4 -
6 hours after injection. In the presence of outflow obstruction early images are sometimes misleading. Where there is doubt scintigraphy should be repeated 15 - 18 hours after injection (Merrick, 1984 & Gordon, 1987).

The images obtained are those of a functional proximal renal tubular mass, the integrity of which is dependent upon many factors, including intact intra renal blood flow and intact enzymatic function that may be affected by infection or tubular disorders (Gordon, 1987).

D. Substances with Mixed Properties

A large number of radiopharmaceuticals are partially fixed by the kidney and partially excreted, that used clinically include technetium gluconate and glucoheptonate. The bone seeking agent technetium pyrophosphate and the diphosphonates also come into this category.

"""Tc glucoheptonate leaves the blood approximately as quickly as """"Tc DTPA, although like """"Tc DMSA, approximately 50% is protein bound. Thirty-eight per cent is excreted in urine within one hour but compared with """"Tc DTPA, more than twice as much remains in the renal cortex a few hours after injection. So, it can therefore be used for perfusion, excretory and cortical imaging. It is stable agent that can be used for several hours after reconstruction (Freeman and Lutzker, 1984).

The two most commonly used agents to perform renogram
are ortholiodohippurate I 131 and Technetium diethylenetriaminepentaacetic acid (**Tc DTPA). Some laboratories prefer the former agent since it undergoes both glomerular filtration 20% and active renal tubular secretion 80%, and is therefore thought to be more likely excreted in diagnostic quantities in patients with impaired renal function. Technetium diethylenetriaminepentaacetic acid is excreted solely by glomerular filtration; however, the radiation dosimetry and imaging characteristics of the **Tc-radiolabel are far superior to the 'I-radiolabel. The comparative dosimetry of these two agents is provided in table (1).

Table (1) Dosimetry (After Koff and Thrall, 1985).

<table>
<thead>
<tr>
<th></th>
<th>Rads/Milli **Tc DTPA</th>
<th>Rads 131 I Hippuran</th>
<th>Rads 5 films</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>0.006</td>
<td>0.11</td>
<td>-</td>
</tr>
<tr>
<td>Kidneys</td>
<td>0.09</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Bladder wall</td>
<td>0.11*</td>
<td>0.29*</td>
<td>0.6</td>
</tr>
<tr>
<td>Testes</td>
<td>0.007*</td>
<td>0.11*</td>
<td>0.76</td>
</tr>
<tr>
<td>Ovaries</td>
<td>0.01</td>
<td>0.13*</td>
<td>0.58</td>
</tr>
</tbody>
</table>

* = Assumes patient voids within 2 hr. of the procedure.

**Tc DTPA is preferred in children due to lower radiation dosage. The usual adult dose of **Tc DTPA is 10 - 15 Mci with the dosage adjusted downwards by body surface area.
area for pediatric patient (Thrall, 1988). While the dose of \(^{131}\text{I} \) OIH can be determined by either the weight or the age of the patient. The recommended dosage schedule as determined by age is 50 Mci for patients less than one year old, 100 Mci for patients 1 to 6 years old, and 150 Mci per kidney for adults. Also, the normal dosage for \(^{123}\text{I} \) OIH is 750 - 1000 Mci for adults (Bueschen, 1988).

Recently, \(^{99}\text{Tc} \text{MAG}^3\) was introduced as a new renal radiopharmaceutical and is considered a promising agent comparable to others. The undesirable physical properties of \(^{131}\text{I} \) iodine (OIH) include high energy beta emission and a long half-life with resulting poor image resolution and higher patient dose per photon. These properties have mitigated against its universal use despite its excellent physiological characteristics. However, OIH remains the physiological standard by which other radiopharmaceuticals must be judged (Ducret et al., 1989). On the other hand \(^{99}\text{Tc} \text{DTPA} \) has excellent physical properties for imaging and gives a low patient dose but it may result in a non diagnostic study in the setting of lower glomerular filtration rate (Taylor et al., 1986). Furthermore, the promise of \(^{123}\text{I} \) as a label for OIH a bridged by its high price and short shelf life and the presence of radiochemical impurities. \(^{99}\text{Tc} \text{MAG}^3\) can bridge the gap between desirable physiological and physical properties (Taylor et al., 1987; Taylor et al., 1988).
Diagnostic Time-Activity Curve Patterns

A renogram time-activity curve consists of three phases:

(a) The vascular or blood pool phase.
(b) Tubular or parenchymal or secretory phase.
(c) Excretory or washout phase.

Each of the phase is named for the predominant function or compartment of localization of the tracer during that time interval, but considerable overlap occurs, and no one phase is strictly representative of a single function or compartment. For example, although the first phase is termed "vascular" 15 to 20 per cent of the activity is already in the tubules. The first phase represents the initial tracer appearance in the kidney and is demonstrated by the initial rapid up slop or spike of activity. It reflects predominantly intravascular activity and to lesser extent intrarenal, perinephric or tubular activity (Shanahan et al., 1979). During the second phase, a more gradual rise in activity occurs to peak activity at 3 to 5 minutes after injection. During this phase, the background (vascular) activity is declining and activity is progressively accumulating in the parenchyma and tubules. Finally, during the third phase, there is a progressive decrease in activity as washout or excretion of activity occurs from the tubule and parenchyma into the collecting system, ureter, and bladder. The third phase is significantly affected by urine flow rate (Reba et al., 1968; Blaufox, 1984 & Veichik, 1986).
The patterns described by Santiago (1969 and O'Reilly and co-workers (1978), using I-131 are essentially identical to those described by Koff and co-workers (1979), using Tc-99m DTPA.

A. The Normal Pattern (Response I)

In normal pelvicalyceal systems, the time-activity curve shows increasing activity that reaches a narrow peak within several minutes following radiotracer injection. This is followed by spontaneous rapid decline in the activity. Furosemide diuresis increases the rate of radiotracer wash out (Fig. Fig. 20a).

In the normal ureter the time-activity histogram is usually flat, indicating a small constant amount of activity. There is frequently a transient spike of activity following diuretic injection indicating the passage of bolus of accumulated activity from the pelvis.

This pattern excludes virtually any evidence of obstruction, representing non-pathologic anatomically large collecting systems noted on IVU (Stage and Lewis, 1981; O'Reilly, 1982a & Koff and Shore, 1983).

B. The Obstructed Pattern (Response II) (Fig. 20c)

The initial time-activity pattern in kidneys with significant obstruction is frequently remarkably similar to the curves in nonobstructed kidneys. The initial slope of the curve may be somewhat less steep than in the normal kid-
Fig. (20) Kof, and Shore (1983).

Fig. (21) Equivocal response (O'Reilly, 1986).
ney and there is either progressive accumulation in the activity or a plateau is reached within 20 to 30 minutes. Following furosemide diuresis, the obstructed kidney time-activity histogram demonstrates a flat response without significant washout. In some instances, progressive accumulation continues and in few subjects, there will be a transient decrease in activity followed by reaccumulation.

The pattern for obstructed ureters is quite similar qualitatively. There is failure of activity to decrease following diuresis (Coolsaet, 1984; Poulsen et al., 1987).

C. Dilated Non Obstructed Pattern (Response IIIa) (Fig. 20b)

In dilated but non obstructed kidneys with good function, the initial portion of time-activity curve may be quite similar to that seen in normal kidneys, but accumulation of activity is progressive. The time activity curve frequently reaches a plateau at 10 to 20 minutes following tracer injection.

Following furosemide diuresis, the level of activity decreases. The rate of decrease is highly variable. In some kidneys the washout is prompt and virtually complete within ten minutes.

Histograms from dilated, non obstructed ureters are similar, demonstrating progressively increasing activity before diuretic injection. Following furosemide diuresis, there is typically a lag in the response due to the serial
nature of the washout phenomenon from renal pelvis to ureter (Koff et al., 1980 & Koff and Shore, 1983).

D. Equivocal Pattern (Response IIIb) (Fig. 21)

An obstructive curve which, following diuresis, shows only slow and incomplete elimination of the tracer. The reasons for this intermediate or equivocal response are variable and remains a subject of some debate. In patients with reduced cortical mass and impaired ability to respond to diuresis and/or large system volume resulting in longer mean transit times for any given urine flow rate. Additional research is necessary to determine the significance of equivocal pattern (Stage and Lewis, 1981; Bevise et al., 1987; Gill et al., 1988). In the original description of diuresis renography this response was considered as indicating partial obstruction. Time has shown that this definition assumes too much. The response should be termed equivocal. To try to clarify this response, in which washout of tracer after administration of diuretic is subtotal, attention first should focus on the underlying renal function. If the function is preserved and the patient is well hydrated then one may assume that the nephron mass responded to the furosemide and, therefore, the subtotal washout indicated subtotal obstruction. In support of this suggestion, subtotal washout was associated with a moderate pressure increase during diuresis, which suggested subtotal impedance to flow (O'Reilly, 1986a).
point is taken as being at three minutes after the injection of furosemide at which time the diuretic begins to take effect on the renogram curve. In obstructive pattern, where there is no response to the diuretic, the DEI is (0) (O'Reilly, 1978 & O'Reilly, 1979). The mixing chamber effect, where excretion commences promptly, usually gives values in excess of 30%. Values between, may reflect some degree of subtotal obstruction (Fig. 22).

English et al. (1987), modified the diuresis renography to be able to quantify the cases of subtotal obstruction. The modified test was quantified by an index of excretion $T_2$ representing the time from the peak of the renogram until the activity in the kidney had fallen to 50% of its maximum value (Fig. 23).

English et al. (1987), reported that normal kidney has $T_2$ value less than 5 minutes, obstructed kidney has $T_2$ value greater than 10 minutes and equivocal $T_2$ value range 5 - 10 minutes.

Whitefield et al. (1978), explained the method of measuring the radioisotope transit time through the kidney. The patient is hydrated normally and studied with gamma camera viewing the back. The patient receives a standard dose of $^{99m}$Tc DTPA I.V. and the gamma camera data are received for 20 - 30 minutes. The data are displayed as a functional image of the distribution of mean times. This
Fig. (22) Standard diuresis renography - diuresis excretion index (DEI) (English et al., 1987).

Fig. (23) Modified diuresis renography - index of excretion (Tf) (English et al., 1987).
mean time image highlights the late arrival of activity in the pelvis and makes the setting up of a region of interest over the pelvis much easier. Regions of interest are also set up over the whole kidney from an image formed at two minutes. From these regions of interest the radioisotope activity/time curves are obtained. The renal parenchymal curve is derived by subtracting the pelvic curve from the whole kidney curve. Using the renal input obtained from the detector over the heart and each parenchymal and whole kidney activity/time curve in turn, "Deconvolution analyses" are performed. Deconvolution analyses involve the use of standard and mathematical technique which can be applied to pair of input and output curves to derive the curve which would have resulted if the input had been a spike injection into the system. So, deconvolution analysis of the input curve and a curve from a region of interest set-up over either the renal parenchymas or over the collecting system will give the retention activity that would have results from a theoretical spike injection into the renal artery. Corrections are made for blood background activity using the "Computer Assisted Blood Background Subtraction". The area under the retention function divided by its height is a measure of the mean renal radioisotope transit time of either parenchyma or whole kidney depending on the region. Since renal transit times are affected by urine flow, the shortest transit time is subtracted from the mean transit
time of the parenchyma to correct this effect (Whitefield and Britton, 1981).

From the deconvolution analysis, the radionuclide transit time through the whole kidney and through the parenchyma can be quantitated. The results are expressed in parenchymal transit time units (A.P. units) and whole kidney units (W.A. units) where one unit equals two seconds. Whitefield et al. (1978), showed that the upper limit of normal for the index of parenchymal transit time (PTT) in an unobstructed kidney is 72 A.P. units. However, Whitefield and Britton (1981), lowered this upper limit to 65 A.P. units.

Prolongation of PTT is indicative of the presence of obstruction. However, dilatation of the pelvis due to whatever cause will lead to prolongation of the pelvic transit time, but in a normal kidney the whole kidney transit time is less than 86 W.A units (Whitefield and Britton, 1981 & O'Reilly, 1986b).

Whitefield et al. (1978), reported that PTT can be used as a means of determining whether an obstructive uropathy was affecting nephron function and thus causing an obstructive nephropathy or not. They confirmed this proposal in a patient with dilated renal pelvis radiologically, the absence of obstructive nephropathy, is demonstrated by a normal PTT despite a prolonged whole kid-
ney time. If obstructive nephropathy has occurred, there will be prolongation of both the whole kidney and parenchymal transit times (Whitefield et al., 1978).

Methodology

Preparation of the Patient

The patient requires no special preparation for radionuclide evaluation since bowel gas and fat do not interfere with the results. All patients must be studied in normally hydrated state. To assure adequate hydration, patients are routinely given (300 - 500 ml) of fluid to drink 30 minutes before testing. Also, full bladder may interfere with the results, so, all patients are asked to micturate before the performance of the test (Bueschen, 1988).

Technique

A. Probe Renography

The first practicable isotope renogram was established by Taplin et al. (1956), using 131I-labelled diodrast. The excretion of diodrast was too rapid to allow an adequate scan. The renogram became clinically effective with the synthesis of tubularly secreted compound orthiodohippurate (OIH) labelled with 131I (Nordyke et al., 1966).

Probe renography can be performed with simple equipment, namely 2 similar scintillation detectors, each between 2 cm and 7 cm in diameter and not less than 2 cm thick. They
should be connected by way of paired pulse height analysers and scalers to a chart recorder. The field of view of each detector must be restricted by collimator, preferably rectangular rather than circular in section, to one kidney. The rectangular field gives some allowance for caudal movement of the kidneys. A third detector to monitor the "background" count rate is positioned. A fourth detector measuring the count rate from the bladder is sometimes employed. The test is most simply performed with the patient seated, leaning slightly forward on a comfortable support. The renal probes are centered over the 12th ribs, equidistant from the midline and parallel to each other to minimise the risk of cross-talk from the contralateral kidney. The chart recorder is started and an intravenous bolus of tracer is administered. If renal function and drainage is normal, recording the count rate for 15 minutes is ample. If renal function is impaired, extending the recording time to up to 30 minutes may permit obstruction to be distinguished from non-obstructive abnormalities. It is rarely useful or practicable to prolong the examination for more than 30 minutes (Merrick, 1984).

This method assumes that the kidneys can be reliably identified from surface landmarks. Although true in the majority of normal subjects, this can lead to major errors. In the presence of a scoliosis, not always evident from palpation, all or part of both kidneys may fall within the field
of view of one detector, leading to totally erroneous tracings. Movement of the patient, although usually obvious, can sometimes produce subtle and confusing artifacts which may not be evident from inspection of the curves, whilst major errors are introduced if there is nephroptosis (Britton and Maisey, 1983).

Radiographs of the renal areas are usually obtained with the patient supine. The degree of caudal shift of the kidneys on changing from the supine to the erect position is variable and unpredictable, ranging from nothing to over 20 cm. As the kidney moves caudally it is forced by the shape of the posterior abdominal wall to move ventrally, and also to rotate about its lower pole. The low kidney is therefore associated with a lower detected count rate because (i) it may be partly out of the field of view of the detector, and (ii) because of increased absorption of gamma rays by the greater thickness of soft tissue between the kidney and the detector. In the extreme case a kidney may fall entirely out of the field of view of a detector (O'Reilly et al., 1978; Lupton et al., 1979).

Probe renography remains a useful, simple screening test provided that the various causes for error are kept in mind. However, the uncertainty in interpretation is relatively great. This test should therefore not be performed if facilities for gamma camera renography are available (Merrick, 1984).
B. Gamma Camera Renography

A wide field of view 15 inch gamma camera with a parallel hole all purpose collimator permits simultaneous imaging of the kidneys, ureters and bladder. Alternatively, a standard field of view (10 to 12 inch) gamma camera with diverging-hole collimator may be used. A 20% energy window is centered at 140 KeV for studies with $^{99}$mTc DTPA (Thrall, 1985).

Gamma camera renography studies may be done with the patient in a sitting, supine, or prone position. Thrall (1988), preferred a sitting position to permit passive drainage of the collecting system. But, Merrick (1984), suggested that gravity plays no part in drainage of urine from the kidney unless the pelvis and ureters are dilated and atonic. Changing from erect to supine does not affect the shape of the renogram curve, except in symptomatic nephroptosis. If this is suspected both erect and supine studies should be performed.

Many authors have preferred a supine position. In this position differences in renal depth are minimised, permitting renal function to be compared more readily without the need for depth correction. A further advantage of the supine position that it virtually eliminates the risk of hypotension following the administration of the diuretic. A substantial minority of patients become hypotensive if these are administered erect, both increasing the risk and result-
ing in a non-diagnostic examination, as hypotension is associated with progressively rising renogram curves irrespective of renal function (Merrick, 1984 & Bueschen, 1988).

Moreover, the supine position is well comfortable and maintainable by the patients during performing the study. Alternatively the examination may be performed with the patient prone. Many subjects find this position difficult to maintain (Merrick, 1984).

The posterior view is used i.e. the collimator is faced to the back of the patient except for the evaluation of the renal transplants, for which the camera is positioned over the anterior pelvis. Also, if one or both kidneys are situated in the pelvis, or if there is a horseshoe kidney, the examination should be performed with the patient supine and camera placed anteriorly (Mac Gregor et al., 1983).

All data are acquired on a dedicated nuclear medicine minicomputer system at a rate of 4 – 6 frames per minute for the initial 5 minutes. The remainder of the examination can be acquired at 2 frames per minute, as there are no longer rapid changes in count rate (Thrall, 1988).

Normality can be confirmed within 15 minutes. However, in the presence of impaired function there is often no clear distinction between obstruction and other abnormalities at this time. The number of equivocal examinations
is reduced by continuing the examination until 30 minutes (Merrick, 1984 & Thrall, 1988).

**Data Analysis**

Each renal unit and ureter is analysed separately with the aid of the computer. The entire study is first inspected, frame by frame to assess renal cortical and collecting system morphology and to select appropriate frames for use in assigning regions of interest. Separate regions are flagged, using a computer light pen, for each kidney and ureter and additional regions are flagged for bladder and for background correction. Background corrected time-activity histograms are generated from each region of interest. The kidney regions are flagged to include the cortex, calices and pelvis but not the ureter. Ureteral regions of interest are flagged to avoid overlap with the renal pelvis and the bladder. This can be a particular problem in infants and small children if the bladder is large, and late frames must be inspected to insure that the bladder does not superimpose on the ureteral regions of interest. When ureterovesical junction obstruction is suspected, it may be necessary to catheterize the bladder to provide a clear view of lower ureters. However, catheterization is not routinely required in adults for evaluation of suspected ureterovesical junction obstruction and only micturation is required before the test (Koff et al., 1979 & Thrall, 1988).
C. Diuretic Renography

A way to overcome the nonspecificity of the absence of the third phase of the renogram is to induce rapid diuresis. This was first done by mannitol infusion (Gray, 1970), and later by furosemide. The great value of a "diuresis renography" (radionuclide washout test) in distinguishing obstructive from non obstructive dilatation has been emphasized by different authors, (O'Reilly et al., 1978; 1981 and 1984; Koff et al., 1979; Stage and Lewis, 1981; El-Haddad et al., 1985; El-Tanawy, 1985; Ireton et al., 1987 & Pawar and Abdel-Dayem, 1984). These authors have emphasized that the test is simple and quick to perform, non invasive, reproducible at frequent intervals and gives simultaneous data on function and urodynamics at low radiation dose to the patient.

The potential usefulness of challenging the kidney with a fluid load has been recognized for quite sometimes. O'Reilly et al. (1978), observed that the renogram which appears normal become quite abnormal after mannitol infusion. O'Reilly applied this observation on a systemic scientific basis and suggested the great potential use of diuresis renography in the assessment of patients with urinary tract obstruction (O'Reilly et al., 1978; Homsy et al., 1988).

In choosing an agent to use for such a diuretic challenge there are a number of possibilities. Water or osmotic diuretics such as mannitol are quite potent and safe. The
thiazides can be administered intravenously, if wished, but probably the most attractive diuretic is furosemide because of its great potency (Dirks, 1979). It should be borne in mind that the constitution of urine varies with the diuretic agents. Furosemide is so potent a diuretic agent that (25%) of the total filtered sodium may be rejected by tubules and added to the urine after its administration, resulting in a very profound naturesis and diuresis. It is effective over a wide range of renal function and if the dose is increased appropriately will be effective even in relatively severe renal insufficiency. Furosemide usually will cause a urinary volume of about 8 ml/minute or more with mildly acid pH and a urinary sodium content of 140 mEq/liter. The diuretic urine contains a relatively small amount of potassium and bicarbonate (Blafox, 1984).

The uniform diuretic of choice for diuresis renography is the anthranilic acid derivative, (furosemide). This "high-ceiling" diuretic has a peak effect for greater than that observed with other diuretic agents. Its mechanism of action is inhibition of sodium and chloride reabsorption from the proximal and distal tubules and from the ascending loop of henle, furosemide also increases renal blood flow by dilatation of renal vasculature (Maizels et al., 1986).

Following intravenous injection, the onset of action of furosemide is prompt; based on time activity curves from
the radionuclide renograms, the diuretic effect may be seen in as little as 30 to 60 seconds. The intravenous route of administration is required, since the peak effect following oral administration may not occur for as much as one hour. The usual dosage range of 0.3 to 0.5 mg/kg for diuresis renography is well within the recommended range for therapy.

Furosemide should be administered somewhat slowly, preferably over a one to two minutes period. Usually, no serious complications or side effects have been encountered, although a small percentage of patients experience nausea, particularly with rapid administration. Parenteral diuretics should not be administered to dehydrated patients, hypotension, electrolyte imbalance and hypokalemia and may exacerbate digitalis toxicity. Children sensitive to sulfas also may be sensitive to furosemide (Maizels et al., 1986).

Mannitol, on the other hand will cause similar urine volumes, a somewhat alkaline urine, but a much smaller sodium content of only about 90 mEq/liter and somewhat greater amount of potassium. The time course of the effect of ethacrynic acid is quite similar to furosemide with a rather prompt response following intravenous injection with a rapid fall in urine osmolality with a rapid increase in potassium and sodium concentration and there will be a fall in the glomerular filtration rate (Dirks, 1979).

In a normal patient, if the diuretic is administered
at any time during the course of renography, the urine flow rate will promptly increase and activity will wash out of the pelvis more rapidly. The activity is not excreted into the pelvis at any greater rate, but the drug simply has shortened the transit time in the urine from the glomerulus to the bladder. If a kidney is severely damaged, no effect may be observed. If a recording is made at a site distal to the kidney, an increase in count rate occurs as radioactivity which has been pooling in the pelvis is washed out by the increased urine volume at a greater flow rate (Blaufox, 1984; Upsdell et al., 1988).

Timing of diuretic injection is variable between laboratories and no single standard has been widely adopted (Thrall, 1985).

Recommended timing of diuretic administration was originally based on the results of studies using probe detectors, which allows synchronous derivation and inspection of the renogram curve on a chart recorder while the study was in progress. The injection of furosemide 20 minutes into the test referred to as the (F+20 method) was based on the desire to obtain a standard renogram with enough data to give an identifiable curve and to fill the renal pelvis with radioactive urine before provoking a modification of the curve by administering a diuretic. There is some advantage in obtaining a renogram curve containing 20 minutes of urodynamic data unmodified by diuretic
administration, which will distinguish normal transit from stasis and then investigating the response to diuresis, rather than modifying the curve by diuresis from the start of the test (Whitfield, 1984; O'Reilly, 1986b; Upsdell et al., 1988).

The alternative method of giving the furosemide 3 minutes before the injection of radiopharmaceutical (F-3) was based on observations that the first effect of the diuretic on the rising renogram curve in cases of non-obstructed hydronephrosis (stasis) was consistently at the 3 minutes point after its injection (Upsdell et al., 1988).

In (1987) English and associates, studied a modified method of diuresis renography in which the diuretic was administered 15 minutes before the injection of radiopharmaceutical (F-15). This procedure was justified by an assumption that the effect of the diuretic for the first 3, 5 or even 10 minutes after injection might not be representative of the maximum potential increase in the urine flow rates, while after 15 minutes the urine flow rate is likely to be greater and may provide more of a maximal stress to the outflow tract (English et al., 1984; O'Reilly, 1986a; English et al., 1987).

This modified (F-15) renogram may clarify some equivocal results obtained by the (F+20) method, i.e. equivocal results may be converted to normal curve with this
modified method (Sukhai et al., 1985; Sukhai et al., 1986; English et al., 1987).

Clinical Applications

The main value of diuretic renography is to discriminate obstructive from non-obstructive dilatation of the upper urinary tract. So, diuretic renography has its applications both in paediatric and adult patients. A summary of the clinical conditions studied to date is provide in table (12). In most institutions, the most common clinical problems encountered are:

A. Dilated non-Refluxing Ureters

In dilated non-refluxing ureters which are not associated with bladder outflow obstruction, diuretic renography can prevent unnecessary surgical exposure of non-obstructed ureters (O'Reilly et al., 1978; Koff et al., 1980; Keating et al., 1989).

B. Residual Dilatation

Persistent dilatation of the pelvis after pyeloplasty or the ureter after either reimplantation or ureterolithotomy, are best evaluated by this technique in order to define cases with reobstruction and requiring resurgery or non-obstructed dilatation and only requiring conservative treatment (O'Reilly et al., 1981; Blaufox, 1984; Hay et al., 1984; Koff et al., 1988; Upsdell et al., 1988).
The technique affords a mean of evaluating these patients prior to hospital discharge. There is a significant risk of mechanical obstruction at either pyeloplasty or neocystostomy sites. The obstruction is often transient but the diuresis renogram serves to identify patients at greater risk and guides follow-up studies (Koff et al., 1979; Koff et al., 1980; Koff et al., 1981; Thrall et al., 1981).

C. Ureterocolic Anastomosis

Patients with ureterocolic anastomosis presenting with fever, loin pain, vomiting may require diuresis renography to exclude obstruction at neoanastomosis (Thrall, 1985).

D. Renal Transplantation

Some degree of dilatation is common and the urologist is faced with distinguishing non obstructive from obstructive hydronephrosis. Of nine patients with suspected obstruction at the ureteroneocystostomy site following transplant, two cases were correctly diagnosed as being obstructed and seven were correctly categorized as non obstructed in a series collected by Mc Gregor et al. (1983). In the transplant patient, it is often advisable to catheterize the bladder due to the overlap of the bladder activity with the ureter (Velchik, 1985).
Urologic conditions studied by diuretic renography (Table 2)
- Ureteropelvic junction obstruction
- Megaureter
  * obstructive
  * non-obstructive
  * refluxing
- Horseshoe kidney
- Multicystic and polycystic kidney
- Upper collecting system duplication
- Prune-belly syndrome
- Ectopic ureterocele.
- Renal transplant rejection
- Urethral valves
- Ureteral injury
- Postoperative
  * pyeloplasty
  * ureteral reimplantation
  * ureterolithotomy
  * urinary diversion

(Thrall, 1985)

Reporting the Renogram

The report of any graphically or imaging study should be in two parts:
(a) A description of what is seen, which should be accurate and is best accompanied by a copy of the graft or image.
(b) An interpretation of the result which depends partly on
the findings obtained and partly on the clinical context in which the test was done (Britton et al., 1983).

To aid description of results of renography, it is convenient to divide the activity-time curve of the normal renogram into three phases. The first phase is the steeply rising activity recorded over the first 30 seconds up to the inflection artifact induced by the combination of the falling blood clearance curve and the rising renal content. The second phase follows the first phase and runs up to the peak. If there is no peak, the second phase may be said to continue to rise. The peak of the renogram separates the second phase from the third phase. A normal renogram rises to a sharp peak and the third phase descends steeply at first and then progressively less steeply in a shape similar to the blood clearance curve (Britton et al., 1983).

When describing the abnormally shaped renogram the first phase should not be ignored as it reflects the vasculature of the kidney, the second phase may be normal, impaired, absent or continue to rise, the peak time may be normal or delayed or there may be no peak; the third phase may be normal, impaired or absent. Both second and third phases may show irregularities, these irregularities may occur in unsteady state conditions typically due to fluctuations in renal blood flow caused by anxiety, pain or sudden noise.
The time to peak depends on the state of hydration of the patient, the urine flow rate, the rate of absorption of salt and water by the nephrons and on the state of the pelvis. Patients should be normally hydrated with a urine flow between 1 and 3 ml/min. It is helpful to give 300 - 500 ml of fluid orally a little more than half an hour before renography. Dehydration is to be avoided (Britton, 1983). The third phase follows the peak and is the most difficult to interpret because of its complexity. It depends on the rate of input of the kidney and its shape is mainly determined by the blood clearance curve and the distribution of transit time. It is a record of what is left behind in the kidney and not what is being excreted (Britton et al., 1975).

An impaired third phase without any change in second phase or sharpness of peak is usually associated with a somewhat prolonged pelvic transit time due to dilatation. A third phase that seems to rise just before termination usually indicates cross talk from a distended bladder.

A renogram that continues to rise does not mean zero removal of the tracer. It may be seen in ischaemia which, if symmetrical, occurs in fainting, in severe pre renal or incipient renal failure. A continuously rising curve may occur in outflow disorder not only when there is obstruction but also when the pelvis is dilated with a much prolonged residence time but not obstructed (Britton et al., 1983).
The results of OIH renography may be affected by any substance that competes with the tubular carrier system. Such substances include PAH, which makes OIH clearances appear low in comparison with PAH infusion techniques; probenecid; penicillin and its derivatives; and gentamicin and related antibiotics. Because it is thought that radiological contrast media infused in amounts of many grams sometimes contain tubularly secreted impurities, it is advisable not to perform renography within 8 hours of IVU or 24 hours of angiography. The latter may also cause a severe temporary reduction in renal flow. Renal biopsy also alters the results of renography, not only when the intrarenal bleeding is sufficient to give symptoms (Britton et al., 1980).

Pitfalls and Limitations of Diuretic Renography

An important aid to insure accurate results is recognizing those conditions or pitfalls which make the test inaccurate.

Poor renal function is by far the most significant limitation of the test and may invalidate the results by preventing the kidney from responding to the diuretic and thereby simulating obstruction. Clearly, a flat response or failure of response following diuretic injection in a patient with impaired renal function is moot, since it can mean either inadequate renal function for effective
diuresis, obstruction or both. However, even with poor renal function, if washout occurs, obstruction is still effectively ruled out (Koff and Shore, 1983). Although, it would be ideal to have a defined level of renal function below which the test is invalid, this has not been possible to date principally because the functional impairment that most significantly affects diuresis is tubular rather than glomerular and the degree of impairment in these separate functions is not usually identical (Koff et al., 1979; Thrall et al., 1988; Koff et al., 1988).

In small children we do not know whether immature kidneys can respond adequately to a diuretic or not (Whitaker and Buxton-Thomas, 1984).

In younger subjects, particularly infants and children younger than 5 years, radioactivity in the bladder frequently overlaps and obscures the lower ureter and in some cases may even reach the level of the kidneys. Moreover, increased pressure in the abdomen and collecting system due to a filled bladder may alter washout response patterns. Therefore, when bladder activity and/or associated increased pressure are likely to confuse the results, the bladder should be catheterized immediately prior to the study. This has not been necessary in the vast majority of patients and should not be necessary in most adult subjects. A special problem arises with low-lying or pelvic kidneys, in which cases such overlap is almost in-
variable (Thrall, 1988).

In some patients with hydroureteronephrosis, the dilatation is associated with reflux rather than obstruction. Reintroduction of the tracer into the upper tracts due to reflux is a theoretical problem that could cause the time-activity histogram to be deflected upwards. In practice, this is generally easily recognized by reviewing the sequential images and by assessing the bladder time activity curve, which should demonstrate a downward deflection if significant reflux occurs (Koff et al., 1979).

Several technical errors can invalidate the results of these studies. One obvious potential error is infiltration of the diuretic dose extravascular. From a practical standpoint, an I.V. "keep-open" line may be used in children and checked for free-flow just prior to diuretic injection. This also reduces the chance for patient motion during the venipuncture (Maizels et al., 1986).

Motion artifacts are a common problem in the diuresis renogram. During the procedure, subjects are required to remain still for a minimum of 30 minutes which is difficult for most patients to accomplish. Motion artifacts can be minimized by supporting the patient with restraints and making sure that the patient position is comfortable prior to initiating the examination (Thrall et al., 1988).
MATERIAL AND METHODS
MATERIAL AND METHODS

This work was conducted on 53 patients whom were suffering from various degrees of upper urinary tract dilatation which had been observed in intravenous urography.

These patients should be neither refluxing nor having bladder outflow obstruction.

The study has been conducted in the Urology and Radiology Departments, Benha University Hospital and Nuclear Medicine Department, Kasr El-Aini Hospital, Cairo University (NEMROCK), during the period from May, 1988 to May, 1990.

The patients presenting symptoms ranged from renal ache, renal colic, renal mass, fever and lower urinary tract symptoms in the form of frequency, urgency, urine symptoms in the form of turbidity.

A complete urological work up was assessed according to a standard sheet, clinical examination and laboratory investigations.

Ascending cystography was performed for all patients to exclude reflux.

The problem in our patients was that whether their dilated non-refluxing tracts are truly obstructed or not or in other words; is an operation necessary or not?
We put forward the following flowchart for assessment of these patients.

\[ \text{I.V.U.} \]

\[ \rightarrow \]

\[ \text{Dilated Upper Urinary Tract} \]

\[ \rightarrow \]

\[ "\text{Ascending Cystogram}" \]

\[ \rightarrow \]

\[ \begin{array}{c}
\text{Non-Refluxing} \\
\rightarrow \\
"\text{Retrograde Study}" \\
\rightarrow \\
\text{Diuresis Renography}
\end{array} \]

\[ \begin{array}{c}
\text{Refluxing} \\
\rightarrow \\
"\text{Out of Work}" \\
\end{array} \]

A. Retrograde Study

Retrograde passage of a 6 CH ureteric catheter was tried in a number of patients and comments were made with emphasis on:
(150)

(1) ureter patent or not (catheter passed or not).
(2) proper emptying of the dye.

B. Diuresis Renography

The patients required no special preparation but all patients were studied in well hydrated state. All the patients routinely drank 300 - 500 ml water 30 minutes before test and evacuated their bladders immediately before test without bladder catheterization.

The supine position is preferred for all patients and parallel hole collimator permits simultaneous imaging of the kidneys, ureters and bladder. The posterior position of the collimator was taken and adjusted perfectly to include two kidneys, ureters and bladder. No anaesthesia or sedation was taken but in children choral syrup was taken (one teaspoonful contains 500 mg choral hydrate) and dosage is 50 mg/kg body weight. The patients was asked not to move at all all-over the test.

Standard dosage of **Tc DTPA was taken in syring in lead insulator. The dosage is 100 μcu/kg body weight. Injection is made in bolus fashion and gamma camera linked with computer system was started. After 20 minutes ½ - 1 mg/kg body weight of furosemide (lazix) was injected intravenously slowly with maximum dosage of 40 mg during the study (two ampoules). At 30 minutes study is finished. Each renal unit is analyzed separately with the aid of com-
Fig. (24) Gamma camera computer system.

Fig. (25) Area of interest are chosen by light pen.
Fig. (26) Supine position of the patient and collimator is adjusted to renal areas and bladder and faced to the back.

Fig. (27) Areas of interest are mapped by light pen.
puter. Separate regions of interest are flagged using a computer light pen. Time-activity curve for each renal unit is generated and interpreted.

The technique provides dull informations, consisting of quantitative data on individual renal function and time activity curves reflecting the uродинамика through the individual upper urinary tracts at normal and high urinary flow rates.

The responses of diuresis renography usually are clear-cut. A normal renogram curve under basal and diuretic conditions excludes obstruction (normal response or response I) (Fig. 28). An increasing curve that is unaffected by a diuretic administered during the test is likely to be obstructed (obstructed pattern or response II) (Fig. 29). An increasing curve that is dramatically converted into a normal third phase by the diuretic (that is equivalent to the sort of normal third phase) suggests a dilated, non obstructed system (response IIIa) (Fig. 30). The least common response but that which produces the most interpretational discussion is the increasing curve that is influenced partially by the diuretic, some improvement in elimination occurs but it is slow and not nearly as rapid as that seen in the dilated non obstructed curve. This response is equivocal (response IIIb) (Fig. 31).
Fig. (28) Diuretic $^{99m}$Tc DTPA renogram. Normal response (Response I).

Fig. (29) Diuretic $^{99m}$Tc DTPA renogram obstructed response (Response II).
Fig. (30) Diuretic $^{99m}$Tc DTPA renogram. Dilated non-obstructed response (Response IIIa).

Fig. (31) Diuretic $^{99m}$Tc DTPA renogram equivocal response (Response IIIb).
Fig. (32) Diuretic **To DTIP renal scan shows: complete elimination on the right kidney and retention of the tracer on the left kidney even after lasix administration.
C. Operative Findings

Some patients in whom obstructed response was encountered were subjected to operative interference to show correlation between diuresis renography and operative findings as regard area of stenosis, vessels, or fibrotic bands.
RESULTS
RESULTS

This study was conducted on 53 patients including 71 renal units with different degrees of hydroureteronephrosis.

A. Patient's History

a. Age and Sex Distribution

In 53 patients included in this study 45 (84.9%) were males and 8 (15.1%) were females. Thus, the male to female ratio was 5.6:1.

The highest incidence of hydronephrosis in this study was in third decade (37.8%). The youngest patient was 2 years old while the oldest one was 60 years old.

Table (3) Age and sex distribution

<table>
<thead>
<tr>
<th>Age in Years</th>
<th>-10</th>
<th>-20</th>
<th>-30</th>
<th>-40</th>
<th>-50</th>
<th>-60</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>7</td>
<td>2</td>
<td>9</td>
<td>17</td>
<td>7</td>
<td>8</td>
<td>45</td>
<td>84.9</td>
</tr>
<tr>
<td>Females</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td></td>
<td>8</td>
<td>15.1</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>5</td>
<td>12</td>
<td>18</td>
<td>15</td>
<td>8</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>3.7</td>
<td>5.7</td>
<td>16.9</td>
<td>37.8</td>
<td>18.9</td>
<td>17</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

b. Residence and Occupation

All patients were born and/or raised in rural areas. Employment at time of presentation included 30 farmers, 8
housewives, 6 city workers, 6 students, 2 children and one engineer.

B. Presentation

Table (4) lists the various symptoms in 53 patients having different degrees of hydronephrosis. Most of patients have had more than one symptom.

It should be mentioned that upper urinary symptoms were calculated per renal unit, while rest of the symptoms were calculated per patient.

a. Upper Urinary Symptoms

1. Renal Pain

Renal pain was the most frequent and main presenting symptom (63.4%).

It was in the form of dull aching pain, or sense of heaviness in the loin.

The pain was either continuous or intermittent, lasting from few hours to few days and usually relieved by analgesics and antispasmodics. The pain was of gradual onset and offset.

2. Ureteral Colic

It represents about 28.2% of renal unit. It may associated with nausea and vomiting in 3 renal units (15%) and radiated to ipsilateral testicle in 8 renal units (40%). In
most of cases it was relieved by analgesics and antispasmodics.

3. Renal Mass

Four patients (7.5%) having hydronephrosis presenting by renal swelling one of them had bilateral renal swelling and three patients had unilateral renal swelling i.e. 5 renal swellings as a symptom (7%) of all renal units.

b. Lower Urinary Symptoms

Most patients had lower urinary symptoms in the form of frequency in 21 patients (39.6%), burning micturation in 24 patients (47%), turbid urine in 6 patients (11.3%), frank haematuria in 3 patients (5.6%) associated with renal stone, suprapubic pain in 5 patients (9.4%) and incontinence in 6 patients (11.3%), one of them was female with cystocele had stress incontinence, four patients had nocturnal enuresis, one child and three patients whom undergone total cystectomy and rectal bladder was performed, lastily 2 patients had urgent incontinence which associated with severe frequency and burning micturations.

c. Fever and Chills

Four patients (7.5%) presented with dull aching pain associated with fever and chills.
Table (4) Symptoms in 53 patients with 71 dilated U.U.T.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>No/Renal Unit</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Upper Urinary Symptoms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal pain</td>
<td>45</td>
<td>63.4</td>
</tr>
<tr>
<td>Ureteral colic</td>
<td>20</td>
<td>28.2</td>
</tr>
<tr>
<td>Renal mass (patient aware of)</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td><strong>b. Lower Urinary Symptoms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>21</td>
<td>39.6</td>
</tr>
<tr>
<td>Burning Mict.</td>
<td>24</td>
<td>47</td>
</tr>
<tr>
<td>Turbid urine</td>
<td>6</td>
<td>11.3</td>
</tr>
<tr>
<td>Haematuria</td>
<td>3</td>
<td>5.6</td>
</tr>
<tr>
<td>Suprapubic pain</td>
<td>5</td>
<td>9.4</td>
</tr>
<tr>
<td>Incontinence</td>
<td>6</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>c. Fever and Chills</strong></td>
<td>4</td>
<td>7.5</td>
</tr>
</tbody>
</table>

C. Past History

a. History of Bilharziasis

The criteria for considering a patient as a bilharzial one were:

(1) History of terminal haematuria
(2) History of antibilharzial treatment
(3) Bilharzial calcification in plain x-ray film
(4) Cystoscopic evidence of bilharzial cystitis.
Out of 53 patients included in this study, 44 had positive history of bilharziasis (83%) and 9 patients (17%) had negative history of bilharziasis (Fig. 33). Fig. (34) shows that males are more susceptible to bilharzial infestation.

b. History of T.B.

There is no positive history of T.B. in all the group (0%).

c. History of Spontaneous Stone Passage

Nine patients have had positive history of spontaneous stone passage (16.9%).

Table (5) Operations encountered in 50 patients.

<table>
<thead>
<tr>
<th>Operation</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uretero lithotomy</td>
<td>36</td>
</tr>
<tr>
<td>Ureteroneocystostomy</td>
<td>19</td>
</tr>
<tr>
<td>Pyeloplasty</td>
<td>9</td>
</tr>
<tr>
<td>pyelolithotomy</td>
<td>4</td>
</tr>
<tr>
<td>Radical cystectomy and ureterorectal anastomosis</td>
<td>3</td>
</tr>
<tr>
<td>Cystolithotomy</td>
<td>3</td>
</tr>
<tr>
<td>Nephrectomy</td>
<td>3</td>
</tr>
<tr>
<td>Ulcer bladder</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
</tr>
</tbody>
</table>
Fig. (33) Incidence of bilharziasis among patients.

Fig. (34) Distribution of bilharziasis among males and females.
Twenty three urine samples (43.4%) were sterile while thirty urine sample (56.6%) proved to be infected. The different organisms isolated are listed in table (7). The commonest organism was *E. coli* (63.3%), then *Staphylococcus albus* (26.7%), *Streptococci* (6.7%) and *Pg. pyocyaneous* (3.3%), in order of frequency.

Table (7) Organisms isolated from cases with hydronephrosis.

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of Cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. coli</em></td>
<td>19</td>
<td>63.3</td>
</tr>
<tr>
<td><em>Staph. albus</em></td>
<td>8</td>
<td>26.7</td>
</tr>
<tr>
<td><em>Streptococcus</em></td>
<td>2</td>
<td>6.7</td>
</tr>
<tr>
<td><em>Pg. pyocyaneous</em></td>
<td>1</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Total 30 100

3. Crystals

As regards the presence of crystals in different urine samples 39 urine samples proved to be different types of crystals (73.6%) while 14 urine samples proved to be free of crystals (26.4%).

Table (8) shows that oxalate present in 20 urine samples (51.2%), urate present in 21 samples (53.8%), uric
acid two samples (5.10%) and phosphate in one sample (2.7%).

Table (8) Distribution of crystals among patients.

<table>
<thead>
<tr>
<th>Crystal</th>
<th>No. Of Urine Sample</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxalate</td>
<td>20</td>
<td>51.2</td>
</tr>
<tr>
<td>Urate</td>
<td>21</td>
<td>53.8</td>
</tr>
<tr>
<td>Uric acid</td>
<td>2</td>
<td>5.1</td>
</tr>
<tr>
<td>Phosphate</td>
<td>1</td>
<td>2.7</td>
</tr>
</tbody>
</table>

N.B.: Four urine samples contain both urate and oxalate.

b. Blood Investigations

All patients had blood urea within normal (20 - 50 mg%) except 2 patients one was 60 mg% and the other 65 mg%. Also all patients had serum creatinine within normal (0.5 - 1.2 mg%). Haemoglobin percentage was done and it was within normal to all patients and fasting blood glucose level was done and 4 patients were diabetics.

E. Radiological Findings

a. Plain Film

The following results were obtained from plain x-ray:

1. Bilharzial Calcification

Eight patients (15.1%) showed bilharzial calcifica-
tion in the form of linear calcification in the bladder or calcification in the lower ureter.

2. Urinary Calculi

Out of 53 patients included in this study 7 patients (13.2%) had calculi located at different sites in the urinary tract. Five patients had kidney stones, and two patients had ureteric stones. These two renal units were excluded from study.

b. Intravenous Urography

1. Degree of Dilatation

I.V.U. showed a dilated upper urinary tract in all patients. Three various degrees of dilatation encountered in these patients:

(1) **Mild dilatation (grade I)**

Subtle distention of the fornices to frank distention of the calices but with the papillae still easily identified.

(2) **Moderate dilatation (grade II)**

Calices ballooned outward and papillae barely visible.

(3) **Severe dilation (grade III)**

Marked dilatation with a sac like collecting system and thin parenchyma.
Table (9) Shows the distribution of patients according to these degrees of dilatation.

<table>
<thead>
<tr>
<th>Degree of Dilatation</th>
<th>No. of Units</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>15</td>
<td>21.1</td>
</tr>
<tr>
<td>Moderate</td>
<td>26</td>
<td>36.6</td>
</tr>
<tr>
<td>Severe</td>
<td>30</td>
<td>42.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>71</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

2. Laterality

In the study of 53 patients having 71 dilated upper renal units, 21 patients (39.6%) had left dilated upper renal units, 14 patients had right side (26.4%) and 18 patients (34%) had bilateral dilated upper renal units (Table 10).

<table>
<thead>
<tr>
<th>Side</th>
<th>No. of Patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>21</td>
<td>39.6</td>
</tr>
<tr>
<td>Right</td>
<td>14</td>
<td>26.4</td>
</tr>
<tr>
<td>Bilateral</td>
<td>18</td>
<td>34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>53</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table (10) incidence of dilated upper renal unit according to laterality (53 patients).
3. Level of Suspected Obstruction

As regards to suspected level of obstruction as shown in I.V.U., the ureterovesical junction represents the highest incidence (78.9%), followed by the pelviureteric junction (15.5%), while the sacroiliac level and lumber ureter represent equal incidence of (2.8%).

Table (11) Distribution of dilated upper renal unit according to level.

<table>
<thead>
<tr>
<th>Level</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ureterovesical</td>
<td>56</td>
<td>78.9</td>
</tr>
<tr>
<td>Pelviureteric</td>
<td>11</td>
<td>15.5</td>
</tr>
<tr>
<td>Lumber ureter</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>Sacroiliac joint</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
<td>100</td>
</tr>
</tbody>
</table>

C. Retrograde Studies

Thirty-one attempts at retrograde catheterization were done throughout the present work. Assessment of the systems was done taking into consideration.

(1) ability to pass the ureteric catheter up and,
(2) if the catheter could be passed up the system, contrast is injected, the catheter is withdrawn and emptying of the system is noted.
- Catheter could be passed
- Proper empty of the dye

Fig. (35) Results of retrograde studies.
A ureteric catheter could be passed up the system under investigation is 16 trials. Three units of these 16 failed to empty injected dye after withdrawal of the catheter.

A ureteric catheter could not be passed up in 15 units. The causes of this failure is inability to visualize the ureteric orifice in 5 systems and arrest to pass up is 10 units. Three of these 10 units could pass to about 1 cm is 2 units and 3 cm in one unit.

If we consider that the inability to pass the catheter or failure of the system to empty are signs of obstruction, then we have only 13 units non obstructed according to the results of retrograde studies (Fig. 35).

Table (12) Retrograde studies.

<table>
<thead>
<tr>
<th>Catheter Passed</th>
<th>Did not Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emptied</td>
<td>No Orifice</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

F. Diuretic Renogram (Fig. 36)

Fifty-three patients had 71 various degrees of dilated upper renal units with suspected obstruction at different levels were evaluated by diuresis renogram.
Fig. (36) Results of diuresis renography and distribution of various degrees of dilatation.

- Mild dilatation
- Moderate dilatation
- Severe dilatation

Non obstructed (Response I and Response IIIa)
Obstructed (Response II)
Equivocal (Response IIIb)
Table (13) shows that mild dilatation is present in 15 renal units and 100% are non obstructed i.e. normal response is present in 6 renal units (40%) and response IIIa is present in 9 renal units (60%).

**Table (13) Diuresis renography (Mild dilatation).**

<table>
<thead>
<tr>
<th>Response</th>
<th>Response</th>
<th>Response</th>
<th>Response</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>IIIa</td>
<td>IIIb</td>
</tr>
<tr>
<td>No. of renal units</td>
<td>6</td>
<td>9</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>percentage</td>
<td>40</td>
<td>60</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table (14) shows that moderate dilatation is present in 26 renal units. Normal response (response I) is present in two renal units (7.6%), obstructed response (response II) in 4 renal units (15.4%), dilated non obstructed (response IIIa) in 19 renal units (73.1%), and equivocal response

**Table (14) Diuresis renography (Moderate dilatation).**

<table>
<thead>
<tr>
<th>Response</th>
<th>Response</th>
<th>Response</th>
<th>Response</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>IIIa</td>
<td>IIIb</td>
</tr>
<tr>
<td>No. of renal units</td>
<td>2</td>
<td>4</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>percentage</td>
<td>7.6</td>
<td>15.4</td>
<td>73.1</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
(response IIIb) is present in one case (3.9%). So, obstruction is excluded in 21 renal units with moderate dilation (80.7%). But in severe dilatation as shown in table (15) 30 renal units were subjects to diuresis renography, 15 patients (50%) are obstructed (response II), subtotal obstruction (equivocal obstruction) are present in 5 renal units (16.7%) but obstruction is excluded in 10 patients (33.3%) with dilated non obstructed response (response IIIa).

Table (15) Diuresis renography (Severe dilatation).

<table>
<thead>
<tr>
<th>Response</th>
<th>Response</th>
<th>Response</th>
<th>Response</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
<td>IIIa</td>
<td>IIIb</td>
<td></td>
</tr>
<tr>
<td>No. of renal units</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>percentage</td>
<td>50</td>
<td>33.3</td>
<td>16.7</td>
<td>100</td>
</tr>
</tbody>
</table>

Collectively, obstruction is excluded in 46 renal units (64.9%) (8) renal units give normal response and 38 give dilated non obstructed response i.e. complete washout of the tracer after diuretic stimulation. But obstruction is diagnosed in 19 renal units (26.7%) i.e. failure of tracer washout after diuretic stimulation. Lastly, 6 renal units (8.4%) with equivocal response i.e. partial washout of tracer after diuretic stimulation as shown in table (16) and fig. (37).
Fig. (37) Results of diuresis renography.
Table (16) Diuresis renography.

<table>
<thead>
<tr>
<th>Degree of Dilatation</th>
<th>Response I</th>
<th></th>
<th>Response II</th>
<th></th>
<th>Response IIIa</th>
<th></th>
<th>Response IIIb</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Mild</td>
<td>6</td>
<td>8.5</td>
<td>9</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
<td>2.8</td>
<td>4</td>
<td>5.6</td>
<td>19</td>
<td>26.8</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>Severe</td>
<td></td>
<td></td>
<td>15</td>
<td>21.1</td>
<td>10</td>
<td>14.1</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>11.3</td>
<td>19</td>
<td>26.7</td>
<td>38</td>
<td>53.6</td>
<td>6</td>
<td>8.4</td>
</tr>
</tbody>
</table>

* Response I: normal response
* Response II: obstructed response
* Response IIIa: dilated non-obstructed
* Response IIIb: equivocal response

Table (17) Causes of upper urinary tract dilatation and diuresis renography results

<table>
<thead>
<tr>
<th>Previous Operations</th>
<th>Response I</th>
<th></th>
<th>Response II</th>
<th></th>
<th>Response IIIa</th>
<th></th>
<th>Response IIIb</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Post ureterolithotomy</td>
<td>10</td>
<td>42.3</td>
<td>4</td>
<td>5.6</td>
<td>3</td>
<td>4.2</td>
<td>21</td>
<td>29.6</td>
</tr>
<tr>
<td>Post ureteral reimp.</td>
<td>19</td>
<td>26.8</td>
<td></td>
<td></td>
<td>11</td>
<td>15.5</td>
<td>6</td>
<td>8.5</td>
</tr>
<tr>
<td>Post pyeloplasty</td>
<td>9</td>
<td>12.7</td>
<td>2</td>
<td>2.8</td>
<td>2</td>
<td>2.8</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Rectal bladder</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>2.8</td>
<td>1</td>
<td>1.4</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>Megareter</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>2.8</td>
<td>2</td>
<td>2.8</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>Post pyelolithotomy</td>
<td>3</td>
<td>4.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>4.2</td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
<td>100</td>
<td>8</td>
<td>11.3</td>
<td>19</td>
<td>26.7</td>
<td>38</td>
<td>53.6</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>6</td>
<td>8.4</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Correlation of Results

Retrograde Versus Diuresis Renography

Throughout this work a combined retrograde and diuresis renography have been to assess 31 dilated renal units. Figure (38) shows the correlation of information obtained from both studies.

Table (18) Retrograde pyelography versus diuresis renography.

<table>
<thead>
<tr>
<th>Retrograde Findings</th>
<th>Diuresis Renography</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-Obst.</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Non obst.</td>
<td>13</td>
</tr>
<tr>
<td>No orifice</td>
<td>5</td>
</tr>
<tr>
<td>Obstructed</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
</tr>
</tbody>
</table>

Operative Findings

Surgical exploration of 11 units proved to be obstructed by diuresis renography have proved obstructed in all cases except one case in which severe hydroureteronephrosis was encountered in I.V.U., obstructed pattern in diuresis renography and failed ureteral catheterization. All indicates obstruction but at surgical exploration, no
Fig. (38) Correlation of retrograde study versus diuresis renography.
obstruction was found (case no x). Ureterovesical reimplantation was not performed. However, the patient's pain disappeared after the exploration. Another case which is pyeloplasty was performed since 3 years and severe hydrocalycosis and hydropelvis and diuresis renography was equivocal obstruction. On exploration no obstruction is present and pyeloplasty was not performed. → (function).
Case Number (I)

Abdel Fattah, M., male patient aged 28 years from Kalioub complaining of left renal pain. This pain was aching in nature, insidious onset, stationary course since one and half year. Positive history of bilharziasis and left pyeloplasty since 2 years.

Clinical Examination

Apart from scar of previous operation, physical examination within normal.

Laboratory Investigations

Urinalysis revealed pus cells 2-5/H.P.F., RBCs 0-2/H.P.F., urate crystals and culture and sensitivity showed no growth. Blood urea 24 mg%, Serum creatinine 0.8 mg%, and hemoglobin percent 13 gm%.

Radiology

Plain free
I.V.U. left moderate hydrenephrosis.

Diuresis Renography

Left kidney: Dilated non obstructed (response IIIa)
Right kidney: Normal response (response I).
Case (I)

Fig. (39) a. I.V.U. left hydrenephrosis (post pyeloplasty).
Fig. (39) Diuretic **To DTPA renogram.
b. Left kidney: dilated non obstructed response (response IIIa).
Case Number (II)

Ibrahim, S., male patient aged 37 complaining of right renal pain and recurrent attacks of fever and chills. This pain was aching in nature, progressive course since 2 years. Past history of bilharziasis and right pyelolithotomy and pyeloplasty since 2 years.

Clinical Examination

Abdominal examination revealed that spleen just palpable, tenderness on right renal angle, scar of previous operation.

Laboratory Investigations

Blood urea 39 mg%, serum creatinine 0.8 mg%, hemoglobin percentage 11 gm%, urinalysis revealed that pus cells 10 - 20/H.P.F., RBCs 0 - 4/H.P.F. and oxalate and urate crystals. Staph albus growth on culture.

Radiology

Plain: Radio-opaque calcular shadow in the region of right kidney.

IVU : Right hydronephrosis.

Diuresis Renography

Right kidney: Equivocal response (Response IIIb)
Left kidney: Normal response (Response I)
Case (II)

a. I.Y.U.: right hydronephrosis post right pyelolithotomy and pyeloplasty.
Fig. (40) Diuretic $^{99m}$Tc DTPA renogram.
- Right kidney equivocal response (IIIb)
- Left kidney normal response (I).
Case Number (III)

Ahmed, F., female patient aged 43 years from Tokh complaining of left renal ache, since 2 years, with progressive course. Negative history to bilharziasis and left pyeloplasty was performed since 2 years.

Clinical Examination

Abdominal examination revealed that blood pressure 160/95, tender left loin, scar of previous operation.

Laboratory Investigations

Urinalysis showed pus cells 8 - 10/H.P.F., RBCs 1 - 2/H.P.F., culture and sensitivity revealed E. coli, growth. Blood urea 38 mg%, creatinine 1.2 mg% and hemoglobin was 12 gm%.

Radiology

Plain: free

IV : Bilateral malrotated kidneys with severe left pyelonephritis.

Ascending pyelography : 6CH ureteric cather was passed up to the pelvic and diluted dye was injected and showed improper drainage of the dye after catheter withdrawal.

Diuresis Renography

Left kidney : Obstructed response (Response II)

Right kidney: Normal response (Response I)

Operative Findings

Through left subcostal incision kidney and pelvis are mobilized. Pelviureteric junction showed severe stenotic area with sagging of the pelvis. Pyeloplasty was performed.
Fig. (41) a. I.V.U. Bilateral malrotated kidneys. Severe left pyelectasis (post pyeloplasty).

b. Ascending pyelography: shows arrest of the dye at P.U.J.
Fig. (41) Diuretic

- c. Right kidney: normal response
- d. Left kidney: obstructed response
Fig. (41) e. Diuretic **To DTPA renal scan shows that complete elimination of tracer from right kidney and retention of the tracer in the left kidney after Iaxix administration.
Case Number (IV)

Ibrahim, S., female patient aged 37 years from Kalioub complaining of right renal colic sudden onset, intermittent course, since one year, relieved by analgesia.

Past History
Positive history of bilharziasis.
Right ureterolithotomy (18 months ago)
Left ureterolithotomy (2 years ago)

Clinical Examination
Underweight, pallor, blood pressure 120/80, pulse 90/minute, spleen just palpable and suprapubic midline scar of previous operation.

Laboratory Investigations
Urinalysis showed pus cells 8-10/H.P.F., RBCs 0-2/H.P.F., urate crystals and culture and sensitivity revealed *Staph albus* organism growth.

Blood Chemistry
Blood urea 39 mg%  
Creatinine 0.9 mg%  
Hemoglobin 9 gm%

Radiology
Plain: no abnormality detected.
IVU: moderate right hydroureteronephrosis.
   Left non visualized kidney

Diuresis Renography
Right kidney shows dilated non obstructed pattern (response IIIa).
(192)

Case (IV)

Fig. (42) a. I.V.U.: right hydroureteronephrosis.
b. Diuretic **To DTPA renogram. Right kidney shows dilated non obstructed pattern (IIIa).
Case Number (V)

Abdalla, M., male patient aged 35 years. Complaining of bilateral renal ache, stationary in course since one and half year. Positive history of bilharziasis and bilateral ureterolithotomy since 2 years.

Clinical examination

Good body built, blood pressure 150/95, scar of previous operation and remainder of examination within normal.

Laboratory Investigations

Urinalysis showed pus cells 20 - 30/H.P.F., RBCs, 5 - 8/H.P.F., oxalate crystals, glucose in urine and growth of E. coli organism in culture, blood urea 46 mg%, serum creatinine 0.9 mg%, hemoglobin 10.5 g% and fasting blood glucose 225 mg%.

Radiology

Plain: Free

IVU : Right severe hydroureteronephrosis and left moderate hydroureteronephrosis.

Diuresis Renography

Right kidney: Dilated non obstructed response (response IIIa).

Left kidney : Dilated non obstructed response (response IIIa).
Case (V)

Fig. (43) a. I.V.U. shows bilateral severe hydroureteronephrosis.
Fig. (43) Diuretic **To DTPA renogram.  
b. Right dilated non obstructed response.  
c. Left dilated non obstructed response.
Fig. (43) d. Diuretic $^{99mTc}$ DTPA renal scan shows complete elimination of the tracer after lasix administration.
Case Number (VI)

Mahmoud, M., male patient, aged 3 years complaining of abdominal pain. Right ureterolithotomy since 6 months.

Clinical Examination

Weight 16 kg, good body built, scar of previous operation.

Laboratory Investigations

Urinalysis showed pus cells 6 - 8/H.P.F., RBCs 0 - 4/H.P.F. urate crystals and no growth on culture. Blood urea 26 mg%, serum creatinine 0.6 mg% and hemoglobin 13 gm%.

Radiology

Plain: Free

IVU: Moderate right hydroureteronephrosis.

Ascending pyelography: 4 CH ureteral catheter passed and good washout of dye.

Diuresis Renography

Left kidney: Normal response (response I)

Right kidney: Dilated non obstructed (response IIIa)
Case (VI)

Fig. (44) I.V.U.

a. Right hydroureteronephrosis.
b. Ascending pyelography.
Fig. (44) Diuretic **Tc DTPA renogram.
   c. right kidney: dilated non obstructed.
   d. left kidney: normal response.
Case Number (VII)

Tamam, A., female patient, aged 47 years complaining of left renal ache and burning micturation, left renal ache with intermittent course since one year but burning micturation had progressive course since 2 months associated with suprapubic pain and pain radiated to genitalia. Past history of bilharziasis and left ureterolithotomy since 18 months.

Clinical Examination

Good body built, spleen just palpable, scar of previous operation and P.V. examination revealed cystocele and on coughing stress incontinence was observed.

Laboratory Examination

Urinalysis revealed 20 - 30 pus cells/H.P.F., 6 - 8 RBCs/H.P.F., urate crystals and *E. coli* and *Staph. albus* growth on culture. Blood urea 39 mg%, serum creatinine 1.1 mg%, fasting blood sugar 117 mg% and hemoglobin 10.5 mg%.

Radiology

Plain: Free

IVU : Left hydroureteronephrosis.

Ascending pyelography: 6 CH ureteral catheter was passed and good drainage of injected contrast media.

Diuresis Renography

Left kidney : Dilated non-obstructed (response IIIa)
Right kidney : normal response (response I).
Case (VII)

Fig. (45) a. I.V.U. left hydroureteronephrosis.
   b. Left ascending pyelography.
Fig. (45) Diuretic **To DTPA renogram.
c. left kidney: dilated non obstructed response.
d. right kidney: normal response.
Fig. (45) e. Diuretic **To DTPA renal scan shows complete elimination of the tracer after lazix administration.
Case Number (VIII)

Atallah, A., male patient, aged 55 years from Benha complaining of left renal pain. This pain of dull aching in nature, insidious onset, interrupted course since 2 years.

Past History
Positive history to bilharziasis
Positive stone passage
Urological operations
- Left ureterolithotomy (3 years)
- Right ureterovesicle reimplantation (11 years)

Clinical Examination
Good body built, blood pressure 120/80, palpable right kidney. Suprapubic midline scar of previous operation.

Laboratory Investigations
Urinalysis showed pus cell 3–5/H.P.F., RBCs 1–3 H.P.F., oxalate crystals. Culture and sensitivity revealed no growth. Blood chemistry: blood urea was 38 mg%, serum creatinine 0.7 mg%, hemoglobin 11 gm% and fasting blood sugar 110 mg%.

Radiology
Plain: No radio-opaque calcular shadow or pathological calcification.
IVU: Left moderate hydroureteronephrosis incomplete duplex.
Right kidney not visualized.
Ascending catheter: not passed.

Diuresis Renography
Left kidney normal response (response I).
Case (VIII)

Fig. (46) a. I.V.U. shows left hydroureteronephrosis diuretic.
b. Diuretic 99mTc DTPA renogram shows left kidney normal response.
Case Number (IX)

Fouad, S., female patient, aged 15 years, complaining of persistent left renal ache, insidious onset, stationary course since 2 years. Past history of bilateral ureteral reimplantation since 2 years.

Clinical Examination

Pale, underweight, tender palpable mobile left kidney, scar of previous operation.

Laboratory Investigations

Urinalysis showed pus cells 10/H.P.F., RBCs 6 - 8/H.P.F., and urine culture showed E. coli growth. Blood urea was 65 mg%, serum creatinine 1.5 mg% and hemoglobin was 9 gm%.

Radiology

Plain: Free
IVU : Left severe hydronephrosis.
Retrograde ureteral catheterization: orifice was not visualized.
Antegrade pyelography: no drainage.

Diuresis Renography

Left kidney : equivocal response (response IIIb).
Clinical course: follow-up for kidney function tests was advised to the patient.
Case (IX)

Fig. (47) a. Infusion urography: left hydroureteronephrosis.
b. Left antegrade pyelography.
Fig. (47) c. Diuretic $^{99m}$Tc DTPA: left kidney equivocal response.

d. Diuretic $^{99m}$Tc DTPA renal scan shows relative retention of tracer within left kidney after Lasix administration.
Case Number (X)

Shawky, M., male patient, aged 38 years, complaining of bilateral renal ache and burning micturation since one year, positive history of bilharziasis and bilateral ureterolithotomy since 2 years.

Clinical Examination

Good body built, palpable right kidney, mobile, slight tenderness on the right renal angle, scar of previous operations.

Laboratory Investigations

Urinalysis showed pus cells above 100/H.P.F., RBCs 20 - 30/H.P.F., oxalate crystals, culture and sensitivity showed E. coli, and Staph. albus growth. Blood urea 50 mg%, serum creatinine 0.9 mg% and hemoglobin 10.2 mg%.

Radiology

Plain: Stone right kidney.

IVU: severe right hydroureteronephrosis and moderate left hydroureteronephrosis.

Accending pyelography: failed.

Diuresis Renography

Left kidney: dilated non-obstructed (response IIIa)
Right kidney: obstructed response (response II).
Case (X)

Fig. (48) a. I.V.U. right severe hydroureteronephrosis left moderate hydrenephrosis.
Fig. (48) Diuretic **Tc DTPA renogram.
b. right kidney: obstructed pattern.
c. left kidney: dilated non obstructed.
Case Number (XI)

Shafik, A., male patient, aged 26 years, presented with right recurrent renal colic, insidious onset progressive course since one year, and frequency of micturation. Positive history of of bilharzial and past history of right ureterovesical reimplantation since one and half years and retrograde endoscopic ureteral dilatation since 6 months.

Physical Examination

Good body built, blood pressure 120/80, spleen just palpable, suprapubic midline scar incision of previous operation, the rest of examination was within normal limits.

Laboratory Data

Urinalysis revealed 60 - 70 WBC/H.P.F. and RBCs/H.P.F. heaving oxaluria, urine culture showed E. coli organism, blood urea was 43 mg%, serum creatinine was 0.9 mg% and hemoglobin was 11 gm/100 ml.

Radiology

Plain K.U.B. : Free
I.V.P. : right severe hydronephrosis.
Retrograde pyelography: 6 CH ureteric catheter passed good drainage of the injected dye.

Diuresis Renography

Left kidney : normal response (response I).
Right kidney : obstructed response (response II).
Operative finding: proved obstruction, ureterolysis and ureteroneocystostomy was performed.
Case (XI)

Fig. (49) a. I.V.U. shows severe right hydronephrosis.
Fig. (49) Diuretic **To DTPA renogram.
  b. right kidney: obstructed pattern.
  c. left kidney: normal response.
Case Number (XII)

Gamil, M., male patient, aged 37 years, farmer, complaining of bilateral renal ache and burning micturation. Renal ache came with insidious onset, progressive course since 2 years, positive history of bilharziasis and past history of bilateral reimplantation since one year.

Clinical Examination

Blood pressure was 140/95, bilateral palpable kidneys, mobile, slight tenderness on right side, scar of previous operation, the rest of clinical examination was within normal limits.

Laboratory Investigations

Urinalysis showed pus cells above 100/H.P.F., RBCs 20 - 30/H.P.F., phosphate crystals, urine culture revealed Staph. albus and E. coli organisms. Blood urea was 65 mg%, serum creatinine was 1.4 mg% and hemoglobin was 10 gm%.

Radiology

Plain K.U.B. Free
I.V.P. infusion: severe bilateral hydroureteronephrosis.
Left retrograde pyelography: 6 CH ureteric catheter could be passed and no drainage to the injected diluted dye.
Right retrograde catheterization failed.
Right antegrade pyeloureterography: No drainage to injected diluted dye.

Diuresis Renography

Right kidney: obstructed response (response II).
Left kidney: equivocal response (response IIIb).
Case (XII)

Fig. (50) a. Infusion urography: bilateral severe hydrourerteronephrosis.
Fig. (50) b. Left ascending pyelography. Drainage film after one hour.

c. Right antegrade pyelography with suspected obstruction at U.V.J.
d -

e -

Fig. (50) Diuretic **Tc DTPA renogram.
  d. Left kidney: equivocal response.
  e. Right kidney: obstructed response.
Fig. (50) f. Diuretic ¹¹¹In-DTPA renal scan shows retention of the tracer with the kidneys after Lasix injection.
Case Number (XIII)

Khalil, A., male patient, aged 52 years complaining of right renal pain and nocturnal enuresis. This pain was dull aching in nature, insidious onset and progressive course since 2 years. Nocturnal enuresis begun since 3 years with daily bed wetness and after 6 months the condition improved to be two times per week. Positive history of bilharziasis and radical cystectomy after squamous cell carcinoma of the bladder and rectal bladder was fashioned since 3 years.

Clinical Examination

Under weight, pallor, blood pressure 150/100, colostomy bag was fitted to the abdomen. Right loin was tender and right kidney was palpable and mobile.

Laboratory Investigations

Urinalysis showed pus cells above 100/H.P.F., RBCs 8 - 10/H.P.F., excessive mucous, culture and sensitivity revealed growth of *Staph. albus* and *E. coli* organisms. Blood chemistry, urea was 50 mg%, creatinine was 1.2 mg%, hemoglobin was 10.5 mg% and F.B. sugar was 82 mg%.

Radiology

Plain radio-opaque calcular shadow in the region of right kidney opposite L.

I.V.U. right severe hydroureteronephrosis, mild left hydroureter.

Diuresis Renography
Right kidney: dilated obstructed pattern (response II).
Left kidney: Normal resoponse (response I).
Case (XIII)

Fig. (51) a. I.V.U. right severe hydroureteronephrosis left mild hydroureter.
Fig. (51) Diuretic $^{99m}$Tc DTPA renogram:
b. Right kidney: obstructed pattern.
c. Left kidney: normal response.
Fig. (51) d. Diuretic $^{99m}$Tc DTPA renal scan shows:
1. complete elimination of the tracer from left kidney after laxix administration.
2. retention of the tracer in the right kidney even after laxix administration.
Case Number (XIV)

Azab, N., male patient, aged 53 years, complaining of bilateral renal ache, burning micturation and recurrent attacks of fever shivering and sweating. Burning micturation. Radical cystourethrectomy was performed and rectal bladder was fashioned.

Clinical Examination

Under weight, pale, blood pressure 170/100, abdominal examination revealed soft abdomen with colostomy pack was fitted to colostomy opening, scar of previous operation, right kidney was palpable, mobile and slightly tender.

Laboratory Investigation

Urinalysis revealed pus cells above 100/H.P.F., RBCs 50 – 60/H.P.F., mucous and *E. coli* organism in culture. Blood urea was 50 mg%, serum creatinine was 1.3 mg% and hemoglobin was 9 mg%.

Radiology

Plain: Free

IVU : Right hydroureronephrosis.

Diuresis Renography

Right Kidney: normal response (response I)
Left kidney: normal response (response I).
Case (XIV)

Fig. (52) a. I.V.U. right hydronephrosis and rectal bladder.
Fig. (52) Diuretic **Tc DTPA renogram.
b. right kidney: normal response.
c. left kidney: normal response.
Case Number (XV)

Soliman, M., male patient, aged 2 years old from Benha, complaining of abdominal colic and mass in right side of abdomen. This mass was discovered by chance in pediatric clinic.

Clinical Examination

Palpable right kidney, mobile, not tender skin over it normal. Congenital right hydrocele. Remainder of clinical examination was normal.

Laboratory Investigations

Urinealysis: no abnormality detected. Blood chemistry, urea was 28 mg% and creatinine was 0.6 mg%.

Radiology

Plain: Free

IVU : Severe right hydroureteronephrosis.

Diuresis Renography

Right kidney: Dilated non-obstructed (response IIIa).
Left kidney : Normal response (response I).
Case (XV)

Fig. (53) a. I.V.U. severe right hydroureteronephrosis.  
b. Post-voiding film shows suspected level of obstruction at U.V.J.
Fig. (53) Diuretic ***To DTPA:
c. Left kidney: normal response.
d. Right kidney: dilated non obstructed pattern.
DISCUSSION
DISCUSSION

Throughout the every day practice, a urologist frequently faces patients with urograms showing a dilated upper urinary tract. The question which comes immediately to mind on seeing such urograms "Is this system obstructed or not" or in other words "Is an operation necessary or is it better to leave the patient to go back to home in piece?". It is critical that the decision that a dilated system is obstructed or not is vital to the management of the patient. While no one denies that obstruction must be relieved, it should be clear that operating on an unobstructed system may produce as many problems as it attempts to solve. Such an operation may result in reflux or true obstruction when neither was present previously.

Whitaker (1973), defined obstruction "a situation in which difficulty is encountered in getting urine through the system". This definition implies that any particular degree of obstruction requires a certain pressure to drive urine through the system at the usual or even at a reduced flow rate.

Because we rely so heavily on intravenous urography, it is perhaps not surprising that we tend to diagnose obstruction confidently by such means. It is fortunate that we are often correct. However, there are undoubtedly situa-
tions in which the urogram will not give the complete answer.

So, it must be realised that although dilatation usually accompanies obstruction, there is no doubt that dilatation may be present in the absence of obstruction (Whitaker, 1973a). It is also well known that after relieving obstruction, the original normal configuration of the pelvicalyceal system may not be completely regained. In these situations a residual degree of persistent dilatation may be perplexing as it may be difficulty, by conventional means, to decide for sure that the present dilatation is due to reobstruction or it is merely the remnant of the previously present obstruction.

This residual dilatation may be encountered in many situations such as, post pyeloplasty, post pyelolithotomy, post ureterolithotomy, post uretero-ureteral anastomosis, post ureterovesical reimplantation and post ureteroenteric anastomosis after radical cystectomy. Or simply after spontaneous stone passage.

The problem of the dilated ureter is very common in our country where Bilharziasis is endemic and affection of the urinary system is frequent. Most of Egyptian urologists are acquainted with cases of ureteral dilatation in which reflux is excluded, by ascending cystography and a ureteric catheter cannot be passed up the ureter. Surgery has been
the traditional way of dealing with such ureters on the assumption that a stricture at the lower end is the cause of dilatation. However, some of these presumably obstructed ureters are found, on exploration, to have no stricture. So, Bilharziasis, can lead to non-obstructive dilatation of the ureter, and entities like the dilated pelvic spindle (Badr et al., 1956 & Safwat, 1961), and atonic bilharzial ureter (Gelfand, 1948 & Fam, 1964), have been identified. Umerah (1981) and Naude (1984), have further emphasized that bilharziasis can lead to ureteral dilatation without a stricture or reflux.

The diagnosis of the upper tract obstruction is often made on radiological signs and symptomatology alone. Symptomatology also has been relied upon, and when combined with urography, is an important factor in deciding whether surgical intervention is necessary. However, in a small but significant population of patients symptoms and urographic appearance may be misleading. A patient with flank pain and an incidental enlarged upper tract may have too much importance place on his or her pain if obstruction is equivocal. This term "equivocal obstruction" has jump to use by many urologists and defended as "a dilated system in which obstruction can not be determined satisfactorily by conventional means, i.e. excretory urography, cystography and ureterography. Since dynamic studies have been introduced, it has become clear that dilatation of the upper urinary
tract and obstruction are not synonymous in all cases and "equivocal obstruction" has come to use (Whitaker and Buxton Thomas, 1984 & O'Rielly, 1986a & 1988).

In fact, none of the available methods of diagnosis of obstruction is perfect. Each method has its shortcomings that may lead to misinterpretation in some cases. The main available methods for diagnosis of obstruction are:

(a) Conventional means:
   - intravenous urography,
   - retrograde pyelography.

(b) Dynamic means:
   - diuresis sonography,
   - P/F studies,
   - diuresis renography.

Intravenous urography is mandatory in every case when obstruction of the upper urinary tract is suspected. However, intravenous urography gives a static still anatomical picture. The classic urographic signs of obstruction, such as delayed emptying or prolonged nephrogram, can occur in the absence of obstruction (Wax and McDonald, 1966).

So, intravenous urography does not differentiate between a tense obstructed system and floppy non-obstructed one. The use of diuresis provocation with urography has been suggested to be more valuable in distinguishing
obstructed systems in difficult situations (Whitfield et al., 1977).

Persistent dilatation after correction of obstruction may mimic obstruction. Among (71) dilated non-refluxing renoureteral units studied in this work encountered in 53 patients. Three patients had no history of previous urological operation and they had 5 dilated renoureteral units due to non-refluxing megaureter. The remaining 50 patients had previous history of urological operations in upper tract, ureterolithotomy in 36 renal units, ureteroneocystostomy in 19 renal units, pyeloplasty in 9 renal units, pyelolithotomy in 4 renal units and radical cystectomy with uretero-rectal anastomosis in 3 patients had 5 renal units among the study providing that combined ureterolithotomy and ureterovesical anastomosis was encountered in 6 renal units and pyeloplasty with pyelolithotomy in one renal unit. Out of these (71) dilated renal units (29) proved to be obstructed by diuresis renography and in need for surgery but 42 renal units proved to be non obstructed and dilatation was shown to be residual and the need for surgery in these units has been obviated.

Retrograde pyeloureterography has been the traditional way of assessing dilated non-refluxing upper urinary tracts. Thirty-one attempts at retrograde catheterization have been performed throughout this work. A system was considered non-obstructed if it:
(235)

(1) allowed the passage of the ureteric catheter and
(2) emptied the injected contrast after the catheter is
removed.

According to these criteria, only 13 renoureteral
units were considered non-obstructed. Diuresis renography
have been performed in these 13 units and revealed that 11
units of these 13 units have been found to be non obstructed
and not in need for surgical intervention and the other 2
systems have been found to be truly obstructed and in need
for surgical intervention. On the other hand, failure of
passing the ureteric catheter or failure of the system to
empty was encountered in the remaining 18 trials. Diuresis
renography showed that 6 units of these 18 units were truly
obstructed and in need for surgical intervention and 4 units
showed equivocal response or subtotal obstruction.

The correlation of the results of retrograde and
diuresis renography (Table 18) shows that retrograde studies
can be relied upon to exclude obstruction. On the hand when
there is failure to pass a catheter or delay in emptying the
injected contrast, one should be cautious before considering
the system obstructed. Failure to pass the ureteric
catheter up the system should also be taken cautiously
before considering it indicating obstruction of the system.
The whole test may be aborted by inability to visualize the
ureteric orifice which is particularly possible in our bil-
harzial patients. We could not see the ureteric orifice in 5
units which were proved by diuresis renography to be not obstructed. Submucous dissection may prevent the upward passage of the ureteric catheter in a non-obstructed systems in 3 non obstructed units. Pfister and Newhouse (1978), have mentioned that if a ureteric catheter passed up and the injected contrast drained immediately after catheter withdrawal, obstruction is unlikely. On the other hand, if there is failure to pass the catheter or delayed emptying, the decision that the system is obstructed should be taken cautiously. Persistence of contrast in delayed films can be produced by low urine flow rate or large capacity of the system as well as oedema at the ureteric orifice as a result of trauma inflicted by the catheter (Pfister and Newhouse, 1978). Eld (1983), has found that obstruction is proved in all ureters in which ureteric catheter could not pass up and all ureters passed up a catheter proved to be non obstructed but Morsy (1986), found that retrograde study is highly accurate in proving non-obstruction but failure to pass up the catheter do not prove obstruction but must be taken cautiously. This is in agree with our results. Retrograde studies are invasive and carries a risk of introducing infection in 2% of cases (Dale, 1975).

The gamma camera diuresis renogram was introduced into clinical practice in 1978. Subsequent reports confirmed it as a useful technique for the assessment of the dilated or equivocally obstructed upper urinary tract. The
purpose of the procedure is to help distinguish between a
dilated urinary tract that is obstructed and requires an
operation and a non obstructed system in which urographic
dilatation and stasis mimic obstruction but no genuine im-
pedance to urine flow exists and an operation is not
required. The technique provides dull information, consist-
ing of quantitative data on individual renal function, and
time-activity curves reflecting the urodynamics through the
individual upper urinary tracts at normal and high urinary
flow rates. The gamma camera images give additional infor-
mation on the site of any suspected obstruction (O'Reilly,
1988).

Diuresis renography have many advantages as regards
to other modalities in diagnosing equivocal obstruction. A
renal scan is physiologic, that is, the amount of radiophar-
maceutical administered intravenously is a "tracer" dose,
chemically negligible and insignificant with respect to
renal function, the radio-isotope produces no osmotic
diuresis, therefore, renal function is unaltered. Hypersen-
sitivity reactions are exceedingly rare. Thus, it is quite
valuable in patients with a known history of an allergic
reaction to contrast material or in patients with severe
renal failure or multiple myeloma.

The radiation exposure is very low, so, it may be
repeated, technique is very easy to perform takes, 30
minutes, no special preparation and the cost is reasonable.
There are no complications, adverse reactions, or contra-indications except for the relative contra-indication of pregnancy (Velchik, 1985).

Diuresis renogram have occupied a well established place in the diagnosis of equivocal upper urinary tract obstruction and have helped to obtain diagnostically useful information which allows therapeutic decisions to be made in difficult cases.

Diuresis renography have been applied to study 71 non-refluxing dilated upper urinary tracts in this work. Obstructed response is encountered in 19 renal units (26.7%) and in need for operative interference.

Non obstructed response also encountered in 46 renal units (64.9%). This response comprises a normal response (response I) and the dilated non obstructed response (response IIIa), and the patient in need for follow-up and conservative treatment. Lastly, equivocal response (response IIIb) is present in 6 renal units (8.4%).

Diuresis renography has a great correlation and agreement with operative findings. Surgical exploration of (11) renal units with obstructed diuresis renogram shows an agreement in 10 cases (91%). This case of false positive result due to severe hydroureteronephrosis in agree with grossly dilated kidney presented by Gill and associates (1988). Shokeir (1990), concluded that diuretic renography
is highly sensitive in diagnosing obstruction in dilated upper urinary tract.

Since the original description of the diuresis renography, the technique has been examined further at the center where it was developed and it also has come under close scrutiny by other investigators involved in the management of obstructive uropathy. Further investigation has included comparison with gamma camera parenchymal mean transit time estimations (Lupton et al., 1984), perfusion pressure flow studies (Senac et al., 1984), morphological changes in operative specimens (English et al., 1982), correlation of the various renogram responses with simultaneous intrarenal pressure measurement (O'Reilly, 1986a), and the long-term follow-up of patients with a dilated, non obstructed response in whom non operative treatment was chosen (Kass et al., 1985).

The results of these independent studies into the diuresis renogram are discussed to examine its current role and value in the management of patients with obstructive uropathic conditions.

Estimation of parenchymal mean transit time using the gamma camera was described by Whitfield and associates (1978). The technique reflects the effect of obstruction on the nephron, giving an index of obstructive nephropathy. It involves the derivation of time-activity curves from regions
of interest over the whole kidney, renal pelvis bladder. The renal pelvic curve is subtracted from the whole kidney curve to give a parenchymal curve. Delay in parenchymal transit in hydrenephrotic kidney is said to confirm obstruction.

Two studies have compared this technique to diuresis renography. Both groups established independently the upper limit of normal for the parenchymal mean transit time to be 4 minutes. Lupton and associates (1984), examined 46 hydrenephrotic kidneys in 36 patients and found that 22 of 29 patients (76%) with dilated non obstructed diuresis renogram had a parenchymal mean transit time of less than 4 minutes, while 14 of 17 (88%) with dilated obstructed diuresis renogram had a parenchymal mean transit time of more than 4 minutes. Also, Cosgriff and Berry (1982), concluded that there was good agreement between the 2 procedures and the conclusion was that the techniques had a similar diagnostic accuracy. The simpler diuresis renogram was preferred in clinical practice.

Perfusion pressure flow studies to investigate obstruction of the upper urinary tract gained widespread publicity since their popularization by Whitaker (1979), dilute contrast medium is infused at 10 ml per minute through a percutaneous antegrade nephrostomy catheter inserted proximal to the site of suspected obstruction and the proximal pressure is recorded. A pressure increase of
greater than 22 cm water during perfusion is said to indicate obstruction, an increase of less than 15 cm water excludes obstruction, while the intervening range is equivocal.

Lupton and associates (1984), made a direct comparison of both procedures in 36 patients with primary pelvic hydronephrosis and showed that there was agreement between both technique in 67%. The area of discrepancy was in patients in whom diuresis renography suggested obstruction but no obstruction on perfusion pressure flow studies. All these patients had gross dilatation. Hay and associates (1984), reported similar study in 64 patients and showed that there was good correlation between the two studies 84%.

Whitaker and Buxton-Thomas (1984), compared both technique in 32 patients with hydroureteronephrosis and found that the agreement was (53%). This wide area of discrepancy in cases with poor renal function and gross dilatation. Senac and associates (1984), compared both procedures in 13 children with hydroureteronephrosis and a good correlation was present in 85%. Shokeir et al. (1990), showed that correlation between both procedures was 60% and showed that diuresis renogram is highly sensitive in diagnosing obstruction.

Two main types of discrepancy between two procedures. First one is diuresis renogram shows obstruction but on per-
fusion pressure flow study shows no obstruction. The main causes of this discrepancy are gross hydronephrosis or poor functioning kidney. Extreme dilatation, especially in a poorly functioning kidney, will not give a reliable diuresis renogram result and, therefore, this discrepancy is predictable. The limitation of any study must be appreciated if reliable results are to be obtained and some degree of function is a prerequisite for reliance on the diuresis renogram, first to get tracer into the collecting system and then to influence it by producing a response to the diuretic. If a system is dilated grossly the diuresis must be efficient enough to wash out the tracer. If doubt exists in such cases a 15 minutes modified diuresis renogram may be useful.

The other main discrepancy is the diuresis renogram does not show obstruction but perfusion pressure flow study shows obstruction. The possible cause for this particular form of disagreement may lie in the relative urinary flow rates pertaining during the vital period of each technique. The standard diuresis renogram produces its main curve changes in the early staged of diuresis when the urinary flow rates are approximately 4 to 7 ml/min/kidney. Preliminary studies at this institution have suggested that the urinary flow rates during the first 10 minutes after intravenous furosemide are of this order but increase to 10 to 12 ml/min/kidney 15 minutes after the diuretic (similar
to the perfusion rates of Whitaker test) and supportive data for the rationale of the modified 15 minutes diuresis renogram. In addition, it must be appreciated that many dilated upper tracts probably have their own individual maximum flow rates, either across the ureteropelvic junction or other sites of obstruction. It is likely that an individual tract will be able to transport urine efficiently at a rate of 5 or even 7 ml/minute but not at 10 ml/minute, giving a non obstructive diuresis renogram result but an obstructive pressure flow study at 10 ml/minute, or when perfusion is increased to 20 ml/minute (O'Reilly, 1986a).

Gosling and Dixon (1978), demonstrated characteristic morphological changes in the renal pelvis of patients with primary pelvic hydronephrosis using light and electron microscopic technique. The light microscopic changes include the deposition of excessive amounts of collagen and elastic tissue between the within the muscle bundles of the renal pelvis. Fine structural electron microscopic abnormalities included a decreased number of myofilaments, and the development of large quantities of granular reticulum and Golgi membranes within the cells of the dilated renal pelvis. Lupton and associates (1979), demonstrated a great correlation and agreement between diuresis renography and changes occurred in morphology of renal pelvis, that reached 100%. Also, English and associates (1982), have agreed with these findings.
Long-term follow up of patients with a dilated non obstructed diuresis renogram gives good idea about the test in management of obstructive uropathy syndrome.

O’Reilly and associates (1981), followed 28 patients with dilated renal pelvis showing non obstructive response to diuresis renogram for 1 - 5 years with diuresis renography performed every 6 months. Renographic evidence of increasing obstruction and decreasing function developed only in one patient and the majority of patients became a symptomatic within 18 months after presentation. English and associates (1982), reported that follow-up of 23 patients on the same basis showed that there was no deterioration in function or drainage and no patient required an operation. Kass and associates (1985), reported that "in more than 200 children studied loss of renal function has not been observed in a single kidney followed non operatively with an unobstructed diuretic renogram.

The core areas where debate and controversy exist regarding diuresis renography are those cases when washout is equivocal making a firm management decision difficult, and when correlation of the results with perfusion pressure flow studies has been poor.

Equivocal washout in the original description of diuresis renography was considered as indicating partial obstruction. Time has shown that this definition assumes
too much. The response should be termed equivocal. To try to clarify this response, in which washout of tracer after administration of the diuretic is subtotal, attention first should focus on the underlying renal function. If function is preserved and the patient is hydrated satisfactorily then one may assume that the nephron mass responded to furosemide and, therefore, the subtotal washout indicated subtotal obstruction (Gonzalez and Chiou, 1985).

When function is impaired and washout is equivocal the situation is far from clear. It must be determined if the washout is the result of a good diuretic effect through a subtotally obstructed outlet or a poor diuretic effect through a non obstructed outlet. When the function is impaired it is unlikely that the modified (15 minutes) diuresis renogram will be of much help to clarify this situation, since the diuretic effect pertaining at any time cannot be quantified in terms of milliliters per minute per kidney to guide interpretation, and doubt regarding diuretic response of the compromised kidney will remain. In these cases perfusion pressure flow studies should be performed to ascertain the transmission capabilities of the outflow tract (O'Reilly, 1986a; Keating et al., 1989).

The available data reviewed suggest that diuresis renography in most cases is an accurate means to assess urinary tract dilatation, showing good correlation with parenchymal mean transit times, renal pelvic morphology, opera-
tive findings, perfusion pressure flow study and clinical progress. Its simple, non invasive nature, and the dual information on renal function and urodynamics provides promote renography over invasive studies after the urographic or ultrasound detection of urinary tract dilatation.

At the sharp end of clinical practice the urologist confronted with the problems of a dilated upper urinary tract usually will rely ultimately on whichever particular investigation his unit is most experienced in and in which he has learned to place the most confidence. Most urologists will realize that to rely exclusively on any single procedure in all cases to the exclusion of the others will be as misleading as to ignore all of the available modern tests and rely solely on urographic data alone. They also will appreciate that the syndrome of obstructive uropathy and the available tests for its clarification are so different that the results of investigation will not necessarily agree in every case in which they all are used or compared (O'Reilly, 1988).

If diuresis renography is used for the assessment of urinary tract dilatation, the following guidelines might be recommended when the results of the procedure are examined to aid accurate interpretation and subsequent management. An operation is indicated when urographic dilatation is found in a symptomatic patient and the diuresis renogram is obstructive. Conservative management is indicated when
urographic dilatation is found in an asymptomatic patient and the diuresis renogram is non obstructive, with repeat internal studies concentrating on function. If urographic dilatation is found in a symptomatic patient but the diuresis renogram shows preserved function and a non obstructive pattern, further investigation may be desired to clarify the cause of the symptoms. If urographic dilatation is found by chance in an asymptomatic patient but the renogram shows obstruction, an operation is recommended. Some patients in whom this is a chance finding will resist this suggestion and renographic follow up is indicated to pre-empt potential complications from silent progression of hydronephrosis. If urographic dilatation is found in any patient and washout on the diuresis renogram is equivocal, the underlying function should be examined. If the function is unimpaired then the subtotal washout should be regarded as indicating subtotal obstruction. If function is impaired and there is doubt about the ability of that kidney to respond to a diuretic, parenchymal transit time studies and/or perfusion pressure flow studies will be required. If urographic dilatation is found in a kidney with poor function, the only value of diuresis renography is to derive divided function. Perfusion pressure flow studies will be preferred to make a clinical decision.

After this discussion we may suggest the following
flow chart for studying equivocal dilatation of upper urinary tract.

I.V.U. 

\[\downarrow\]

Dilated U.U.T.

\[\downarrow\]

Asc. Cystogram  \[\rightarrow\] refluxing

\[\downarrow\]

non-refluxing

\[\downarrow\]

Diuresis renogram

\[\downarrow\]

Obstructed  

\[\downarrow\]

Surgery

\[\downarrow\]

Equivocal  

\[\downarrow\]

Function

\[\downarrow\]

non-obstructed

\[\downarrow\]

F

O

L

O

W

U

P

\[\downarrow\]

Follow-up

\[\downarrow\]

Non-Obst.  

Obstructed

\[\downarrow\]

P/F

\[\downarrow\]

Obstructed

Surgery

\[\downarrow\]

Non-obstructed

Equivocal
In this flow-chart, we suggest that diuresis renography can be applied as a screening test to patients with dilated non-refluxing upper urinary tracts. This modality being rapid, simple, safe and highly accurate can represent a good method for selecting cases which needs further assessment with more invasive techniques.

From this flow-chart we can document that obstructed response needs surgical interference and non-obstructed response needs follow-up for clinical and function of kidney. Equivocal response needs more assessment. As regard good function, this means subtotal obstruction and needs P/F study to exclude obstruction. But in poor function, modified 15-minutes renogram is performed; if obstructed response is the result, P/F study is the final assessment.

So, diuresis renography can minimize the role of P/F studies in equivocal obstruction being limited to poorly function kidneys or hugely dilated system.
SUMMARY
AND
CONCLUSION
SUMMARY AND CONCLUSIONS

In this work a study of 71 dilated non-refluxing renoureteral units in 53 patients has been performed. Patients having reflux, shown by ascending cystography, were not included in this work.

All the cases presented with I.V.U.s showing dilated upper urinary tracts. According to the I.V.U., obstruction has been suggested at the lower end of the ureter in 56 units, at the P.U.J. in 11 units, at the level of sacroiliac joint in two systems and in lumber ureter in two systems.

All the patients have past history of urological operations except three patients.

Ascending cystography excluded the presence of reflux in all the 71 units.

The aim of studying these cases was to determine those in which dilatation is due to obstruction and in need for surgery or those in which obstruction is not present and no need for surgery.

The diagnostic work up of these cases was:

(1) Detailed history taking,
(2) clinical examination,
(3) laboratory investigations,
(4) retrograde pyeloureterography,
(251)

(5) diuresis renography.

In retrograde studies, assessment of the dilated systems was done taking into consideration:
(a) passage of the catheter up.
(b) emptying of the injected contrast after removal of ureteric catheter.

Accordingly, only 13 units allowed the upward passage of ureteric catheter and emptied the injected contrast and thus could be considered non-obstructed. In the remaining 18 units (out of 31) a catheter could be passed but the injected contrast not emptied in 3 units and the catheter could not be passed in the other 15 units.

Diuresis renography was performed in 71 dilated renal units.

The results of diuresis renography were classified into:
(a) Normal response: spontaneous rapid decline in the activity (response I).
(b) Obstructed response: progressive accumulation in the activity and flat response without significant washout after furosemide administration (response II).
(c) Dilated non-obstructed pattern progressive accumulation of activity and prompt complete washout after furosemide administration (response IIIa).
(d) Equivocal pattern: progressive accumulation of the ac-
tivity and only slow incomplete elimination of the tracer (response IIIb).

According to these criteria normal response is present in 8 units and dilated non obstructed response is present in 38 units i.e. collecting obstruction is excluded in 46 renal units. Obstructed response is present in 19 renal units and equivocal response in 6 renal units.

Comparison of the results of retrograde studies versus the results of diuresis renography has shown that:
(a) when retrograde studies suggested that we have a non obstructed system this was correct in 84.6%.
(b) If the catheter could not passed or the dye was not evacuated. True obstruction was present in 33.3% of cases only.

Surgical exploration of 11 units proved by diuresis renography to be obstructed showed true obstruction was present in 10 cases and reconstructive surgery was performed.

So, the following conclusions can be got out of this work:
(1) Dilatation may be present without obstruction.
(2) Diuresis renography presents a new, simple, rapid, physiological, non invasive modality that can be used to screen all patients with suspected obstruction of the upper urinary tract.
A flow-chart for diagnosis of obstruction in dilated upper urinary tracts has been suggested.
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ARABIC SUMMARY
الخلاصة

لقد كانت القدرة على تمييز انسداد الجهاز البولي العلوي والسدد من غير السدد تكمن على
أساس أجزاء اضعة بالصفحة والتاريخ المرضي للمرضى.

وأن أجزاء أضعها بالصفحة مازالت هي الخطوة الأولى لفحص مرضى السالك البولي ولكن
في معظم الحالات المصاحبة بإنسداد الجهاز البولي العلوي يحتاج المريض لأجراءات كمية
للتفقد بين انسداد الجهاز البولي العلوي السدد أو الحال نادر التفوق.

ان تصور الكلية بالمواد المشعية عن طريق زيادة آثار الرثير بعد حق مدر للبول نسبي
التمييز بين انسداد الجهاز البولي السدد وغير السدد كمية قصوى حيث أنها طريقة سهلة
ويمكن أجراؤها في وقت قصير يقدر بحوالي 30 دقيقة وهي حساسة لقياس وظيفة الكلية ولا تؤثر
على المريض حيث أنه لا يتأثر بالأشعة تم إجراء البحث على 35 مريض يعانون من انسداد الجهاز
البولي العلوي في 11 كلية كما هو واضح من الآشعة بالصفيحة.

وكذلك استعاد بالأمر الذي يعانون من ارتفاع الرثير من الثمانية إلى الحالة من البحث.
نما 30 المريض تحت البحث تتضمن الأشعة بالصفحة أن انسداد الجهاز البولي العلوي عند اتصال الحالة بالثاني في 166 جهاز بولي طولوى وقد اشترت الكلية فسيhes
الحالة في 11 حالة عند نقل الحالات في جهازاتي في الحالة البليشة أيضا في مختبرين.
جميع المرضى تحت البحث تلقي علاجات جراحية متراكمة في قسم السالم بمعدا 3 مرضى فقط.

الغرض من البحث هو التمييز بين انسداد الجهاز البولي العلوي من عدمه في حالات
اتصاعه وأنا المريض الذي يحتاج إلى عملية جراحية أم لا، ولذلك تم إجراء التالي لكل مريض:
(1) التاريخ المرضي
(2) الفحص الالتهابي
(4) أشعاع صاعدة بالصفحة
(5) تصوير الكلية بالأشعة بعد حق مدر للبول.

بالنسبة للاشعة الصاعدة بالصفحة يتم عليها أخذين في الاعتبار:
(أ) مرور قطرة الحالة الى أعلى
(ب) تفريغ الصفيحة بعد زوال القسطرة.
طبقاً لذلك، تم عمل 31 حالياً وانتج أن 13 حالياً لم تمت مرور القسطرة إلى أعلى وتم تغريب الصبغة ولكن في 18 حالياً تم مرور القسطرة إلى أعلى في انتظار مع عديد من الصبغة.
ولكن القسطرة لم تتم إلى أعلى في 15 حالياً.

أما تصوير الكليه بالمواد المشعة بعد حقن مدر للبول يتم تقسيم النتائج إلى:

1) الاستجابة العادية
2) استجابة الطريقة المسودة
3) استجابة الطريقة المسودة بعد حقن المدر للبول تتحول إلى غير مسودة
4) استجابة الطريقة المسودة بعد حقن مدر للبول تحرق قليلاً فقط

طبقاً لذلك، تم أن الاستجابة الأولي ظهرت في 8 وحدات والاستجابة الثالثة في 38 وحدة ولهذا تم استبعاد أنسداد الجهاز العلوي في 41 وحدة ولكن ظهرت الاستجابة الثانية أن المسودة في 19 وحدة والاستجابة الرابعة في 6 وحدات.

بالمقارنة بين الدراسات بالمواد المشعة والأشعة الصاعدة تبين أن هناك اتفاق في تشخيص أكسدة الجهاز البولي الركسي. هذا تشكل نسبة أنسداد الجهاز البولي في 33.2% فقط.

وقد تم عمل علاجات جراحية لعدد 11 وحدة وقد تبين بالعملية أن ثبت الأنسداد في 10 حالات فقط ولم تتم إجراء أنسداد في 5 حالات فقط. ولم تتم إجراء أنسداد في 5 حالات فقط. ولم تتم إجراء أنسداد في 10 حالات فقط ولم تتم إجراء أنسداد في 10 حالات فقط.

هذا هو من أفضل الطرق للتعرف في تلك الحالات التي يسبط وسريعاً وسلامة وظائف الكلي.
تصوير الكتلة بالمواد المشعة بعد حقن مدر للبول

دراسة اكلينيكية لتقييم اتساع الجهاز البولي العلوي

رسالة مفهومة من الطبيب:
حمدى محمد عبد الحليم

تميداً للحصول على درجة الدكتوراه
في المسالك البولية

تحت إشراف

الاستاذ الدكتور
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كلية طب القصر الرئيسي

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استاذ م. العلاجية والطب النووي
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1991