# Pelvi-ureteric obstruction

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RIJKSUNIVERSITEIT TE GRONINGEN

# PELVI-URETERIC OBSTRUCTION

PROEFSCHRIFT

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Stellingen
behorend bij het proefschrift van
J.A.P.Hooykaas
Pelvi-ureteric obstruction.
Groningen, januari 1981.

STELLINGEN

1. Bij de pyelum-ureter obstructie dient bij voorkeur een pyelumplastiek volgens Anderson-Hynes te worden verricht.

2. Het diurese-renogram is een belangrijk aanvullend onderzoek in die gevallen, waarbij het niet duidelijk is of een hydronephrose wordt veroorzaakt door een afvloedbelemmering.

3. Een nier met een "gesloten" bolvormig nierbekken kan zich ontwikkelen tot een hydronephrose.

4. Het intermitterend (zelf-)catheteriseren is een behandelingsmethode van ontledingsstoornissen van de blaas, die frequenter toegepast dient te worden.

5. Na het ligeren van de vena spermatica blijven de verwachtingen op verbetering van een aantal semenkwaliteiten en de kans op fertiliteit te hoog gesteld.

6. Niet voor alle niercarcinomen is nephrectomie, bij ontbreken van disseminatie, de beste methode van behandeling.

7. Te vaak wordt door, zowel de patient als de medicus, inadequaat gereageerd op het alarmerende symptoom van de macroscopische haematurie.

8. Wegens het veelvuldig voorkomen van blaasontledigingsstoornissen na rectumoperaties, verdient het de voorkeur om tijdelijk een cystostomie aan te leggen.

9. Uit het oogpunt van preventie van (neurologische) blaasfunctiestoornissen na een uterusextirpatie, verdient de abdominale benadering de voorkeur boven de vaginale.

10. Stomata zoals een colostomie, een ileostomie of een urostomie moeten door de rectusmusculatuur heen worden aangelegd. Een anus praeternaturalis kan zonodig in de mediaanlijn worden geplaatst.

To my parents

To Guusje

Rutger

Willem

Marc

# Contents

# 1. History

The aetiology and surgical correction of the pelvi-ureteric junction obstruction have long been discussed. Probably no problem in urological surgery has been approached by more divergent opinions among urologists than that of pelvi-ureteric junction obstruction (PUJO).

Hippocrates (460-377 B.C.) already knew the difference between hydronephrosis caused by a stone and a pelvi-ureteric junction obstruction.

Nicolaas Tulp (Tulpius 1672) first mentioned the condition of intermittent hydronephrosis which only happened by full moon. It lasted five days and was cured by bloodletting. An explanation for this could be that in those days full moon was a good reason to pay a visit to the local pub to drink beer, which increased the diuresis and caused the hydronephrosis. The bloodletting might have caused an oliguria and the complaints disappeared. Boissiers de Sauvage (1773) agreed completely with Tulp's opinion and called it: "Ischuria lunatica Tulpii".

By the end of the 17th century, most surgeons were more or less in accord that the true indication for nephrotomy was the infected calculous kidney, distended by an accumulation of pus, and those kidneys in which the calculus could be palpated in the organ itself or through a sinus.

The first accurately recorded nephrolithotomy on an otherwise healthy kidney was performed by Henri Morris in 1880 when he successfully removed a stone.

The birth of renal surgery actually took place in 1862 when Gustav Simon, Professor of Surgery at the University of Heidelberg, deliberately and successfully removed a kidney.

The first conservative operation for relief of PUJO was performed by Trendelenburg (1886). Küster (1891) was the first to perform resection of the upper ureter with reimplantation into the renal pelvis. Fenger (1892) applied the Heinecke-Mikulicz technique for pyloric stenosis to a PUJO. Bazy (1896) performed a partial resection of the renal pelvis and lowered the insertion of the ureter and Albarran (1986) published about the uretero-pyeloneostomy done by him. Braasch (1909) pointed out that a plastic operation should not be attempted if the pelvis contained over 180 ml. of urine. Peck (1910) used an ureteric catheter passed through the kidney and down the ureter as a splint for the sutured ureter, the catheter being allowed to remain in place for about 5 days. From that moment on until the present day there have been and are "splinters" and "non splinters". Von Lichtenberg (1921) described a lateral uretero-pelvic anastomosis of the ureter to the pelvis thus increasing the size of the pelvic outlet. Foley and Schwyzer (1923) used an Y-shaped incision in the pelvis and ureter to form a flap which was sutured down the ureter to enlarge the pelvic outlet. Young (1932) proposed a method of resecting the anterior and posterior portion of the renal pelvis in such a way that the ureter was drawn away from the aberrant vessel thus eliminating the necessity of sectioning either the vessel or the ureter. Davis (1933), Vose (1934), Bidgood and Roberts (1935) have each performed an operation on a stricture of the pelvi-ureteric junction corresponding to the Ramstedt operation for pylorospasm. More recently the pyeloplasty advocated by Andersen and Hynes (1949) became the technique most in favour. The pelvic-flap technique of Culp and de Weerd (1951) has been in favour for a long time, especially in the United States.

The literature is filled with conflicting statements regarding both the aetiology and treatment. From the aetiological aspect most interest has been paid to mechanical factors such as aberrant vessels, adhesions, kinks, high insertion of the ureter and post-inflammatory strictures. The theory of Murnaghan (1958) laid the foundation for a more dynamic aspect. He found a muscular anomaly in the pelvi-ureteric junction (PUJ), with an excess of longitudinal muscle fibres in relation to the circular ones, which could be the cause of the disturbance in the conduction of the peristaltic waves. In his opinion aberrant vessels only accentuate the further development of the condition.

The successful treatment of PUJO postulates both knowledge of the aetiological factor or factors involved and their proper recognition and evaluation at operation. Moreover the surgical procedure chosen for correction must be that one which is adapted to a given deformity. The result should be a funnel-shaped, dependent, well draining pelvi-ureteric outlet with a good coordination between pelvic and ureteral neuro-muscular urodynamic functions.

# 2.1. Embryology

## 2.1. Embryology of the kidneys and ureters.

The greater part of the urinary system is formed from the mesoderm of the intermediate cell mass. Three sets of structures appear successively, called the pronephros, the mesonephros and the metanephros.

### Pronephros.

The pronephros of each side is rudimentary in the human subject and consists of several tubules formed from mesodermal cells of the intermediate cell mass in the cervical region. Glomeruli do not develop and the tubules do not open into an excretory duct. The first formed tubules regress before the more caudally placed last ones are formed and the entire pronephros disappears by the end of the fourth week.

### Mesonephros.

The mesonephros, like the pronephros, consists of a number of tubules and is formed from the mesodermal cells of the intermediate cell mass in the thoracic and lumbar regions. The medial end of each tubule enlarges and becomes pear-shaped, and its wall is invaginated by a cluster of capillaries which form a glomerulus. The capillaries are connected to a branch of the aorta. The lateral end of each tubule opens into a longitudinal collecting duct called the mesonephric (or Wolffian) duct. The mesonephric duct develops as a solid rod of cells in the intermediate cell mass. This canalizes and its caudal end grows to reach the lateral wall of the cloaca, which it perforates. Meanwhile each mesonephric tubule undergoes further development. With the formation of the glomerulus, the indented medial end of the tubule forms the glomerular capsule. The glomerular capsule and the glomerulus together are known as the mesonephric corpuscle. The increase in the length of the tubule causes it to become bent and S-shaped and the equivalent of the proximal and distal convoluted tubules and the collecting tubules are formed. As the mesonephric tubules continue to form and grow, the mesonephros forms a spindle-shaped ridge, which projects into the coelomic cavity on each side of the midline. Later it becomes an ovoid body, which is suspended from the posterior abdominal wall by a thick mesonephric mesentery. During the second month, the mesonephros reaches its maximum degree of development and extends on each side from the region of the septum transversum down to the third lumbar segment. After functioning for a short period, the tubules start to degenerate, and this proceeds in a craniocaudal direction. By the beginning of the third month, the majority of the mesonephric tubules and glomeruli have disappeared. However, a few caudal mesonephric tubules remain and become associated with the genital system in both sexes.

Metanephros.

The metanephros, or permanent kidney, develops from two sources:

1. the ureteric bud from the mesonephric duct;
2. the metanephrogenic cap from the intermediate cell mass of the lower lumbar and sacral regions.

The ureteric bud arises as an outgrowth of the mesonephric duct near the opening of the latter into the anterior part of the cloaca. The bud grows dorsocranially into the mesoderm of the intermediate cell mass, which condenses around it to form the metanephrogenic cap. The ureteric bud forms the ureter, which dilates at its upper end to form the pelvis of the ureter. Later the pelvis gives off branches that form the major calyces, and these in turn divide and branch to form the minor calyces and collecting tubules. New collecting tubules continue to be formed until the end of the fifth month of foetal life.

The mesodermal cells of the metanephrogenic cap form the glomerular capsules (Bowman's capsules), the proximal and distal convoluted tubules, and the loops of Henle. The glomerular capsule becomes invaginated by a cluster of capillaries that form the glomerulus. Each tubule elongates in a manner similar to that seen in the development of the mesonephric tubule. It is important to realize that the metanephrogenic tissue proliferates and divides with the ureteric bud, so that each new tubule has its own cap of mesoderm. Each distal convoluted tubule formed from the metanephrogenic cap tissue becomes joined to a collecting tubule

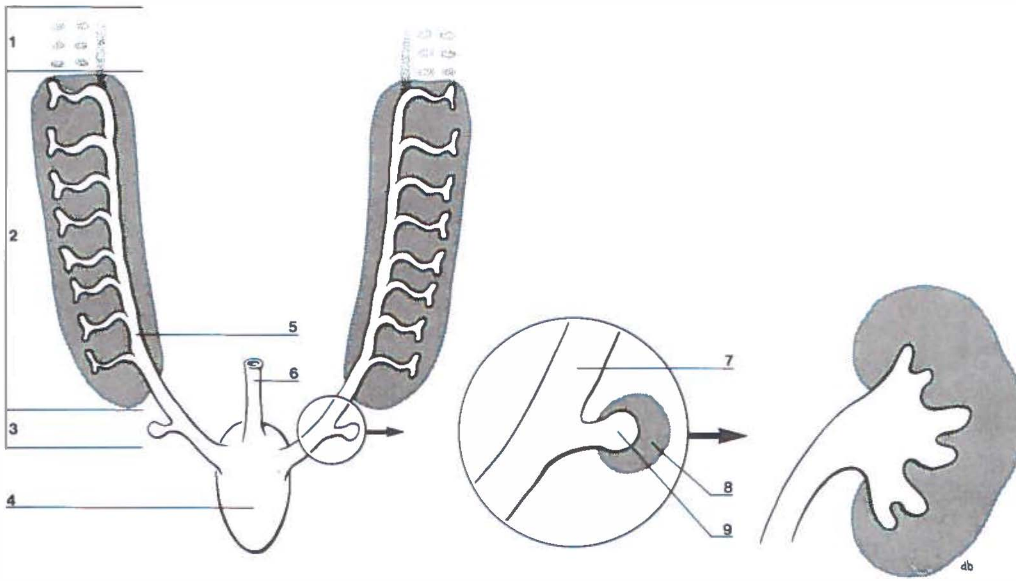



Fig. 2.1. 1. Pronephros; 2. Mesonephros; 3. Metanephros; 4. Cloaca; 5. Mesonephric duct; 6. Allantois; 7. Mesonephric duct; 8. Metanephrogenic mass; 9. Ureteric bud.

derived from the ureteric bud. The surface of the kidney is at first lobulated, but after birth this lobulation usually soon disappears.

The metanephros is at first a pelvic organ. It is found at the level of the upper sacral segments and receives its arterial supply from the pelvic continuation of the aorta, the middle sacral artery. As development proceeds, the kidneys change their position and gradually "ascend" up the posterior abdominal wall. This so-called ascent of the kidney is largely apparent and is caused mainly by the growth of the body in the lumbar and sacral regions and by the straightening of its curvature. The ureter elongates as the "ascent" continues. The kidney is vascularized at successively higher levels by successively higher lateral splanchnic arteries, branches of the aorta. The kidneys ultimately reach their final position opposite the second lumbar vertebra. Because of the large size of the right lobe of the liver, the right kidney lies at a slightly lower level than the left kidney.

It is generally believed that the mesonephric and metanephric kidneys produce urine before birth. This is passed via the cloaca into the amniotic cavity and contributes to the liquor amnii. It should be pointed out, however, that the placenta functions as the kidney in the foetus, and it is only at birth that the kidneys assume their important function.

# 2.2. Anatomy

## 2.2. Anatomy of the kidneys.

### 2.2.1. Gross appearance.

The kidneys lie along the psoas muscles and are therefore obliquely placed. The position of the liver causes the right kidney to be lower than the left. The adult kidney each weigh about 150 g.. Both kidneys are supported by the perirenal fat (which is enclosed in the perirenal fascia), the renal vascular pedicle, abdominal muscle tone, and the general bulk of the abdominal viscera. Variations in these factors permit variations in the degree of renal mobility. The average descent on inspiration or on assuming the upright position is 4-5 cm.. Lack of mobility suggests abnormal fixation, but extreme mobility is not necessarily pathological.

On longitudinal section, the kidney is seen to be made up of an outer cortex, a central medulla, and the calyces and pelvis. The cortex is homogeneous in appearance. Portions of it project toward the pelvis between the papillae and fornices and are called the columns of Bertin. The medulla consists of numerous pyramids formed by the converging collecting renal tubules, which drain into the minor calyces.

### 2.2.2. Blood supply.

Arterial. Usually there is one renal artery, a branch of the aorta, which enters the hilum of the kidney between the pelvis, which normally lies posteriorly, and the renal vein. It may branch before it reaches the kidney, and 2 or more separate arteries may be noted. In duplication of the pelvis and ureter, often each renal segment has its own arterial supply. This artery further divides into the interlobular arteries, which ascend in the columns of Bertin (between the pyramids) and then arch along the

base of the pyramids (arcuate arteries). From these vessels smaller (afferent) branches pass to the glomeruli. From the glomerular tuft, efferent arterioles pass to the tubules.
For many years "aberrant" or "accessory" arteries have been of interest to the clinician, because of their suspected part in the causation of hydronephrosis. In this case, the words "aberrant" and "accessory" are synonymous. In fact, however, they are both misnomers. It had long been assumed that any additional artery which entered one pole of the kidney was necessarily an extra source of supply to that provided by the main-stem of the renal artery. In an injection study of a post-mortem kidney which also had an aberrant renal artery, Graves (1954) found that this vessel was not additional in any way, but was in fact the artery to the lower segment whose origin was more proximal than usual. This and subsequent similar studies, confirmed that the "aberrant" or "accessory" artery was a normal segmental artery of precocious origin, often from the aorta instead of the renal artery. The incidence of arteries entering one pole has been shown to vary between 10 and 40% (Merklin and Michels, 1958). Graves found that in 63% of casts the lower segment artery had the most proximal origin of all the segmental vessels; certainly those to the lower pole are approximately twice as common as those to the upper pole.
Venous. The renal veins are paired with the arteries, but any of them will drain the entire kidney if the others are tied off.
Lymphatics. The lymphatics of the kidney drain into the lumbar lymph nodes.

## 2.3. Anatomy of the renal pelves and ureters.

### 2.3.1. Gross appearance.

The pelvis may be entirely intrarenal or partly intrarenal and partly extrarenal. Inferomedially it tapers to form the ureter. If the pelvis is partly extrarenal, it lies along the lateral border of the psoas muscle and on the quadratus lumborum muscle; the renal vascular pedicle is placed just anterior to the pelvis. The left renal pelvis lies at the level of the first or second lumbar vertebra; the position of the right pelvis is a little lower.

The adult ureter is about 30 cm. long, varying in direct relation to the height of the individual. It follows a rather smooth S-curve. Areas of narrowing are found at the PUJ, in the lower abdomen where the ureter crosses over the iliac vessels, and also where it courses through the bladder wall.
From cranial to caudal, the ureter lies on the psoas muscle, passes medially to the sacroiliac joint and then swings laterally near the ischial spines before passing medially to penetrate the base of the bladder. The uterine arteries are closely related to the juxtavesical portion of the ureters. The ureters are covered by the posterior peritoneum; their most distal portions are closely attached to it, while the juxtavesical portions are embedded in retroperitoneal fat.

2.3.2. Blood supply.

The renal calyces, pelvis, and upper ureter derive their blood supply from the renal arteries. Because the renal pelvis has a constant rich arterial and venous anastomotic blood supply interference through surgical incisions appears unlikely.
The mid-ureter is fed by the internal spermatic (or ovarian) arteries. The lowermost portion of the ureter is served by branches from the common iliac, hypogastric, and vesical arteries. The veins of the renal calyces, pelvis and ureters are paired with the arteries.
Lymphatics. The lymphatics of the upper portion of the ureter as well as those from the pelvis and calyces enter the lumbar lymphnodes. The lymphatics of the mid-ureter pass to the hypogastric and common iliac lymph nodes; the lower ureteral lymphatics empty into the vesical and hypogastric lymph nodes.

# 3. Histology

Detailed study of the microscopic and ultra-microscopic anatomy of the ureter during recent years has substantially increased our knowledge of the function and pathology of the organ, though much remains to be learned. Many misconceptions of the past have been corrected; all investigations have revealed the fallacy, still often perpetuated, of drawing analogies between the physiology of the ureter and of the intestinal tract by postulating a comparable pathology in cases of obstruction.

## 3.1. Anatomy of the ureter as described in the literature.

### 3.1.1. Microscopic anatomy of the ureter.

By light microscopy the wall of the human ureter can be seen to comprise three layers, an external adventitia, a smooth muscular coat and an inner mucous membrane.

A. 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 tissues. It is preponderantly composed of fibrocytes and multitudinous collagen fibres between which small blood vessels are present and bundles of unmyelinated nerve fibres which run to and from the ureter.

B. The muscular coat consists of one layer of smooth muscle fibres. By light microscopy, only few details of the structure of the muscle cells or their connections can be demonstrated. Similarly orientated fibres are collected together in bundles which are separated from one another by loose connective tissue. The bundles exhibit varying and seemingly haphazard orientation in the muscular layer. Accordingly it is very difficult to see how the concept of an "outer circular" and an "inner longitudinal layer" of smooth muscle bundles can be supported, although this is the arrangement described in many texts. Satani (1919) observed that the muscular coat of the ureter varies in thickness at various levels and he claimed that in the upper ureter the bundles proceed in all directions to produce a "braided" histological appearance, whilst in its lower part the inner bundles are disposed longitudinally and the outer ones circularly. Murnaghan (1958) however, described bundles forming an interlacing series of spirals, each commencing as longitudinal strands in the outer region of the musculature, next forming a middle circular layer as they describe their spiral turn before terminating again as longitudinal bundles adjacent to the lamina propria. Murnaghan found the spirals to be intermingled in the upper ureter, in a similar way as Satani's "braided" bundles. Tanagho (1971) has extended this, and described a helical arrangement of individual muscle bundles in the ureteric wall. It is obviously an extremely difficult procedure to follow individual bundles, as Tanagho has attempted, but it is a more accurate procedure than making assumptions from the appearance of transverse sections only. Allen (1973) extended Tanagho's general concept by describing a single layer of muscle with fibres, though intertwining extensively, orientated predominantly in a longitudinal direction. These descriptions certainly afford a more meaningful interpretation of transverse sections through the ureteric wall. It would seem advisable to abandon the historical concept of "layers" of muscle fibres disposed in longitudinal or circular fashion, in favour of a concept of an intermingling mass of fibre bundles laid down in a spiral or helical fashion.

Below the muscular layer is a loose connective-tissue layer, the lamina propria. It contains multitudes of collagen fibres and their supporting fibrocytes, the majority of the fibres arranged parallel to the long axis of the ureter.

C. Lining the lumen of the ureter is its third layer, the transitional epithelium. In transverse section, the epithelium and lamina propria frequently exhibit an irregular zig-zag pattern because in vivo the outer elastic layers of the ureter apparently pull the epithelium into longitudinal folds resulting in the ureteric lumen appearing stellate. Only if the ureter is fixed in a distended condition are these folds absent. The transitional epithelium is composed of four to five superimposed cell layers. The superficial cells tend to be flattened, particularly if the ureter is fixed after distension. The basal cells are plump with more densely staining nuclei. With light microscopy no basement membrane is revealed between the lamina propria and the epithelial cells.

3.1.2. Ultrastructure of the ureter.

With the electronmicroscope the three layers, adventitia, muscle coat and mucous membrane, can easily be identified in the wall of the human ureter.

A. The outer layer of the ureter is an adventitial connective tissue sheath of variable thickness. It is composed mainly of dense bundles of collagen fibres coursing in all directions, the majority however along the long axis of the ureter. They are accompanied by numerous fibrocytes. In the adventitia numerous blood vessels of varying size are present. Most are disposed longitudinally, a few pass obliquely through the thickness of the adventitia. Many vessels are accompanied by bundles of unmyelinated nerve fibres; the larger vessels especially receive a rich innervation. Bundles of such fibres are present throughout the adventitia and are scattered unevenly around the circumference of the ureter. They vary in size diameter and contain between 10 and 150 unmyelinated axons enclosed in Schwann-cell cytoplasm.

B. The muscular coat of the adult human ureter measures approximately 750 µm in thickness and is composed of bundles of smooth muscle cells. These cells are elongated and contain densely-staining myofilaments arranged parallel to the long axis of the cell. There is no continuity of the contractile elements from one cell to another and no evidence of the existence of a syncytium constituted by the cells. Two types of muscle cells can be differentiated, a pale cell and a dark cell; the dark cells appear so by virtue of having abundant myofilaments which are tightly packed together, while the pale cells have few myofilaments which are more widely spaced. A minority of the muscle cells shows both pale and dark areas within their cytoplasm, and it is not uncommon to see a "halo" around the nucleus where the myofilaments are less closely packed. Small collections of clear vesicles, probably endo- or pinocytotic vesicles, about 50 nm. in diameter occur in many of the muscle cells, closely aggregated beneath the plasma membrane. Each muscle cell is surrounded by a basement membrane, about 40 nm. thick, situated about 40 nm. from the plasma membrane. Numerous contacts are observed between adjacent muscle cells. At these points the basement membranes of contiguous cells are fused together so that the plasma membranes of the two cells are in close apposition. These junctions take various forms: they may be present between two more or less flat or reciprocally curved cell surfaces; the contiguous surfaces may be infolded and interdigitated: a process from one cell interlocking with a recess in another cell; or two cells may have corresponding processes, the ends of which make contact. Using special fixation techniques, the plasma membranes have been shown to be in actual contact with fusion of the membranes to form a nexus. The individual muscle cells are arranged in bundles most of which are totally or partially enclosed by fibrocytic processes. All the cells in a bundle are similarly orientated. Bundles of muscle cells are cut longitudinally, obliquely and transversely in all areas of the muscle coat and a consistent feature is their wide spacing with many collagen fibres between them.

Throughout the thickness of the muscle layer small blood vessels are present. Small bundles of unmyelinated nerve fibres accompany many of these vessels and seem to innervate the vessel walls. Bundles of collagen fibres occur throughout the muscle coat, between the individual muscle fibres and in large groups between the bundles of muscle fibres. They are arranged mainly parallel to the long axis of the ureter, but a minority is orientated in all directions. Fibrocytes are present between the muscle cell groups; their processes enclose them totally or partially.

C. The transitional epithelium is from four to five cells in height. Two types of cells are present: a large light cell and a smaller dark cell. The lumen of the ureter is mainly lined by the large pale cells with only occasional dark cells intervening. The deepest, or basal, layer of the epithelium consists entirely of small dark cells, whilst the intermediate layer is made up of both types of cells, with a predominance of the dark type. The dark cells have a densely-staining granular cytoplasm which contains abundant small, rounded, dark mitochondria. The mitochondria are usually aggregated at one side of the nucleus around a

Golgi-zone in which a centriole is seen in appropriate sections. Most basal dark cells show conspucious large collections of coarse granular, dark-staining material which is preferentially aggregated close to one side of the nucleus. The basal plasma membrane, which is deeply infolded, contacts a continuous basement membrane, about 25 nm. thick, which extends about 30 nm. from the cell wall. "Attachment-plates" seem to be absent (Notley 1968). In the pale cells, small, rounded, densely-staining mitochondria are present in lesser numbers than in the dark cells and are scattered throughout the cytoplasm. The plasma membranes of the lateral borders and bases of the cells of the transitional epithelium are infolded and interdigitated with the processes of neighbouring cells. The cells are joined together at the luminal end of their lateral borders by a dense junctional complex. Between the basement membrane of the epithelium and the muscular layer of the human ureter is the 350-700 $\mu$m thick lamina propria. This layer is characterised by large numbers of collagen fibres arranged in bundles and interspersed with fibrocytes and their processes. The collagen fibres have a similar orientation as the majority of other collagen fibres in the ureteric wall: mainly longitudinally. Scattered randomly throughout the lamina propria are small blood vessels cut in various planes. Many are associated with small bundles of non-myelinated nerve fibres. Lying closely applied to the basement membrane are many longitudinally disposed capillaries. Throughout the lamina propria, bundles of unmyelinated nerve fibres enclosed in Schwann cell cytoplasm are observed. They range from large bundles containing 40-50 axons enclosed in several Schwann cells to small collections of 8-10 axons in a single Schwann cell.

## 3.2. Pathology of the pelvi-ureteric junction.

### 3.2.1. Lightmicroscopy.

Hydronephrosis is the most common sequel to pelvi-ureteric junction obstruction encountered in infants and children. Despite numerous reports of diverse pathologic findings at the PUJ in hydronephrosis due to PUJ obstruction, there is still a widespread conviction that the actual cause is a "functional" obstruction. This should be suggested by the persistence of pelvic dilatation after all adhesions have been freed. If the ureter is transected just below the pelvi-ureteric segment urine will not drain freely from the pelvis, although a probe can easily be passed upwards. Evidently, the pelvi-ureteric segment is unable to transport urine from the pelvis in a normal manner. Several theories have been put forward to explain this abnormal function.

In a light microscopic study of the obstructed PUJ, Murnaghan (1959) reported a predominance of longitudinal muscle fibres and suggested that a developmental muscular anomaly exists in this region, the spiral muscle fibres being deficient. The affected pelvi-ureteric segment would therefore be unable to propel its contents downwards during peristalsis. It is unlikely that one single causal factor will be found responsible for all cases of PUJ dysfunction. Indeed a spectrum of abnormalities was observed in 35 obstructed segments in the study of Hanna et al (1976). Three groups were investigated. Eight specimens were morphologically entirely normal. Reduced muscle bulk in the PUJ was observed in 13 specimens. The third group of 14 cases exhibited muscular malorientation, thickened adventitia, and a variable degree of inflammatory cell infiltration.

Foote (1970) noted in 7 of 58 patients a complete absence of muscle or of the presence of abnormal, small muscle fibres at the PUJ in 37 patients. The bundles became smaller and less numerous as the junction was reached from below, sometimes disappearing totally, or remaining as miniature bundles. In most cases muscular hypertrophy was present above this defect. Occasionally the hypertrophied muscle would have been a secondary obstructing factor and the area of primary muscle deficiency was hardly apparent. These segments, collapsed by hypertrophied muscle, may show the gross appearance of a valve. In this series there were 6 patients with normal muscles and 8 with hypertrophy of the muscle layer in the renal pelvis.

Fladderer (1975) demonstrated in 15 out of 21 patients a significant increase of collagenous tissue within the PUJ, along with a relative deficiency of monocytes. Each of the smooth muscle fibres was surrounded by fibrous tissue, which could have caused interruption of the "nexus" function and therefore deficiency of muscle contractions. Thus, insufficient muscle contractility within the

PUJ could be a major factor in the pathogenesis of hydronephrosis associated with PUJO. The remaining 6 showed muscle hypertrophy and subepithelial fibrosis.

3.2.2. Electronmicroscopy.

Electronmicroscopic studies of the abnormal pelvi-ureteric segment by Notley (1971) have revealed normal muscle cells with normal nexus and a normal innervation of the region, but have also demonstrated a considerable increase in the amount of fibrous tissue in the ureteric wall. Not only were the muscle bundles widely seperated by collagen fibres, but occasionally the lamina propria was as much as one millimetre thick. A corset of inelastic collagen would prevent distension of the pelvi-ureteric segment by urine so that only a small constant volume of urine will escape from the renal pelvis (an aperistaltic segment); during diuresis urine will accumulate in the pelvi-calyceal system, producing hydronephrosis. This finding was partly confirmed in a detailed study by Hanna (1976). Excessive collagen between the muscle cells of the obstructed PUJ and compromised muscle cells in the area immediately proximal to the junction were noted. In moderately dilated pelves a progressive increase in numbers of normal muscle cells was observed as sections were inspected in progressive cephalad directions away from the PUJ. In gross hydronephrosis there was a severe muscle cell distorsion and an increased collagen and ground substance deposition over a more extended area of the renal pelvis. The nexus were markedly attenuated or ruptured accounting for structural and functional discontinuity between the muscle cells. It is believed that these abnormalities have a prognostic impact on the results of surgical repair.

In cases of primary obstructive megaureter and hydronephrosis due to PUJO,Gosling (1978) observed excessive amounts of connective tissue extending throughout the entire length of the distended ureter and renal pelvis. Structural changes in the smooth muscle cells included a reduction in number of myofilaments and the development of unusually large quantities of granular endoplasmatic reticulum and Golgi complexes. The connective tissue separating smooth muscle cells, consisted of bundles of randomly orientated collagen fibres together with numerous pale staining elastic fibres. This infiltration of connective tissue and the smooth muscle changes continued distally as far as the "narrowed" segment (pelvi-ureteric junction and ureterovesical junction) where it ceased abruptly.

Gosling proposed two alternative hypotheses. Firstly, a primary anomaly of renal pelvic smooth muscle is present which is reflected in fine structural and histochemical changes associated with the manufacture of excessive amounts of connective tissue. On this basis an intrinsic malfunction of muscle cells should be the aetiological moment in this condition. Alternatively, the morphological features of the wall of the dilated renal pelvis could secondarily arise in response to distension, the latter being due to obstruction from an as yet indetermined cause. In other words: is hypotonic dilatation of the renal pelvis associated with normal morphological features aetiologically a different condition from the established dilatation associated with pelvi-ureteric junction obstruction with abnormal morphology? Alternatively, do the two groups represent different stages of the same disease process?

# 4.1. Physiology

Which are the mechanisms taking care of urine transport in the normal calyces, pelvis and ureter?
There are three forces which act on the urine in the renal pelvis and encourage its transport into the ureter and the bladder: these are the pressure produced in the nephron (glomerular filtration and tubular excretion), the peristalsis and the hydrostatic pressure (gravity). Glomerular filtration is a process mainly dependent on blood pressure and is less affected by intrapelvic pressure than tubular excretion. Intravascular pressure is about 100 cm. $H_2O$ (80 mm. Hg). This is opposed by a colloid osmotic pressure of 33 cm. $H_2O$ and a tubular resistance approximating 33 cm. $H_2O$. The resultant filtration pressure in the glomerulus is therefore approximately 34 cm. $H_2O$. Tubular secretion is an active physiological process, requiring cellular activity. The tubules alone are capable of considerable secretory pressure. The total excretion pressure is approximately the result of the combined pressures of glomerular filtration and tubular secretion.
The role which each of these factors plays in transport is dependent on the circumstances which prevail at the time. Whilst lying in bed with an empty bladder, for instance, the hydrostatic pressure will be almost zero, whereas the renal excretion pressure difference in both positions is minimal. Peristalsis is almost wholly responsible for transport in this situation. Whilst during the day the hydrostatic pressure caused by the height of the kidney above the bladder assists in keeping the urine flowing down the ureter, the peristalsis is the active factor propelling boli of urine down to the bladder, perhaps with an enhanced frequency because of the hydrostatic factor.
The forces active when a peristaltic wave propels a bolus of fluid down the ureter (Whitaker 1975), are shown in Fig. 4.1..
Although the ureteric muscles are spirally orientated, the con-

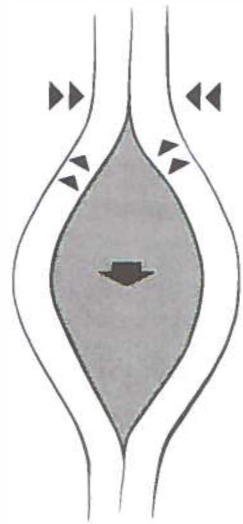


Fig. 4.1. Resolution of forces on a bolus of urine in the ureter.

traction forces can be resolved into radial and longitudinal forces. There is a strong radial contraction at the top of the bolus and at the same time a shortening longitudinal contraction pulls the ureter up over the bolus. This action is most effective only if the radial forces have completely obliterated the lumen of the ureter preventing escape of urine in the cranial direction.
Peristalsis is able to conduct fluid down the normal ureter by means of circumscript moving areas with a closing contraction.
As the bolus reaches the ureterovesical junction the onward movement of the radial closing forces will drive the bolus through the orifice and at the same time the longitudinal shortening force will help by pulling the last few millimetres of ureter up over the bolus. By this coordinated activity the orifice is pulled open to allow the bolus through. It is probable that there is a minimum pressure, perhaps of only a few centimetres of water, needed to assist the muscular activity to open the orifice in the normal ureter. To be effective the pressure must be higher than in the bladder.
Increased flow of urine will initially cause increased frequency of contractions of the renal pelvis with correspondingly increased

contractions distally (Weinberg 1967).
According to Kiil (1957) the normal renal pelvis and ureter can tolerate a flow of 8-10 ml./min. per ureter without increasing pelvic pressure. If the production of urine increases at such a rate to reach a pelvic pressure of 30 to 40 cm. $H_2O$, the contractions of the pelvis and proximal ureter will come to a halt (Bäcklund 1936). Risholm et al (1960) call this a pelvic dampening effect, whereby increased flow will distend the ureter and pelvis to a free column of urine, the pressure in the ureter then causing enough resistance to prevent radial forces from closing the ureteric lumen. The peristalsis at the lower end may finally be superseded by a continuous flow into the bladder. This is produced by a pressure within the whole upper tract which is sufficiently raised to constantly overcome the minimal resistance of the orifice.
The normal pelvi-ureteric junction is inconspicuous and ill-defined as there is a gradual tapering between the renal pelvis and the upper ureter. It is this gradual tapering which makes it so effective as an emptying system (Fig. 4.2.).
The question arises as to whether there is an innate frequency of peristalsis to form and propel a bolus or ureteric activity initiated by a stimulus, produced by the rate of renal excretion. Actually both, an innate peristalsis, enhanced by a neuromuscular response to dilatation, probably coexist (Glassberg 1977). Bäcklund (1963) demonstrated that there is electrical conduction between the muscle cells and that an electrical wave can progress down the ureter. But for this to occur something, somewhere, needs to initiate or at least to alter the conduction. Peristaltic muscular activity within the urinary transport system may be initiated when the volume of excreted urine stretches the cells in the wall of the collecting system.
The majority of contractions appear to arise somewhere in the vicinity of the pelvi-ureteric junction, but specialised pacemaker cells cannot be identified by histological or physiological studies. Whether a contraction is due to a pacemaker or a local area of distension by the production of urine is immaterial to the present discussion. In fact, it appears that peristaltic activity may begin in any portion of the collecting system, depending

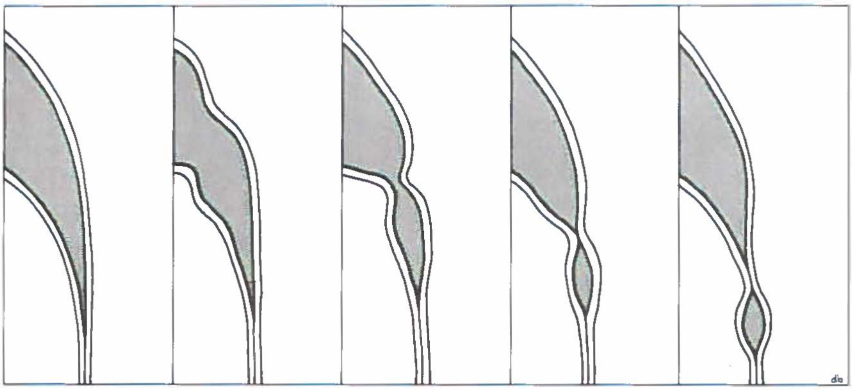


Fig. 4.2. Sequency of peristalsis at the normal pelvi-ureteric junction.

upon the point at which the stimulus is applied and whether the local factors are receptive to the stimulus. Cinefluorographic observations have demonstrated repeatedly in the same patient a wandering site from which peristaltic waves progress downward through the remainder of the transport system. On more than one occasion we and other investigators observed these peristaltic waves starting in the calyx or infundibular area only to shift to another location (Culp 1972). However, in most instances the site of origin seems to be the region of the renal pelvis.
At least some of these contractions reach the PUJ and pass down to the upper end. In the lower part of the funneled renal pelvis there is a point at which the downward moving contractions are able to close the lumen to form a bolus.
Peristaltic activity then carries the bolus on downwards. Once the bolus is formed, the pressure within it can exceed the pressure within the renal pelvis (Kiil 1957), but is dependent on the resistance below the bolus. The pressure in the pelvis can thus remain low and the kidney is protected (Whitaker 1975).
The mechanism or progression of the peristaltic waves has been, and remains, a point of controversy between those who believe in the myogenic and those who favour the neurogenic theory of ureteric peristalsis. However, more recent studies of ureteric function seem to indicate that mechanical, electrical and pharma-

cological stimuli all affect the rate and amplitude of peristaltic activity.

Lapides (1948) came to the following conclusions:

- tonus and rhythmic contractions of the intact human ureter are entirely independent of the central nervous system including the autonomic nervous system and all its ganglia.
- the normal stimulus for the initiation and maintenance of ureteric peristalsis is a stretching of the smooth muscle fibres of the ureter by the urine excreted by the kidney.
- peristaltic activity of the ureter can be altered by changes in urine volume output, within certain limits.

Boyarsky (1968) wrote:

- electrical, mechanical and pharmacological stimulation of the renal nerves in the renal pedicle or posterior to the calyces can slow down or speed up ureteric peristalsis.
- the myogenic and neurogenic theories of ureteric peristalsis may both be true in part.

In this way we consider the process as a neuromuscular activity, taking into account that combined mechanical, electrical and viscoelastic activities and forces are present.

Conclusions:

The normal pelvi-ureteric junction is funnel shaped which enables the peristaltic activity, somewhere in the course of the funnel, to close the lumen; in this way a change is taking place from a mixing activity to a real propulsive activity of a preformed bolus.

The site of origin of the peristaltic waves is the calyx or infundibular area of the renal pelvis.

The frequency of the peristaltic waves depends on the urine volume produced by the kidney.

# 4.2. Pathophysiology

Obstruction, occurring in the upper urinary tract, implies that the usual flow is reduced or only maintained at the cost of a higher than normal pressure within the renal pelvis, which will act as a back pressure on the renal parenchyma. If there is obstruction in the transport of urine to the bladder it results in more activity and leads to hypertrophy of the conducting structures. Later on when the hypertrophied muscles are no longer able to overcome the antagonistic force, atony, muscular atrophy, dilatation and parenchymal destruction follow.
Muscular hypertrophy is marked above the obstruction, which is usually partial. Hypertrophy begins distally in the region of the urinary tract just above the obstruction, and it is also here that decompensation first occurs. For this reason, isolated changes can be observed in the terminal part of the ureter if the obstruction is located at the uretero-vesical junction. With continued muscular activity, dilatation results even when the increased contractile force of ureteric peristalsis cannot overcome the obstruction. Since the ureteric muscle is arranged as a helix, its lengthening will enlarge the ureter not only circumferentially but also longitudinally, resulting in the typical tortuosity seen on roentgenograms.
Dilatation and parenchymal destruction follow muscular decompensation, since the hyperactive peristalsis and muscular hypertrophy of the second stage no longer empty the calyces, pelvis and ureter sufficiently and do not keep in balance with the volume produced by the kidney parenchyma. This is the most demaging stage in the process of hydronephrosis. Dilatation and higher pressure cause parenchymal destruction by stretching the conducting structures, interfering with the circulation of blood and compressing the cells of the tubules (Hinman 1935). The mechanical pressure of the enlarging renal pelvis gives rise to atrophy of

the renal parenchyma ("backpressure atrophy"). This could result from ischemic atrophy caused by impairment of renal bloodflow, compression of the interlobar and arcuate arteries and direct parenchymal damage due to the pressure. The severity of renal damage not only depends upon the degree but also on the duration of the obstruction.

The term obstructive uropathy has been accepted as a convenient expression for the abnormalities of renal function associated with obstruction; however, it must be admitted that when the emphasis is laid on changes in the nephron rather than in the urinary tract the term obstructive nephropathy is a more precise one. In general, the urologist tends to think of obstruction in terms of pathophysiology, urodynamics and operative technique, whereas the nephrologist's special interest is directed to the abnormalities in renal function, especially salt and water excretion. The change in urodynamics, however, is the base of it and the term obstructive uropathy is the more comprising one, obstructive nephropathy only indicating what happens in the parenchyma of the kidneys.

A continuing production of urine is essential for the production of hydronephrosis. One could speculate that in the earliest stage of hydronephrosis due to a partial pelvi-ureteric obstruction, the intrapelvic pressure might be elevated. It is known that a temporary occlusion of the ureter leads to an immediate intraureteric pressure rise. Depending upon the degree of pressure increase, the smooth muscle must give way to accommodate a greater volume of urine than normal, and the presence or absence of an intra- or extrarenal pelvis could be a factor influencing the degree of renal parenchymal damage. Any smooth muscle fibre that is continuously overstretched gives way and loses its contractile ability, and it could be that the end stage of hydronephrosis would then show lowered pressures.

The other possibility is that in longstanding hydronephrosis the kidney eventually produces less urine so the dilatation may decrease and a new balance is set between the volume produced and the capacity of the pelvi-ureteric junction.

Atony of the pelvis and ureter increases throughout the course of progressive hydronephrosis; this is reflected in their dilatation and capacity for increasing volumes of fluid. At first an easier distension upon overhydration or reflux with lower pressures will occur. As imbalance continues, as in longstanding partial but high grade obstruction, large quantities of urine may accumulate, resulting in complete atony and muscular atrophy of the pelvic and ureteric walls and disturbance of renal function. As renal impairment progresses there is a tendency for the kidneys to produce a greater volume of more dilute urine. This higher flow rate in the presence of a fixed degree of obstruction will in itself demand a higher pressure to overcome the obstruction. Vascular derangement develops from elongation and compression of the vessels during pelvic dilatation; the blood supply to the cortex gradually decreases. The renal function is proportional to renal arterial blood flow. The diameter of the renal artery after complete ureteric occlusion diminishes in proportion to the overall decrease in renal function. Removal of the obstruction allows partial return of function, and the arterial diameter increases proportionally. The longer the obstruction persists, the less the percentage of return of renal function. After 30 days, only minimal function returns in dogs; in humans, however, instances of recovery of function after much longer periods of obstruction have been reported. Basically, the longer and the more severe the obstruction, the greater the irreversibility of the damage will be.

The interplay between urine formation and resorption-excretion is illustrated better by partial obstruction than by complete obstruction. In partial obstruction, instead of resorption assuming the entire task of correcting urine imbalance, excretion takes over part or most of that function. The pathological changes are the same, however. Because the balance is delicate and a lower pressure is maintained (which delays renal atrophy), hydronephrosis may be more advanced. In cases of partial obstruction, intrapelvic pressure measured in the human hydronephrotic kidney usually approaches normal levels because an equilibrium is established between urine formation and urine transmission down the ureter. Atrophy will result from recurrent episodes of increased urine formation during diuresis or from transient increases in the degree of obstruction as a result of minor trauma, oedema, or change in position. Statements vary as to the effect of urete-

ric obstruction on the kidney. The best evidence is that with sudden complete obstruction resulting in closed hydronephrosis, the kidney may undergo atrophy with decrease in size. Such atrophy may follow not only complete obstruction, but also partial and intermittent hydronephrosis.
In trying to compare what happens in other organs in case of obstruction, we can see that the frequency with which the pancreas and salivary glands shrink after obstruction of their main ducts indicates a response of these organs strikingly different from that of the kidney. In the case of all three organs, the abrupt cessation of secretion or glomerular filtration after obstruction would seem to be the simplest and most reasonable explanation for primary atrophy. However, the development of atrophy of the kidney gives a quite different picture in both humans and animals, because the kidney in most instances enlarges with hydronephrosis after ureteric obstruction.

### 4.2.1. Backflow.

In the case of obstructive uropathy great importance has been given to the unique role of backflow. Since glomerular filtration is a mechanical process depdendent on purely physical factors and since tubular secretion also can continue during complete obstruction, there must be either auxiliary routes for external excretion of the urine or resorption of it along the excretory pathway. Otherwise, the pressure within the conducting structures would rapidly rise until glomerular filtration and tubular secretion were completely stopped; the result would be primary atrophy rather than progressive dilatation of hydronephrosis. The urine may escape by way of the fornices into the venous system (pyelovenous backflow), through the tubules (pyelo-tubular backflow), by way of the lymphatics (pyelo-lymphatic backflow) and sinus efflux into the peripelvic and perirenal tissues.
The role of the renal lymphatics in obstruction was investigated in dogs by Naber (1973). From the composition of the renal lymph, it could be demonstrated that the hilar, but not the subcapsular lymph is draining the occluded pelvis. However, pyelovenous backflow was found to be more effective than pyelolymphatic backflow since only approximately 0.3 per cent of the hilar lymph

represented reabsorbed urine.

The balance between renal excretion and backflow must be delicate, as is shown by the finding of a normal or only slightly elevated intrapelvic pressure in chronic partial obstruction. Underwood (1937), Kiil (1957) and Melick (1961) agreed that in established pelvi-ureteric obstruction the intrapelvic pressure was normal. An increase in excretion will raise the intrapelvic pressure, which in turn will increase the rate of backflow and perhaps slow down the excretion and so reestablish a balance.

For pelvic pressure recordings and infusion, most earlier investigators have used a catheter passed through the pelvi-ureteric junction from below. These catheters no doubt disturb the outflow through the PU-junction. This was circumvented by the study of Bäcklund et al (1965). With different perfusion rates by way of a needle in the renal pelvis, he tried to mimic a diuresis within physiological limits. In his study, he found a threshold value of interest i.e. the maximum flow not inducing an increase in intrapelvic pressure during prolonged perfusion. According to Kiil (1957) the normal renal pelvis and ureter can tolerate a flow of 8-10 ml/min. per ureter without increasing pelvic pressure. He gave data on 4 patients with hydronephrosis due to pelvi-ureteric junction obstruction and of one patient with pyelonephritis and a normal pelvi-ureteric junction.

If only a nephrogram is evident on intravenous urography during acute obstruction, it may be assumed that little or no backflow is occurring. If contrast dye appears in the pelvis, however, backflow must be taking place. Further proof of the presence of backflow is manifest if the dye is excreted on the non-obstructed side, many hours after the initial injection; evidently the dye is being picked up in the blood and lymphatics on the obstructed side and then excreted by the normal kidney (Hinman).

Pyelovenous backflow is quantitatively the most important route for resorption in acute hydronephrosis. The fornix of the minor calyx is the site of breakthrough into the venous plexus surrounding the base of the calyx. Tubular backflow is often seen after overfilling during retrograde pyelography. The typical tuft formation is not uncommon, especially if the kidney is infected. Pyelolymphatic backflow is seen on both retrograde and intravenous

urography as wavy lines coursing from the hilum toward the midline.
The rate of hydronephrotic atrophy is greater in higher obstruction than in lower, more distal ones, this may be due to the buffer effect of ureteric peristalsis, which maintains a more even intrapelvic pressure, or it may be due to increased backflow via the ureteric lymphatics.
Pyelo-interstitial backflow is a more extreme form of backflow; it is seen in intravenous urography only in cases of acute obstruction or severe abdominal compression. Hinman saw 5 patients, most of whom had ureteric obstruction due to calculi, with peripelvic extravasation on intravenous urography. Studies of infection in animals showed the leak starting in the rim of the fornix and then passing between the caliceal and the pelvic walls and the renal parenchyma to the peripelvic tissues.

4.2.2. Infection of the pelvi-caliceal system.
Hydronephrosis results from back pressure on the kidney, while pyelo-nephritis results from infection which is perpetuated in the upper urinary tract because of stasis. The urinary tract is unable to get rid of bacteria by washout with urine. Although back pressure and stasis are both consequences of obstructive lesions, they are different pathological processes. Their evolution and damaging effects can best be assessed separately, since prophylaxis and urological treatment for hydronephrotic atrophy may be quite different from that for chronic upper urinary tract infection.
Stasis means incomplete exchange of urine. Since bacteria double in number approximately every half hour, the movement of new urine into and of all old urine out of a conduit must be complete in half an hour if the number of bacteria is to diminish. Incomplete exchange can result from one of the following two factors:
1. a volume in the conduit exceeding the half hour rate of urine production and
2. incomplete mixing of new and old urine, so that urine in certain areas of the conduit remains longer than the period required for bacterial doubling.
ad.1. The normal pelvi-caliceal complex holds an average of 6 ml.

(2 to 12 ml.) of urine. With a total urinary output of 1,200 ml/day an average ratio between volume present and flow rate is 1:2.
A better ratio for washout is seen during periods of diuresis. Stasis is present when obstruction increases the volume in the conduit and when the ratio falls to less then 1:1.
ad.2. Urine passes through the calyces and pelvis at a rate that permits laminar, rather than turbulent, flow; this means that the urine in the center of the stream flows at a normal or higher rate while the rate decreases progressively to reach zero at the wall itself. As a result, bacteria in urine adjacent to the wall have ample time to multiply even though there is good total volume exchange. Observations of the pelvicaliceal musculature and mobility lead to the conclusions that generally the caliceal and pelvic activity is not purely peristaltic, that is, movement of urine occurs in both antegrade and retrograde directions. The mixed antegrade and retrograde activity of the renal pelvis, moves the urine in and out of the calyx. Hinman concludes that the role of caliceal (and pelvic) activity is to mix the urine to ensure a total washout. In hydronephrosis with pelvic and caliceal dilatation, effective mixing ceases and, since the basic exchange rate between new urine and resident pelvic urine is already marginal because of the increased pelvic volume, bacteria are not eliminated. Hence, if infection is initiated, it is maintained. Caliceal diverticula are prime examples of interference with mixing plus imbalance in urinary exchange.
Recent experimental evidence shows and confirms the clinical evidence that certain bacteria immediately and directly affect ureteric peristalsis. Clinically, roentgenograms confirm these changes in contractility, By decreasing pelvic contractility, endotoxins increase the transit time of urine into the ureter and decrease mixing, permitting greater bacterial propagation with inefficient washout.
Stones promote infection not so much because they irritate the mucosa, but because they interfere with flow.
The reduction of urine formation that ultimately occurs in the later stages of hydronephrosis further favours growth of the bacteria. The distinction between infected hydronephrosis and frank pyonephrosis is poorly defined. Perhaps the only tenable

difference is that in pyonephrosis, renal function has virtually ceased, so that the pelvic contents are appreciable thicker than urine and increasing at the expense of parenchymal destruction. If the obstruction is relatively complete, pyonephrosis can be the end stage of infected hydronephrosis, for as function falls, bacteria and pus increase to fill eventually the closed sac. The formation of stones combined with stasis is common. In fact, a stone that is partially obstructive, grows at a faster rate than a stone that produces complete obstruction; the latter depresses renal function, and, hence, the supply of ions necessary for stone formation. Many small stones would pass spontaneously if obstruction were not present; a calculus itself, however, can be the primary cause of the obstruction.

4.2.3. Compensatory mechanism of the kidney.

Compensatory hypertrophy of a kidney develops after occlusion of the ureter of the opposite kidney and/or after contralateral nephrectomy. Donadio et al (1967) studied five donors of kidneys for renal allotransplantation who lent themselves well to the study of functional and anatomic renal hypertrophy as they were otherwise healthy individuals. Functional hypertrophy was evident at 6 to 11 days after nephrectomy. The GFR amounted ± 70% of the original kidney function. In animal experiments it has been shown that the hypertrophy of the tubular cells is greater in young animals than in the more mature ones. This could explain the better response of the kidney in the human infant than in the adult (Vaughan 1973) after release of the obstruction.
Renal counterbalance, proposed by Hinman in 1923, implies that a damaged kidney cannot compete with its normal mate and therefore atrophies. If this conclusion were true it would be useless to attempt any plastic procedure that would save a kidney damaged by obstruction long enough to cause the opposite kidney to take over the full or partial functional responsibility. These experiments were carefully repeated some years later by Joelson et al. The results published in 1929 were not in accord with the findings of Hinman. Joelson clearly demonstrated that a kidney completely obstructed for a period of 19 days could recover its function after the obstruction was removed, although the opposite kidney

had undergone compensatory hypertrophy. Regardless of these results Hinman contended that insufficient time was allowed in Joelson's experiments for compensatory hypertrophy to become complete in the opposite kidney. He draws a rather sharp distinction between full anatomical hypertrophy of the kidney and the full reserve functional output.

Regardless of these rather divergent views on the repair of damaged kidneys one knows from practical experience that a kidney partially obstructed for long periods of time increases its functional output after the obstruction has been removed regardless of the changes which have taken place in the opposite kidney.

Schulhof (1937) came also to the conclusion that Hinman's theory was not supported by the clinical evidence. On the basis of tests applied by him, kidneys were found to be functionless, but following surgical drainage,there was a return of function.

Experiments with dogs, performed by Vaughan (1971, 1973) also emphasized the ability of the damaged kidney to recover in the presence of a healthy contralateral kidney, thus failing to fulfill the prophecy of Hinman.

Shapiro (1976) described three patients with apparently complete unilateral ureteric obstruction of at least 28,28 and 150 days. The contralateral kidney was normal. Urography and renal scanning were used to document the presence or absence of renal function. After corrective surgery there was good recovery of function in all cases. He concluded that the decision to relieve obstruction in an attempt to save a kidney should not be made on the basis of a poor renal scan or urogram.

4.2.4. Postoperative renal function.

The results of both clinical and experimental studies have defined several patterns of abnormal renal function due to obstruction alone (Chisholm 1970). There is also evidence that these abnormalities occur in all patients both during and after the relief of obstruction, though they may be complicated either by infection or by osmotic diuresis. The fact that a disturbance of nephron function is not always clinically obvious is due to several factors. Most of the abnormalities are transient and disappear after the relief of an obstruction within a short time. In addition, difference in glomerular filtration after unilateral obstruction will not be detectable without differential bilateral clearance studies because otherwise abnormal losses will be obscured if only total filtration rates are measured.

Remarkable post-obstruction polyuria has been recorded on several occasions and may be so severe as to threaten life. Since these abnormalities occur in urological patients the urologist must not only recognize their potential hazard but also be sufficiently familiar with the pathophysiology to correct the losses. It is essential that blood chemistry and electrolyte losses are measured in the laboratory. Clinical signs, carefully kept fluid balance charts and regular measurement of the blood pressure are sufficient to signal the onset of hypovolaemia in a majority of patients.

The urgency to relieve an asymptomatic obstruction, such as an "idiopathic" (pelvi-ureteric) hydronephrosis, is often debated. Provided that the obstruction is both asymptomatic and non-progressive, a case for conservatism can be made. This however, overlooks the fact that any rise in intrarenal pressure with a change in diuresis is a potential cause of damage. Thus a better case can be made for a functional assessment of equivocal pelvi-ureteric obstruction (Whitaker 1975).

The prognosis of a kidney with obstructive uropathy is often unpredictable. It is not only difficult to measure the extent of renal damage on clinical presentation, prior to the release of the obstruction, although kidney scanning and renography are helpful, but it usually remains unknown until after treatment. Thus the clinician must be alert to the existence of obstruction in unexplained uraemia and familiar with the syndromes of abnormal function associated with obstruction.

### 4.2.5. Hypertension.

Experimental and clinical experiences have shown that unilateral and bilateral hydronephrosis may be associated with hypertension. The increased pressure in the renal pelvis and calyces may lead to ischaemia caused by compression of the renal parenchyma. This can be the cause of increased plasma renin activity. It is very useful to be informed about the possible cause of hypertension in PUJO before the operation. If by selective renal vein cathete-

risation a lateralisation of the abnormal renin activity values is found, the patient may become normotensive after nephrectomy or pyeloplasty.
Several papers about this subject have been publishes. Vaughan et al (1974) found normal or low peripheral plasma renin activity (PRA) in 12 patients with unilateral PUJO and hypertension. It is possible that they found these data because the patients were not sodium depleted before the PRA was measured. However, Chapmen and Douglas (1975) presented two patients (out of 3) with PUJO and increased PRA preoperatively. Nephrectomy cured the hypertension in these patients. Chapman and Douglas also reported two children who became normotensive after pyeloplasty. Davis (1973) described a 5-year old boy with hypertension and hydronephrosis due to PUJO in a solitary kidney. After pyeloplasty the PRA returned to normal, his renal function improved considerably and he became normotensive.

4.2.6. Conclusion.

A pelvi-ureteric junction obstruction with a rise in pressure leads to hypertrophy of the renal pelvis wall and later to decompensation with atony, dilatation and parenchymal destruction. The latter is due to ischemic atrophy from impairment of renal bloodflow by compression of the arteries.
Initially, renal impairment is especially caused by tubular dysfunction, which leads to polyuria.
The kidney could "escape" the rise in pressure by the various types of backflow.
Hypertension associated with hydronephrosis is renindependent in some cases.

# 5. Aetiology

When the diagnosis hydronephrosis due to PUJO in a patient has been established, the following "causes" have been considered although they only describe what was found at operation, while the real cause was still obscure.

5.1. "Extrinsic causes".

5.1.1. accessory vessels to the lower pole of the kidney

5.1.2. fibrous bands crossing the junction

5.1.3. a peripelvic fascial sheath binding the ureter to the pelvic wall with or without accessory vessels

5.1.4. kinking of the ureter

5.1.5. nephroptosis

5.2. "Intrinsic causes".

5.2.1. congenital and acquired stenoses

5.2.2. congenital mucosal valves

5.2.3. high insertion of the ureter

5.2.4. neuromuscular dysfunction

5.2.5. intussusception

5.2.6. non-specific granuloma

5.2.7. inflammatory polyps

Other diseases causing obstruction at the pelvi-ureteric junction (or more distally), together with secondary hydronephrosis due to urodynamic changes have also to be excluded.

## 5.1. EXTRINSIC CAUSES OF PELVI-URETERIC JUNCTION OBSTRUCTION.

### 5.1.1. Accessory vessels.

There are many conflicting reports in the literature regarding the role of aberrant vessels in the development of PUJO. Whether the aberrant vessel is a primary cause or a secondary enhancing factor of hydronephrosis is debatable, but it is the consensus of many observers that aberrant vessels are an important contributing factor in the development of PUJO.

Boogaard (1857) attributed hydronephrosis to compression of the junction by accessory vessels to the lower pole of the kidney. Duval and Grégoire (1906) thought that the pounding of an artery on the junction might interfere with peristalsis, but they suspected a lesion of the ureteric wall to be the basic cause of obstruction.

It was thought too, by some workers, that a constant pulsation of the vessel against the ureter might transform the normal ureteric musculature into fibrous tissue, resulting in an intrinsic as well as an extrinsic obstruction.

Winsbury White (1925) wrote: "Among the numerous references in the literature to hydronephrosis there are very many in which the aberrant vessel is cited as the cause. In the large majority of operated cases there is no detailed account of the actual origin of the vessels or of the points at which they leave the kidneys. In noting this lack of detail one has to bear in mind how difficult it is during an operation on a distended kidney to be sure of the origin of certain vessels. No doubt this difficulty has often led to the erroneous conclusion, that a normal vessel is an abnormal one. Küster, Israel, Bazy, Duval and other able observers all reject the abnormal-vessel-theory. In a number of reported cases there is an illustration of the diseased kidney. In each one, the same relationship between pelvis, ureter and bloodvessels existed.However, although in many instances the vessel is described as abnormal, it is obviously a normal one!"

The arteries may pass anterior (66%) or posterior (33%) to the junction (Ekehorn, 1907).

Jewett (1940) believed that polar vessels were the sole cause of obstruction in 24 of his series of 71 patients with PUJO. Adams

(1951), Bibus (1958), Quinby (1937) and others claimed that such vessels, by compression of the ureter, may be primarily responsible for hydronephrosis. Soley (1946) reported 19 cases of PUJO in children under 14 years of age with 24 ureters involved. In his series, aberrant vessels were found to be the cause in 7 of these cases. Henline (1935) reported a series of 66 cases of PUJO in 29 of which the cause was proven to be an aberrant vessel. After a careful and exhaustive study, Jewett (1940) demonstrated that there is no absolute PUJ. Instead the pelvis blends into the ureter as a funnel. Where a definite PUJ exists, obstruction should be considered, particularly where there is pyelectasis.
Applying this observation to the finding of compression of the upper ureter by an aberrant vessel, it must be realized that one is speaking in terms of an arbitrary PUJ, which exists by virtue of the obstruction.
Aaron (1948) presented two brothers with PUJ which he thought were definitely caused by aberrant lower pole vessels.
On the other hand, the facts that the accessory vessels to the lower pole are frequently encountered (see anatomy, chapter 2) in the absence of obstruction (Brosig 1948, Dodson 1956) and that hydronephrosis is also observed in adult life, indicate that a combination of factors may be involved and the majority of urologists agrees that aberrant vessels act as a secondary obstructing factor to an already enlarged pelvis. A vicious cycle is thus established and the greater the hydronephrosis the more pronounced the obstruction becomes.
Van Sambeek (1973) theorized that with progression of the PUJO the pelvis dilates in the direction that offers least resistance. The pelvis is surrounded on the mediodorsal side by the psoas muscle, on the lateral and cranial side by the kidney parenchyma and on the dorsal side by the quadratus lumborum muscle and the 12th rib, so the pelvis can only bulge in the ventral or caudal direction. On the ventral side it can herniate between the main artery and the artery to the lower pole. When the bulging progresses the PUJ may be pulled over the accessory vessel (Fig. 5.1.)
Anderson (1962) was disturbed by the fact that when the kidneys were divided into cases with an intrarenal and with an extrarenal pelvis, accessory vessels were chosen as the causal factor

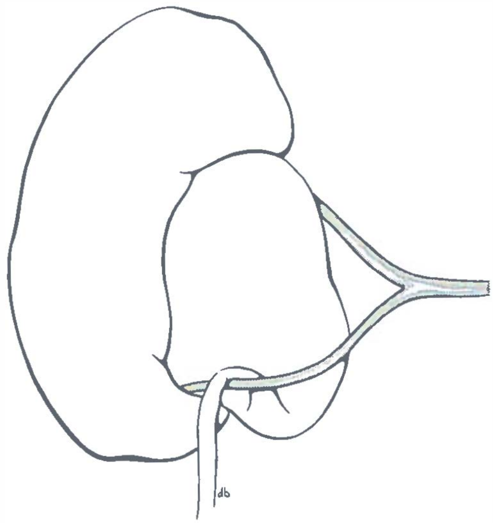


Fig. 5.1. Accessory vessel.

in an undue number of extrarenal hydronephroses, and that when accessory vessels were present but not regarded as causal, most of the cases had intrarenal pelves. He wrote: "This leads me to think that I have attached too much importance to vessels as the immediate causative factor, although I firmly believe that they are a serious aggravating factor in extrarenal cases, where the dilated pelvis herniates between leashes of vessels. The embarrassment caused by such vessels is sufficient to convert a mild case into one that requires surgical intervention to save the kidney. I maintain that accessory vessels are the primary causative factor in some cases. My reasons for this are: 1. Hydronephrosis occurs in cases of retrocaval ureter, 2. At operation, in a case that is obviously functional, when the ureter is freed, the pelvis seldom propels its contents down the ureter with each contraction; in other words, a ureteric contraction does not follow each pelvic contraction, and when the ureter is cut across, pelvic contractions do not expel a spurt of urine from the stump. In such cases there is often a persistent constriction of the ureter, presumably due to spasm, because there is no demonstrable organic stricture. In contrast to this, when vessels appear to be the cause, the segment of ureter above the vessels is dilated, it contracts in sympathy with the renal pelvis and the contraction stops at the vessels. When the ureter is freed from the vessels, the contractions are propagated down the ureter, and when the ureter is cut across a spurt of urine accompanies each pelvic contraction, 3. The undoubted success of Hamilton Stewarts operation (Stewart 1947) must to some extent depend on vessels being the cause".

Maluf (1956) concluded that it is shown that the calyco-pelvi-ureteric system of a completely normal urinary tract will undergo dilatation during forced diuresis. He postulated that dilatation of an extrarenal pelvis may lead to its herniation within a wide extrahilar bifurcation of the main stem artery and/or vein and thus result in acquired obstruction of the pelvis.

5.1.2. Fibrous bands crossing the junction.

5.1.3. A peripelvic fascial sheath binding the ureter to the pelvic wall with or without accessory vessels.

5.1.4. Kinking of the ureter.

Nixon published his series of 78 children with hydronephrosis in 1953. In 15 of the 19 cases, which were explored and where a conservative operation was performed, an anomaly of the pelvi-ureteric junction was described. In all 15 there was some extrinsic abnormality. In 10 this consisted of "adherence" of the ureter to the pelvis and in 5 there was kinking caused by "bands". These bands showed the same appearances as have been described in the cases associated with aberrant vessels and the successes following their division demonstrate the ability of the bands to obstruct urinary outflow even though the lumen is not intrinsically narrowed.

These adhesions have often been attributed to previous inflammation, causing peri-ureteritis. Evidence of such an inflammatory origin however is not convincing. They have a constant localisation, so that it is difficult to believe that they are caused by spread of a diffuse pelvic and peripelvic process. Also histological examination of the region has not supported an inflammatory origin (Oestling 1942). Bands are found as commonly in early and

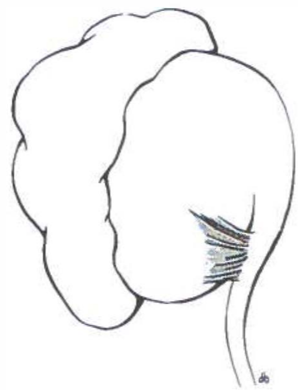


Fig. 5.2. Pelvi-ureteric adhesions.

uninfected cases as in late and infected ones. Oestling's (1942) study of foetal and older specimens supports the view that they are congenital in origin. They appear to arise in connection with the growth of the adventitial coat. Fig. 5.2. represents a typical adhesion from the lateral side of the upper end of the ureter to the pelvis. This is Oestling's "sail-shaped fold". When the pelvis expands during diuresis or due to other causes, the ureter is dragged up against the pelvis, kinking it. The dilatation resulting from this obstruction, and the consequent rotation of the pelvis forward over the psoas muscle, would then cause a secondary obstruction over any vessel that may be present.

O'Conor (1955) wrote in his paper: "In America we believe that most instances of dilatation in the urinary tract are the result of obstruction. We all recognize many instances of ureteric and renal pelvic dilatation that exist in the absence of evident obstruction, but the causal factor involved in these cases is often obscure and incomplete. The European pathologists of a previous generation summarily dismissed this discussion by explaining that these dilatations were the result of either "faulty innervation" or "congenital overgrowth of tissue". In fact, both Stoerk and his successor, Bauer of Vienna, called our description of obstructive lesions of the ureter and renal pelvis "the American disease".

This meant, of course, that they did not believe in what we term "mechanical" causes of obstructive uropathy. Actual proof of their own theories was never evident".

5.1.5. Nephroptosis.

Rayer (1941) regarded excessive mobility (nephroptosis) as a cause of hydronephrosis, but Ekehorn (1907) felt that it was only important if it stretched the junction over vessels or fascial bands. Jones (1909) cited the numerous failures of nephropexy to alleviate hydronephrosis as evidence that ptosis alone did not cause obstruction. Kelly and Burnam (1914) and Mathé (1928) shared Ekehorn's views. Winsbury White (1925) referred to Henri Morris who is reported as saying: "I am much disposed to think that in several cases in which hydronephrosis and movable kidney coexist, the mobility was acquired after and not before the hydronephrosis". And he continued: "The Dietl's crises, sometimes to be observed in cases of movable kidney, are no doubt due to renal retention, not from an obstructed outlet of the pelvis, but from a congested kidney resulting from a pyelitis consequent on chronic intestinal trouble so often present with general visceroptosis, of which the nephroptosis is a part. Many cases having long histories of crises, fail to show any indication of a dilated pelvis when submitted to operation".

Tuffier (1916), in describing the results of 45 nephropexies for attacks of pain, could find no evidence of dilatation in 36. Geraghty and Frontz (1918) quote the combined figures of seven authorities, based on a total of 4576 cases. These showed that a mobile kidney occurred in 20% of females and in 2% of males. The authors also referred to Kelly and Burnam's review of 245 cases. They found a mobile kidney on the right side in 177 cases, on the left side in 25, and bilaterally in 43. The writers point out that if a mobile kidney were the cause of hydronephrosis, we should find an overwhelming majority in women, with a right sided predominance, and the bilateral condition should be more common than the unilateral left sided. None of these facts could be substantiated by them, for although the disease was twice as common in women as in men, it occurred with equal frequency in either kidney, and bilateral disease was rare. Moreover, the mobile kid-

ney is a condition with a markedly increased incidence in the fourth decade, while it is during the first and second decade of life that most cases of hydronephrosis occur.
Quinby (1930) critisised the importance placed on ptosis. He pointed out that with the descent of an abnormally mobile kidney, it is not only the organ itself which moves but the bloodvessels move with it as a whole. In a typical case of mobile kidney, the mobility takes place on the vascular pedicle as a centrally fixed point and the peripheral ends of the vessels move with the organ itself. It is hard to see, how one portion can be assumed to move while another intrinsic structure remains behind. Mathé (1937) concluded that: "It is generally accepted that renal mobility alone does not cause hydronephrosis. However, when the kidney descends and the upper redundant portion of the ureter sags, hangs, or comes in contact with aberrant vessels, with fibrous bands or with its upper attachment to the perirenal fascia or to the posterior peritoneum, obstruction occurs resulting in hydronephrosis. There is no doubt that a mobile kidney in which the upper ureter has been obstructed, is a definite cause of moderate hydronephrosis. Repeatedly regression of the hydronephrotic sac was noted by making serial pyelograms on patients in whom the kidney was suspended. This fact proves that ptosis plays a role in obstruction because surgical suspension is followed by anatomical involution of the hydronephrotic sac".

## 5.2. INTRINSIC CAUSES OF PELVI-URETERIC JUNCTION OBSTRUCTION.

### 5.2.1. Congenital and acquired stenoses.

Wölfler (1877) described a congenital stenosis at the junction. Jewett (1940) found signs of inflammation in 16 of 33 such stenoses and consequently regarded only 17 as congenital and the others as acquired. Stenoses may be caused by a thickening of the musculature, the development of hyperplastic fibrous tissue and a fibrous contracture producing a small stoma (Deming 1943).

Geraghty and Frontz (1918) studied specimens from 9 patients with obstruction at the PUJ with respect to inflammatory changes. Their conclusion was that even in the absence of urinary tract infection the histological picture indicated a lesion of inflammatory nature.

Schreiber (1927) reported after a study of 100 cases that "ureteric stricture as a localized inflammatory process in the ureteric wall due to local infection does not occur or is relatively rare".

Oestling (1942), in a study of 250 foetuses and newborns in various stages of development, demonstrated that narrowing at the pelvi-ureteric junction developed at an early embryonic age and undoubtedly produced the subsequent malformations. He also stated that in the foetus, from the fourth to the fifth month of gestation, differences in the lumen of the ureter and its tortuosity seemed to be localized in the upper third of the ureter. On histological examination, there appeared to be folded muscle tissue in this region. He proposed that after birth the surrounding tissues grow more rapidly and this increased growth caused the ureter to straighten.

In 1970 Allen wrote an excellent paper about congenital ureteric strictures. He found that the muscular wall of the normal collecting system was not divided into distinct layers but existed as a single-layered, meshwork of smooth muscle, the individual fibers of which were oriented primarily in a longitudinal direction.

According to Allen the congenitally narrowed ureter does not deviate fundamentally, from this pattern but is altered instead in a qualitative way, that is its lumen tends to be reduced in caliber and there is often a relative and absolute decrease in muscle bulk. In addition, the obstruction may be aggravated by external compression from overlying vessels and by dilatation of the collecting system proximally with resultant kinking of the ureter and alteration in the direction by which the individual muscle fibers approach the stenosis itself. In the case of the pelvi-ureteric junction, this angulation may approach 90 degrees so that contraction of the pelvic musculature pulling at right angles to the junction might act much like a purse string to close the narrow opening even further. The practical effect of all these factors is to restrict the propulsive efficiency of the ureter at that point. These observations are consistent with the belief that the obstruction produced by congenital ureteric strictures is fundamentally mechanical in nature, and not the result of some vague and elusive neuromuscular or dyskinetic phenomenon.

Any explanatory neuromuscular concept would have to be tempered by the fact that ureteric peristalsis is a myogenic rather than a neurological phenomenon. The possibility that myogenic conduction might be impaired by an inadequate muscle-to-muscle contact within the diseased segment is worth considering.

Aetiologically, congenital ureteric stenoses appear to represent areas of localized developmental arrest. The proposal that the stenosis results from pressure upon the ureter by some external force is not without precedent.

Mehta (1967) postulated that the physiological narrowings described in the normal ureter might be the result of compression during muscularization. Allen (1970) was intrigued by the relationship which seems to exist between congenital ureteric stenosis and certain major branches of the foetal arterial tree. However, if one subscribes to the proposal that these congenital stenoses are the consequence of incomplete ureteric development resulting from compression by contiguous foetal vessels, one must also accept the amendment that persistance of the vessels is not an essential part of this concept since such vessels are not always demonstrable. One could assume, in the face of the rapidly changing events of intra-uterine life, that a vessel might cause a stricture, then vanish, leaving the stricture behind as the sole evidence of its former existence.

5.2.2. Mucosal valves have received only little attention. When a so called "high insertion" develops a valve is formed at the PUJ.

5.2.3. High insertion of the ureter into the renal pelvis has evoked considerable comment. Since the pelvis is merely an expansion of the ureter, the term "high insertion" is a misnomer but will be used because it is conventional. "Upward displacement" or "high location of the PUJ" would be more accurate. Englisch (1870) regarded it as secondary to pelvic dilatation. Simon (1871) thought it was the cause rather than the result of the hydronephrosis. Hellström (1934), von Lichtenberg (1929), Hryntschak (1925), Oestling (1942) and others shared his view.
High insertion is now considered as secondary to PUJO. Because of the obstruction the inferior pelvic wall, lateral to the PUJ bulges and displaces the latter upward.

5.2.4. Neuromuscular dysfunction means that the renal pelvis is dilated and the ureteric lumen is normal, without a detectable mechanical obstruction. It has been the subject of lengthy and often very vague speculations. One can divide these speculations into those of the neurogenic and of the myogenic protagonists. Underwood (1909) spoke of "lack of inhibition". He thought that there were inhibiting medullated nerve fibres in the arteries and in the muscles of the normal junction, but not in the abnormal one. This might be the same as the "spasm" mentioned by Pannet (1923). Rümpel (1922) opted for faulty innervation, and Blatt and Swenson (1952) suspected a lesion of ganglion cells. In the myogenic category Lequeu (1927 noted a disturbance of tone, and Bard (1936) a congenital weakness of the pelvic musculature.
In Roberts and Slade's (1964) series of 200 cases, there were many cases which showed no obvious reason for the obstruction. Although at operation a probe entered the pelvis easily from the ureter when this was divided immediately below the PUJ, the pelvis remained distended and required digital compression to produce emptying. Zwahlen (1970) called it muscular dysplasia. In Uson's series (1968) of 130 cases, there were also severe cases in which the pathological report read "advanced hydronephrotic atrophy", but the PUJ could be probed easily without meeting any

intrinsic obstruction.

The most satisfactory explanation for this group of cases is that given by Murnaghan (1958). He elaborated upon the theory of Schneider (1938) that there was a conducting defect, meaning a functional obstruction and not an anatomic obstruction. He came to the following conclusions:

- the movement pattern of the normal PUJ segment as seen on cine-pyelography, at the operation or during perfusion, suggests that co-ordinated contractions of the renal pelvis and upper ureter are associated with the uniform distribution of mixed muscle spirals at the PUJ.
- in congenital hydronephrosis pelvi-ureteric incoordination can be demonstrated at operation or during percutaneous perfusion by raising the intrapelvic pressure and may be associated with a predominance of longitudinal muscle fibres at the PUJ in place of the normal spirals.
- as the hydronephrosis progresses and the pelvis becomes more distended, the adhesions form a curtain and bind the upper ureter to the pelvis; this fixation combined with sagging of the lower part of the pelvis leads to upward migration of the renal pelvic outlets. This process caused by adhesions has usually been recognized as a secondary factor in the aggravation of the hydronephrosis rather than as the primary cause.
- when lower polar renal vessels are associated with congenital hydronephrosis the aetiology of the pelvic dilatation becomes more uncertain. The clinical response of many cases to simple dissection or division of the aberrant vessels indicates that such vessels may be directly responsible for the impaired drainage of the renal pelvis. However, vascular bundles cross 6% of PUJ's unassociated with the pelvic dilatation (Eisendrath 1942), and this "high" incidence in normal cases suggests that aberrant vessels should be considered as aggravating factors in cases of congenital hydronephrosis initiating from a definite intrinsic abnormality of the junction itself.

A predominance of longitudinal muscle at the PUJ has been found occasionally in cases of hydronephrosis which presented with anterior lower polar vessels. It is not intended to suggest that a muscular defect is the sole cause of congenital or idiopathic hydronephrosis. Other lesions at the PUJ are possible and have in fact, been demonstrated. Perfusion of such preparations has suggested that blocking of muscular contraction is probably the basic mechanism in the production of the dilatation of the renal pelvis. Can a pelvi-ureteric obstruction be explained by any structural deviation from the normal situation?

Data also from Bäcklund's (1965) small series suggest the existence of a "functional stenosis", because the easy passage of ureteric catheters failed to show an anatomical stenosis. No obvious anatomical stricture could be found at operation, and he concluded that the abnormal histology must in some way interfere with the function. An explanation could be that, when the urine enters the ureteric cone, an insufficient stretch reflex is elicited in the more circular oriented muscles and this results in an inadequate stimulus for the propulsion of urine by the ureter. The importance of mechanical stimulation to the ureter was pointed out by Bäcklund (1963) among others; he studied the conduction mechanism of the ureter in dogs. A certain minimum distension of the smooth muscle is necessary to promote peristalsis. The orientation of the muscle fibres may be of importance in this connection and it seems logical to assume that circular fibres become more distended and are therefore more easily excited than longitudinal muscles by increasing pressure in the ureteric cone. If the intraluminal pressure is not high enough to produce an adequate muscular distension in the abnormal region, which lacks an adequate circular layer, the urine may merely be forced through the abnormal segment without causing any peristalsis until it reaches a lower segment of the ureter.

Whitaker's (1975) theory is as follows:

The lack of consistent or gross findings in the obstructed pelvi-ureteric junction suggests that a search should be made elsewhere. One explanation is that the basic defect lies not at the junction but in the renal pelvis above. If the renal pelvis is abnormally distensible, it rapidly loses its funnel shape to become more like a bath with a plug-hole. This is the more usual configuration in the obstructed junction. The larger the pelvis, the greater is the probability of problems caused by polar vessels and a high ureteric insertion. A high diuresis or a slight compression by vessels

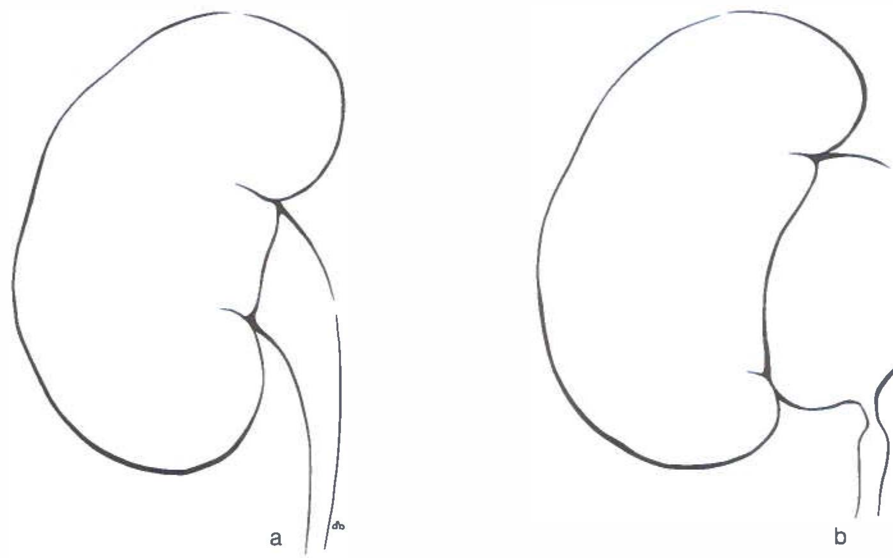



Fig. 5.3. A: Funnel shaped pelvis. B. Closed pelvis.

can convert the renal pelvis from A to B and this is seen in the intermittent type of hydronephrosis. (fig. 5.3.).
Perfusion studies at the time of operation can show the true contribution to the obstruction by the lower polar vessels (Whitaker 1973). The sequence of events during pelvic wall contractions in the abnormal renal pelvis, as described by Whitaker, is shown in Fig. 5.4.. A wave of contraction passes along the rounded pelvic wall. At no point before the orifice do the walls meet to occlude the lumen and no bolus is formed. Because of this there is no appropriate muscle action to pull open the orifice (cf. section on lower end of wide ureter). The combination of circular and longitudinal muscles have no bolus to grip on, and without a bolus their action is wasted, as it is only with a bolus formation that the orifice can be pulled open. To make matters worse the contraction of the circular muscles continues down to the point at which the ureteric walls finally do meet at the orifice itself. Their action at this point is to close the hole firmly and actively prevent any fluid passing through. The analogy with the lower ureter is obvious, but there is a greater tendency for selfperpetuation at the PUJ than elsewhere in the tract. As

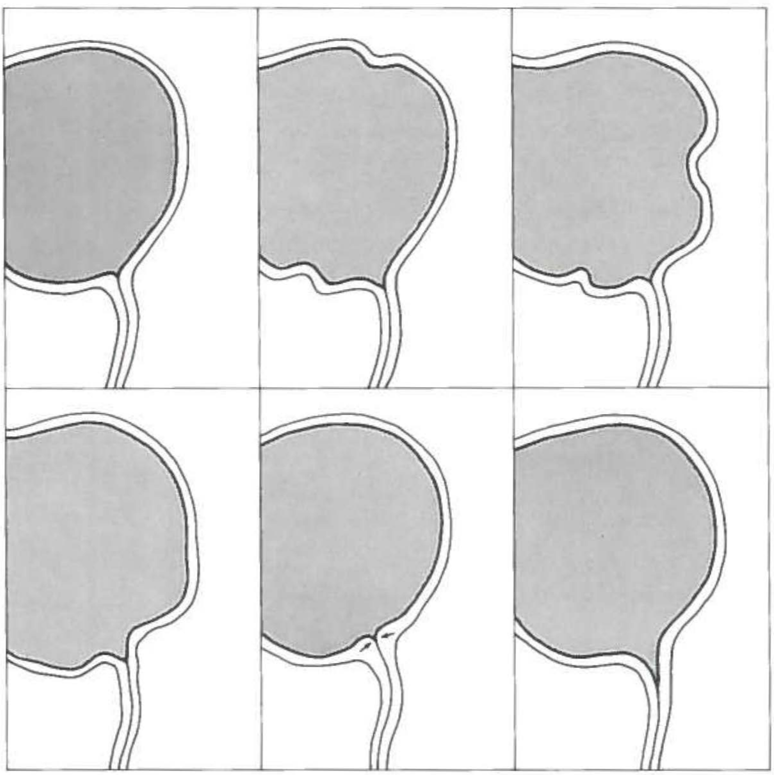


Fig. 5.4. Sequency of events in the closed type of renal pelvis.

the tension rises in the renal pelvis, its walls contract harder and the final squeeze of the circular muscle at the orifice is stronger. Thus the obstruction is due to an unopposed and inadvertent contraction of the circular muscle fibres at the PUJ. This contraction, however strong, can easily be overcome by passing a probe through the orifice at the time of pyeloplasty. There is a gush of fluid as the probe is withdrawn, but this rapidly stops

as the circular muscle contracts again.
How does this situation resolve itself? After the diuresis, which has precipitated the overdistension of the renal pelvis and distorsion of the PUJ has abated, the pressure within the renal pelvis slowly drops. Initially, whilst the pressure is high, the tension on the pelvic walls opens the weakest point, which is the orifice leading to the ureter and some fluid will passively drain out. This results in a reduction of pressure and cessation of drainage. Pyelovenous and pyelolymphatic backflow may also help to dissipate the pressure. Finally, at least in the "intermittent type" of PUJ-obstruction, the shape of the pelvis returns to its original form and drainage returns to "normal" until the next attack.
Recent work of Hanna (1976), Notley (1976) and Gosling (1979) has put new light on the "functional obstruction" theory. Electron microscopic studies of the pelvi-ureteric segment in patients with a hydronephrosis due to PUJO, have demonstrated a considerable increase in the amount of fibrous tissue in the ureteric wall. Not only were the muscle bundles widely separated by collagen fibres, but occasionally the lamina propria was as much as one millimetre thick. A corset of inelastic collagen would lead to an aperistaltic segment.

5.2.5. Intussusception has only been mentioned by Creevy (1976).

5.2.6. Creevy (1941) reported one case of non-specific granuloma in the mucosa of the junction in a patient with hydronephrosis.

5.2.7. Creevy also found two examples of inflammatory polyps at the PUJ.

5.2.8. Reflux and obstruction at the pelvi-ureteric junction.
Urologists and radiologists are aware of the tremendous variations in the size, shape and emptying capacities of normal renal pelves. Under physiological conditions, these variations are insignificant because all the different types of normal pelves can comfortably transport the volume of urine produced by the kidneys. We are so accustomed to think of the kidney as the sole source of urine in the ureter and of the concept that the flow of urine

is from above downward, that we have not considered the changes that may be produced by the upward surge of large volumes of urine. In complete reflux the renal calyces and pelvis limit the upward passage of the refluxing urine, and if this is associated with a reduced efficiency of the PUJ, dilatation of the calyces and pelvis occur.

It is a reasonable conclusion that repetition of this process could result in permanent dilatation of the renal pelvis (Hinman, 1965).

In 1962 Hutch and associates studied voiding films (ciné-fluoroscopy) and noted that some X-ray pictures of renal pelves overfilled by refluxed urine were identical to the X-ray pictures characteristic of primary obstruction of the pelvi-ureteric junction. They postulated that the combination of reflux occurring concomitantly or at some time in the past, with a "closed type" of renal pelvis could result in the permanent dilatation of the renal pelvis characteristic of obstruction at the pelvi-ureteric junction.

5.3. Conclusion.

The cause of pelvi-ureteric junction obstruction is still unknown. All extrinsic factors, like accessory vessels and fibrous bands, are thought to be secondary and may aggravate a developing hydronephrosis due to pelvi-ureteric obstruction.

"High insertion" of the ureter is also regarded as secondary to dilatation and bulging of the inferior pelvic wall which leads to an upward displacement of the pelvi-ureteric junction.

It is still unknown if "stenosis" at the pelvi-ureteric junction is a primary or secondary cause of hydronephrosis.

In recent years it has become clear that a functional obstruction at the pelvi-ureteric junction is the most probable cause. The peristaltic waves of the renal pelvis are interrupted due to local pathological changes. Electronmicroscopy revealed excessive collagen between the muscle cells of the obstructed PUJ and adjacent muscle cells in the area just proximal to the junction.

# 6. Symptomatology

## Clinical Picture.

Almost characteristic of this condition is that most patients begin to have trouble in the first and second decades, but it is also seen in children with less specific symptoms. The development of the process however, may be extremely slow and insidious. In Engels' (1951) series of 52 patients, 30% had symptoms for 10 or more years and 55% for at least 3 years before the diagnosis was made. Slade (1967) had 35 patients out of 200 who were completely asymptomatic, in 30 of them the anomaly being found at autopsy, after death due to other causes and during a routine examination. In most series the left side is affected more frequently than the right and the male-female ratio varies from 1:2 to 2:1. In cases of bilateral obstruction, the obstruction is usually more severe on one side than the other. In general the condition should always be regarded as potentially bilateral. In symptomatology pain, haematuria, a palpable mass in the renal area, gastro-intestinal manifestations, urinary tract infections, hypertension, polycythaemia and renal failure play a role. The symptoms in children are less specific.

## 6.1. Pain.

There are no specific symptoms in pelvi-ureteric obstruction. The most outstanding complaint is pain in the flank, which may vary from a dull ache to severe pain. More commonly there is a history of recurrent attacks of pain in the upper lumbar region. In acute obstruction there is a severe sharp colicky pain in the costovertebral angle and flank, sometimes radiating down along the course of the ureter. Pain caused by pelvi-ureteric obstruction may well be intermittent and can sometimes be produced by fluid loading. When a patient comes with a history of recurrent attacks of pain after taking more fluid than usual, the presence of a

pelvi-ureteric obstruction is probable.
The region of the non-affected kidney may also be the seat of some pain, which is usually due to engorgement of the normal kidney resulting in compensatory hypertrophy, although the possibility of a bilateral hydronephrosis must always be considered (Braasch 1909).
When the urine becomes infected, the pain usually becomes more severe, probably because the resultant inflammation increases the obstruction and/or causes swelling of the kidney with tension in the capsule. In the presence of infection, chills, fever, tenderness in the flank and symptoms of bladder irritation usually coexist.
The differential diagnosis of the patient with vague upper abdominal pain arising in the right upper quadrant includes the standard considerations such as appendicitis, cholecystitis and cholelithiasis, nephrolithiasis, ulcer disease, functional bowel distress, and prolapse of a vertebral disc. The pain also may be caused by nephrolithiasis secondary to pelvi-ureteric obstruction. David and Lavengood (1975) reviewed 106 patients with nephrolithiasis and in 16% pelvi-ureteric junction obstruction was demonstrated. They proposed the theory that too often the responsible pelvi-ureteric junction obstruction goes undetected when a "routine" pyelolithotomy or nephrolithotomy is performed.

### 6.2. Haematuria.

Haematuria is commonly seen and can be caused by a relatively minor injury, but it seems to be particularly associated with episodes of acute obstruction, causing sudden distension of the pelvis. Also calculi in the hydronephrotic kidney can be the cause of gross or microscopic haematuria.

### 6.3. Palpable tumor.

This finding is sometimes revealed on physical examination as a solitary symptom. It is a special feature in acute episodes after fluid loading, in combination with colicky pain in the lumbar region.

### 6.4. Gastrointestinal manifestations.

Reflex symptoms like nausea, vomiting and abdominal pain with flatulence and diarrhoea may occur and are occasionally the only symptoms present. Some patients had X-ray and other examinations performed and also abdominal operations without relief of symptoms, before the right diagnosis was made by intravenous urography with fluid loading. In many cases appendicectomy is done before the diagnosis of pelvi-ureteric junction obstruction is made. When urinalysis is normal, in patients with abdominal distress, attention is directed from the urinary tract and the diagnosis may be long delayed.

### 6.5. Urinary tract infection.

Urinary tract infection may sometimes lead to the discovery of a pelvi-ureteric junction obstruction. It may present as an urosepsis caused by pyelonephritis. In female patients with symptoms of lower urinary tract infections, a routine IVU may reveal hydronephrosis due to a pelvi-ureteric obstruction. This may be sterile but can become infected if the cystitis causes temporary reflux into the hydronephrotic kidney.

### 6.6. Hypertension.

In some cases of pelvi-ureteric junction obstruction, hypertension is found. Belman (1968) and Schiff (1975) demonstrated, by renal vein catheterization, greatly increased activity of the renin-angiotensin system in the affected kidney. Corrective surgery or nephrectomy resulted in reversal of the hypertension in their patients. The mechanism by which ureteric obstruction is associated with renin release is not clearly defined; functional ischemia secondary to decreased renal bloodlfow (increased intracapsular pressure?) seems likely (Stamey 1963). It may well be that reversal of hypertension is only possible in the early stages of the disease. Although initiated through the renal-pressor system by hydronephrosis, hypertension may be perpetuated by other mechanisms. Neural or vascular factors may account for the failure of delayed surgery in lowering the blood pressure.

### 6.7. Polycythaemia.

Renal cell carcinoma and benign renal lesions e.g. solitary cysts, multiple cysts, polycystic disease and hydronephrosis may cause polycythaemia. This is a secondary polycythaemia in which the increased proliferation of the bone marrow is limited to the erythrocyte series. Narayana (1976) presented two patients with PUJO and polycythaemia which were cured following nephrectomy.

6.8. Renal failure.

If a patient has a solitary kidney or bilateral hydronephrosis due to pelvi-ureteric obstruction he or she may present with symptoms of renal failure.

6.9. Symptoms in children.

The most common mode of presentation in non-communicative children is the discovery of an abdominal mass on routine examination. Abdominal pain is the most important symptom and older children frequently complain of loin pain. A history suggestive of urinary infection, failure to thrive, nocturnal enuresis and spontaneous haematuria often after minor trauma may also be present. In Johnston's (1977) series of 219 children 74 had a history of fever or disturbances of micturation suggestive of urinary infection but only 39 (17%) had a significant bacterial count in a bladder urine specimen. In Kelalis' series (1971) symptoms suggesting urinary infection were conspicuously rare, being noted in only 6 of 109 patients. Half of these cases had concurrent vesico-ureteral reflux. A mass was discovered by the parents or a physician in 14 children, most of whom were young. Whereas most children presenting with masses were diagnosed and treated within 2 weeks, the duration of symptoms in the remaining children varied from 1 few months to 13 years. The average interval between the onset of symptoms and the discovery of the lesion was 2½ years. This length doubtless was due to the bizarre clinical pattern. In the series of children (56 boys, 32 girls) presented by Drake (1978), the presenting symptoms and signs were divided as follows: pain 51 patients, infection 32 patients, haematuria 11 patients, neonatal abdominal mass 2, asymptomatic (incidental finding) 9. In Eckstein's series (1971) of 24 children the condition was bilateral in 5 children. To give some perspective into the frequency of pelvi-ureteric obstruction he mentioned that in the same period from 1963 to 1969 he saw approximately twice as many cases of obstruction at the uretero-vesical junction and approximately three times as many cases of vesico-ureteric reflux requiring surgical treatment. Eckstein (1971) saw in his series of 24 patients 5 and Johnston in a series of 219 patients 34 associated anomalies such as uretero-vesical obstruction, myelomeningocele, vesico-ureteric reflux, undescended testis, hypospadius and contralateral renal lesions such as agenesis, dysplasia and horseshoe kidney. The association of hypospadius with upper urinary tract abnormalities is well  recognized, and there are urologists who are in favour of performing routinely an IVU to exclude upper urinary tract abnormalities in children with hypospadius. It is not exactly known how frequent abnormalities occur that need treatment or follow-up to prevent upper tract dangers in time.

# 7. Diagnostic Procedures

7.1.1. General aspects.

Since the introduction of excretory urography in about 1930, there has been widespread use of this important diagnostic procedure. With the high dose urography technique one can obtain a picture of the hydronephrotic kidney(s) in the majority of cases.
In many papers nowadays the term IVU (intravenous urogram) is used instead of IVP (intravenous pyelogram). The examination is one of the entire urinary tract, not just of the collecting system. The intravenous examination can produce an excellent nephrogram, thus opacifying renal substance, in addition to its ability to demonstrate the anatomy of the collecting and transport system. Strictly speaking, the term urogram per se indicates the roentgenographic delineation of the entire urinary tract with opaque contrast medium. The term urogram does not state whether the medium was introduced by the retrograde or by the intravenous method. Some writers have confused the terminology by employing the word urogram to mean roentgenograms made by the excretory method as contrasted to the word pyelogram, which they use to indicate a roentgenogram made by the retrograde injection of opaque medium. It is obvious that such terminology is inaccurate. It is better to use the term urogram to denote the roentgenogram that visualizes the urinary tract by means of opaque contrast medium, regardless of the method of its administration. If the descending or excretory method is used, one could speak of it as excretory or intravenous urography. If the retrograde method is employed, it is called retrograde pyelo-ureterography, retrograde uretero-pyelography or retrograde urography. Speaking of a pyelogram one usually means a roentgenogram that outlines with opaque contrast medium the calyces, renal pelvis and ureter. The term pyelogram in itself means only the delineation of the pelvis. Nevertheless, the term has become so widely used, that it probably will always be accepted

in the literature to mean a film which includes the calyces, the pelvis and ureter. It must necessarily be accompanied by the adjective retrograde or excretory (intravenous) to denote the method by which it was made. In this thesis we use the term IVU.

7.1.2. Preparation of the patient.

The techniques of examination and the opaque materials used have undergone frequent changes. However, certain fundamentals in preparing the patient and in making the urograms have been generally adopted and constitute a "routine procedure" in most hospitals. Certain variations are apparently due to preferences of individual examiners. In the preparation of patients, some advocate no purging and no enemas, whereas others prefer thorough purging and enemas, if necessary. In many clinics routine preparations call for restriction of food and fluids for a period of 12-18 hours prior to urographic study.
We prefer thorough purging without fluid restriction because the IVU should be made under "normal" circumstances and not when the patient is dehydrated.

7.1.3. Procedure.

The excretion of the urographic contrast medium is a physiological process which depends on the functional status of the kidneys. This fact led to a tendency to equate an early appearance of contrast medium and dense opacification of the renal pelvis with a good renal function. As urographic techniques have improved and as more accurate measures of renal function have become available to the clinician, it has become clear that ordinary urography is not a reliable test for either the presence or the severity of renal functional impairment. A gross reduction in renal function resulting from obstruction, renal vascular insufficiency, or severe parenchymal disease is accompanied by delayed appearance of contrast medium and poor opacification of the renal collecting system in most cases. Even in the severe cases of PUJO, however, only a qualitative and not a quantitative estimate of renal function is possible. In the presence of less advanced disease, the ordinary excretory urogram often fails to demonstrate either a delay in appearance or poor concentration of contrast medium and the presence of mild or moderately severe functional impairment may not be suspected. With the larger doses of contrast medium, now commonly used in excretory urography, even severely depressed renal function may be masked because of relatively dense opacification of the kidneys. In advanced cases of hydronephrosis, function may be so reduced, that in the routine series of excretory urograms the usual 20- and 45-minute films show no excretion of contrast medium. In such cases the use of reinjection or infusion type excretory urography plus films delayed over several hours may result in visualization sufficient for diagnosis. In occasional cases urograms made 24 hours after injection of contrast medium may finally visualize conditions sufficiently for a diagnosis.

One should in general not use any abdominal compression because it can have considerably influence on the urogram and in cases of hydronephrosis one wants to see the "true" picture (Zwahlen 1970). In cases of unilateral hydronephrosis the concentration of contrast medium depends on the remaining function of the hydronephrotic kidney and the function of the contralateral kidney. Contrast medium administered in a single injection or during a short infusion time is rapidly excreted by the normal contralateral kidney without maintaining the plasma level long enough to obtain sufficient urinary concentrations in the hydronephrotic kidney. This excretion by the normal kidney can be compensated for by continuous infusion urography for several hours with large doses of contrast medium. It can improve the diagnostic possibilities of excretory urography, especially in cases of unilateral obstruction, and can minimize the need for retrograde pyelography (Naber 1975).

All urologists are familiar with the diagnostic problems of longstanding and progressive hydronephrosis. There is however, a type of temporary hydronephrosis caused by intermittently recurrent obstruction at the pelvi-ureteric junction. Between attacks of obstruction the patient may be asymptomatic or have minimal symptoms and the IVU findings are usually those of an almost normal upper tract. Many investigators (Covington 1950, Nesbit 1956) have stressed that it is of the utmost importance to make an IVU during an attack of pain, or after diuresis is induced by the ingestion of a large amount of fluid or a diuretic. An IVU of the

same patient, performed following the "routine" fasting period of 14 hours, could very well show no abnormalities.
Whitfield (1979) concluded that standard intravenous urography was unreliable in the diagnosis of pelvi-ureteric junction obstruction. Frusemide intravenous urography (FIVU) is a more accurate screening test that will resolve the problem of whether pelvi-ureteric junction obstruction is present in 85% of cases. He advocated the adoption of the FIVU as the initial investigation of choice.

### 7.1.4. Radiological signs of obstruction.

The first radiological signs of obstructive back pressure occur in the calyces. To appraise early changes accurately, it is important that the variations in appearance of normal calyces are understood. The shape of a calyx depends on the contour of the renal papillae. A narrow pointed papilla presents a narrow deep conical calyx ; a large broad papilla presents a widely "cupped" calyx; other papillae may present a sessile, almost flat, contour. In general, however, the general configuration of the normal calyx is that of a "Y". Progressive papillary atrophy and flattening allow more contrast medium to collect at the base of the papilla, finally resulting in a definite "clubbing" of the calyx. As the process continues, the papilla no longer projects into the calyx, but it becomes flat, and, later, concave; also the walls of the calyx separate and become widened. In the majority of cases, this latter state represents essentially complete atrophy of the renal papilla. The process of atrophy is not limited to the renal papilla, rather it proceeds throughout the entire renal substance. Although the obstructed kidney may appear either enlarged, unchanged, or reduced in size, the end-result is nearly always some reduction in size and thinning of the renal cortex. It is usually possible to distinguish obstructive parenchymal atrophy from the atrophy due to inflammation (pyelonephritis), because the former tends to be more even and symmetrical while the latter tends to be local and spotty. When estimating the degree of renal atrophy, the basis of comparison is usually the "normal" contralateral kidney. This may provide a possible source of error, however, for instance, if one sided renal damage is of long standing and the kidney has a relatively poor function, compensatory hypertrophy of the "normal" contralateral kidney may have increased its size. Usually dilatation of the pelvis and calyces proceeds at a fairly uniform rate. In some cases, however, this progression is unequal, and it is not uncommon to see substantial degrees of pyelectasis with normal calyces or significant calyectasis with little or no pyelectasis. When the medial side of the renal pelvis lies flat against the psoas muscle, one speaks of the symptom of Hutter.

It has been thought that obstruction near the renal pelvis predisposes to dilatation of the pelvis whereas more distal obstruction produces more dilatation of the calyces rather than of the pelvis. The value of this observation is open to question. It is also apparent, that an extrarenal type of pelvis dilates more easily than the intrarenal variety, which is supported and contained within a more rigid and confined space.

Innes Williams (1976) found in his series of 190 children with PUJO no definite relationship between the size of the renal pelvis and the degree of dilatation of the calyces.

Megacalicosis is not an uncommon finding on urography in children. In this condition the minor calyces show various grades of dilatation but the pelvis is undilated and cones normally into a normal ureter. Although urinary stasis in the megacalyces may be apparent on urography and isotope renography, there is no demonstrable urinary obstruction and the pelvis is seen at fluoroscopy to empty freely into the ureter. The pathogenesis of megacalicosis is uncertain but it has generally been considered to be caused by a congenital underdevelopment of the renal pyramids. However, the radiological appearance strongly suggests that the disease is the result of a transient obstructive lesion, which, having produced its effects on the renal parenchyma, has subsequently corrected itself spontaneously. Johnston (1973) supported this concept by a case in which a typical example of megacalicosis in one kidney was associated with a contralateral hydronephrosis of unquestionable obstructive causation. He thought that megacalicosis may be the result of a transient obstruction caused by foetal ureteral folds which subsequently involute and disappear with growth.

In advanced cases of pyelocaliectasis, due to PUJO, dramatic urograms may be obtained. Huge round, dilated calyces may be all that can be visualized in an excretory urogram, because there may not be sufficient function to enable early visualization of the large hydronephrotic pelvis. In such a case, the pelvis may be visualized if a 2- to 6-hour or even a 24-to 48-hours delayed film is taken. The pelvis may become so large that by its own weight the kidney descends and rotates on the anteroposterior axis thereby decreasing the angle at the pelvi-ureteric junction and increasing the degree of obstruction. In far-advanced cases a huge dilated sac may be all that remains of the kidney and pelvis.

In advanced hydronephrosis, in which little or no function remains, diagnosis by excretory urography may be impossible even with the use of high dose excretory urography and delayed films. If pressure or angulation from the greatly dilated pelvis has occluded the ureter and a catheter cannot be passed, it may be impossible to make a retrograde pyelogram. In such cases the lesion may be confused with a tumor. A finding that is often misunderstood is the occasional marked difference in appearance between a routine excretory urogram and a retrograde pyelogram. Most urologists have encountered cases in which the kidneys and ureters looked normal on excretory urography, yet the retrograde pyelograms demonstrated marked pyelectasis or pyeloureterectasis. And also cases in which the excretory urogram without abdominal pressure appeared normal, but an urogram made with abdominal pressure showed marked pyeloureterectasis. At present this is thought to result from previous damage to the urinary tract by obstruction or infection or both. Sometimes the IVU shows a marked dilatation while on retrograde pyelography the picture is almost normal. This is caused by the ureteric catheter that drains a good part of the fluid in the kidney and is partly replaced by contrast medium.

The renal pelvis is usually situated at the level of the second lumbar vertebra. In the routine supine position used for urography, the kidney lies in a depression formed by the superior portion of the lumbar lordotic curvature and consequently the proximal ureter transports its contents in an up-hill-direction. As the hydronephrotic state progresses, the pelvi-ureteric junction must rotate anteriorly, since expansion is prevented posteriorly by the abdominal wall and medially by the psoas muscle. In the supine position, the pelvi-ureteric junction is displaced anteriorly from the plane of the calyces.

Since muscular distension and atrophy result from pelvic dilatation, active ejection of urine is inefficient and urinary propulsion is partly due to the force of excretion, so long as the patient remains supine. Another factor that may be responsible for poor ureteric visualization with the patient supine is that urine containing a contrast medium has a higher specific gravity than normal urine. The contrast material, therefore, gravitates to a position below the pelvic exit. Early mixing at the superior level is poor, urine of relatively low contrast density enters the ureter, and inadequate ureteric definition is obtained. With the patient prone, the relationships between the calyces and the pelvi-ureteric junction are reversed; the proximal ureter runs downhill and the force of gravity makes up for the deficit in motor function.

Hanley (1959) studied 500 IV-urograms and divided human beings into two main types with regard to their renal pelves: those with a perfectly smooth funnel which appears to be "open" at all times, and those with a rounded pelvis and clearly marked junction which appears to be "closed" in the resting phase. These two types merge imperceptibly into each other. The ideas about the shape and size of the pelvis are based upon what one can see on X-ray films taken with the patient lying flat on his back. When a patient is in the prone position, the pelvic enptying rate is accelerated, while the upright position produces a totally different radiological picture in most individuals (Hanley). The funnel-type junction was found in over 80% of 500 routine pyelographic studies of "normal" junctions, but was present in less than 10% of the hydronephrotic cases. Some 90% of the hydronephroses had a "closed" type junction, even after a thorough ureterolysis, and it is probably fair to assume that persons born with this type of junction are more likely to develop a clinical hydronephrosis than those possessing a wide open funnel type of junction. It must be stressed that even in the "closed" type a relatively large bougie can be passed through the junction with ease in most cases.

7.1.5. Follow-up of the operated patients.

The postoperative urogram presents evidence of a final result and is stressed in all presentations. It is often disappointing in its appearance, because of persistent dilatation of the calyces and renal pelvis. The urogram is a pictorial documentation but fails to reveal the entire story and is often of secondary importance, because unobstructed flow is the aim of the operation. The final postoperative evaluation should be made on the physiological improvement, the absence of urinary tract infection and on the clinical result.

An important question is always when the postoperative urography should be performed. Many different views about this have been published. Most urologists are anxious to see the result before the patient leaves the hospital. However, one cannot obtain an accurate picture of the result so soon after surgery. At that time there is residual oedema and infiltration of tissues associated with the repair process. The urogram will reflect this healing process by still showing an obstructive picture and the urologist may consider that the operation was unsuccessful. Accordingly (Eberhart 1963) one should not expect a "true" picture until at least 3 months postoperatively. By this time the healing process has subsided. The urogram at 3 - 6 months will provide a good impression of the ultimate result, as after this period, little, if any improvement occurs.

Large series have been published which conclude that the results are disappointing, particularly in terms of the urographic appearance.

The pre- and postoperative urogram should be compared with respect to:

1. The degree of dilatation of the calyces;
2. The emptying of the pelvis as judged by visualization of contrast material in the ureter;
3. The concentration of the contrast medium in the calyces, pelvis and ureter.

Roberts et al (1972) found radiological improvement of calyceal size in only 15 out of 75 operated cases. Frödin and Karström (1973) reported pessimistically on the radiological results because there was almost always a residual dilatation of the calyces.

In 26 cases of Innes Williams' (1976) series of 190 children the IVU was performed about the 3rd month with later improvement by the

A.Boy,11 years

B.3 months postoper.(Foley)

A.Boy,6 months,preoper.

B.2 months postoper.(A-H)

C.2 years,postoper.

A.Boy,9 years

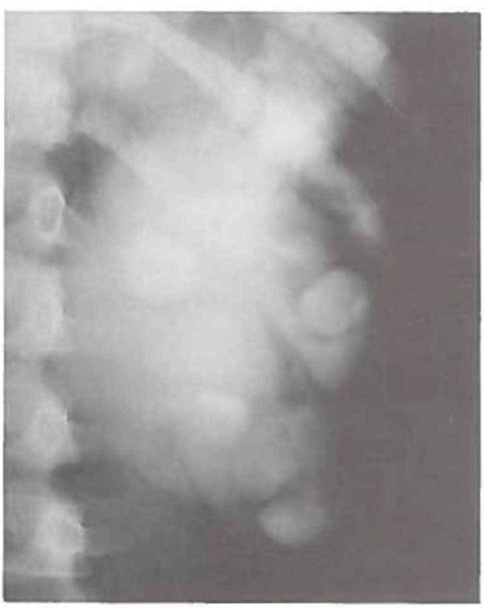
B.3 months postoper.(Anderson-Hynes)

A.Male, 27 years

B.5 months postoper.(Anderson-Hynes)

A.Female,24 years

B.4 months postoper.(Anderson-Hynes)



A.Girl,9 years

B.4 months postoper.(Anderson-Hynes)

6th month. It was also repeated in 33 cases in periods up to 5½ years, following operation. In these cases the picture showed no change from those of the 6th month series. The maximum improvement was therefore attained at this stage and all patients in the latter part of the series had only one postoperative IVU at 6 months. In Johnston's series (1977) of 219 children maximum urographic improvement was apparent on the urogram between 6 and 12 months postoperatively. In those cases in which later urograms were performed no more improvement was noted. However Johnston believed that a more lenghty follow-up and repeated radiography were particularly required in cases in which the hydronephrotic kidney needed to be removed. In one of his patients the opposite kidney, normal at the time of nephrectomy, was severely hydronephrotic 5 years later, presumably because the pelvi-ureteric junction was unable to cope with the obligatory increase in urinary flow rate. The postoperative change, as observed in the calyces, showed that the greatest improvement occurred where the preoperative urogram was performed during an acute phase of obstruction. In the kidneys with severe excavation of the calyces, despite some general decrease in kidney size, following removal of the obstruction, hardly any significant improvement in the shape of the calyces could be demonstrated. The size of the renal pelvis was considerably decreased in all cases, but this indicated the extent of the operative procedure rather than the relief of the obstruction. Return of the radiographic appearance to normal occurred in about 10% of cases, mostly in those with an originally mild degree of obstruction. The dilatation of the calyces caused by parenchymal destruction is permanent, only dilatation of the elastic tissues can regress by lowering the pressure in the renal pelvis. There are obvious fallacies in trying to draw inferences concerning changes in renal concentrating power and in pelvic emptying from comparing preoperative and postoperative urograms. Delayed or poor radiopacity in the kidney preoperatively may be caused by dilation of contrast material in a dilated, obstructed pelvis rather than by impaired renal function. In a routine IVU series the detection of contrast medium in the ureter is often a matter of chance, depending upon the moment the exposure was made. However, improvement in caliceal size and contour, can be taken to indicate improved kidney emptying. On the other hand, lack of change may simply mean that irreversible parenchymal changes existed preoperatively.

Newling (1974) concluded that of the radiological parameters investigated the single most important one seemed to be the preoperative non-visualization of the ureter and its subsequent visualization in the postoperative series. Failure to demonstrate the ureter on the postoperative IVU seemed to correlate with a poor functional result.

Whitfield (1979) concluded that frusemide-IVU was useful in distinguishing between obstructive and non-obstructive dilatation of the renal pelvis, before as well as after pyeloplasty.

7.1.6. Conclusion.

Intravenous urography is the most important diagnostic procedure in pelvi-ureteric obstruction. In long-standing cases one should administer more contrast medium and make "late pictures". If one suspects a patient of having a pelvi-ureteric obstruction one should perform an IVU during an attack of pain or after increasing the diuresis by giving large amounts of fluid or a diuretic. The postoperative IVU should be made after 3 - 6 months, because by this time the healing process has subsided.

7.2. Micturating cystourethrography.

The relationship between reflux and hydronephrosis is not clearly established, but the phenomenon is certainly of value in demonstrating the anatomy of the upper urinary tract in the small infant with reflux. The picture of pelvi-ureteric obstruction which is induced by vesico-ureteral reflux is well documentated but ill understood (Whitaker 1976). The radiographic findings can be so impressive that PUJ obstruction is probably often over-diagnosed. Where the urogram is not suggestive for PUJ obstruction, a reimplantation of the ureter will usually stop the gross pelvic dilatation and can result in a dramatic reversion to normal pelvi-ureteric function. Confronted with an abnormal amount of fluid to be excreted the rounded or closed type of renal pelvis fails to function efficiently and cannot empty fast enough to accomodate the increased amount of urine. This results in a dilatation of the renal pelvis. Hanley (1959) achieved overhydration by forcing fluids orally. Alternatively, the repeated flooding of a normal but closed type of renal pelvis by reflux would be an even better stimulus than overhydration to produce dilatation of the renal pelvis. Theoretically, therefore, the combination of reflux and a closed type of renal pelvis can produce the classical picture of obstruction at the PUJ.

Leadbetter (1961) pointed out that in some patients, who appear to have pelvi-ureteric junction obstruction, reflux is the basic pathological process. He illustrated this with a case report of a patient whose left kidney was removed because of hydronephrosis, presumed to be due to obstruction of the ureteropelvic junction. Later it was found by micturating cysto-urethrography that the basic disorder was bilateral reflux. Hutch (1961) has shown that the intravesical ureter at birth is very short (about 5 mm.), whereas this same structure in the adult measures about 13 mm.. He also showed that the intravesical ureter reaches adult length at about the age of 12. From this he postulated that the tendency for reflux (or the ease with which a normal valve could be made to reflux by vesical infection and oedema) is greatest at birth when the intravesical segment is shortest. As the child grows older, and the intravesical segment becomes longer, the tendency to reflux decreases. One can combine these two conclusions:

1. Vesicoureteric reflux may cause permanent dilatation of a closed type of renal pelvis and
2. Silent or undiagnosed reflux may occur in early childhood and disappears as the child grows older.

This gives a possible explanation for pelvi-ureteric junction obstruction in cases in which the reflux is no longer demonstrable at the time the upper tract disease is diagnosed.

Hutch and Tanagho (1965) presented a theory to explain "non-occlusive" dilatation of the upper urinary tract, including hydroureter (obstruction at the uretero-vesical junction) and hydronephrosis (obstruction at the pelvi-ureteric junction) in the presence of vesico-ureteric reflux. The theory was based on the premise that any normal ureter will dilate if called upon to transport a volume of urine exceeding that of the emptying capacity of any of its segments. Since the segments of the ureter with the lowest emptying capacities are the pelvi-ureteric junction and the uretero-vesical junction, the dilatation of the ureter invariably begins above one, or the other, or both of these points. The excess urine that the ureter is forced to excrete could come from the bladder by means of vesico-ureteric reflux. Although the so called pelvi-ureteric obstruction due to vesico-ureteric reflux might improve or disappear after operative correction of the reflux, Deklerk (1979) presented two patients who did not follow this pattern. This might be expected in cases with a severe degree of pelvi-ureteric tortuosity, kinking and periureteritis, or intramural changes of the PUJ.

### 7.3. Retrograde pyeloureterography.

Before high-dose urography became available in almost all cases retrograde pyelography was performed to obtain a picture of the diseased collecting system of the kidney(s). The catheter, if it will pass, sometimes acts as a splint and straightens the ureter, while the unsplinted ureterogram may show obstructing kinks.

It is important to stress that by retrograde pyelography and ureterography, infection can be introduced. Infection of a poorly draining renal pelvis is a very serious matter. Moreover passing an ureteric catheter upward may cause oedema of the PU-junction which makes drainage of the system even worse.

Probably a retrograde investigation with the bulb (Chevassu) catheter is less traumatic and gives a more accurate picture of the actual situation. The safest procedure is to perform a retrograde investigation (if necessary) just prior to surgery.

In our opinion it is only necessary to perform a retrograde pyeloureterography (urography) if high dose urography gives inadequate information. In some cases of PUJ-obstruction the ureter is not visualized. In these cases it is advisable to perform preoperative retrograde pyeloureterography to demonstrate the ureteric morphology and rule out at the same time existing pathology of the ureter below the PUJ.

Lalli (1967) concluded that in his series of nine patients the ureter of the affected kidney was never opacified or identified on IVU. In the series of 109 children of Kelalis (1971) retrograde pyelography was necessary in only 21% of cases and these included 11 instances in which the obstructed kidney was urographically functionless.

7.4. Angiography.

In 1947 Doss wrote: "The enlarged hydronephrotic kidney is too often hastily considered unworthy of preservation. The decision to extirpate the kidney is usually based on the pyelographic appearance and on findings resulting from study of renal function tests as ordinarily performed. Unfortunately, most of these tests can be misleading. For example, poor concentration of contrast medium in the roentgenogram or the appearance of spurts of diluted indigo-carmine -even the absence of the latter- by no means confirms the existence of inadequate function. Often pyonephrosis or even multiple cortical abscess formation does not preclude the possibility of plastic surgery in an effort to rehabilitate the kidney. Instead of relying on these ordinary efforts of determining renal function, I have felt that the condition of the arterial tree in each kidney should determine whether the organ is to be preserved or removed. This method of study has been carefully applied during the past 6 years with gratifying results. It is my feeling, that an organ is no better than its blood supply. If the blood supply is good, even though there is marked thinning of the renal cortex proven at surgery, every effort should be made to save the kidney. If on the other hand, the blood supply is poor, the kidney may be sacrificed. Often, the hydronephrotic, apparently more diseased kidney, is as good if not the better of the 2 kidneys as determined by outlining the arterial tree. The superimposition of an abdominal arteriogram on the retrograde pyelo-ureterogram is of further assistance in determining the presence of an aberrant vessel as the agent responsible for obstruction, except where the lumen of the vessel is obliterated. Should the vessel be patent, it is possible to determine the amount of renal parenchyma which will be destroyed upon its ligation, often a very welcome bit of information at the operating table".

Since 1947 the situation has changed considerably as the search for accessory vessels preoperatively is no longer necessary, because they are no longer thought to be an important factor in the aetiology of PUJO. Moreover, even when an accessory vessel (or vessels) is found, it should not be ligated (see chapter 8). The high dose IVU technique, renography, renal scintigraphy, ultrasound and CT scan give us so much information about hydronephrosis due to PUJO that there is no indication for angiography. The only indication for angiography in this respect could be in cases of horseshoe kidney, because if one decides to divide the isthmus it is useful to have information about the vascular pattern, and in cases with hypertension, especially when there is PUJO with nephroptosis (De Zeeuw 1980).

### 7.5. Pelvi-ureteric junction pressure-flow study.

Most urologists are from time to time faced with difficult problems of upper urinary tract obstruction. Because neither pyeloplasties nor ureteric reimplants are free from morbidity or even mortality, the urologist must be absolutely sure that the operation is necessary. This may be difficult as in the truly equivocal case radiographic and radio-isotope techniques have severe limitations. However, with the better understanding of urodynamics and the advent of clinically applicable perfusion (pressure/flow) studies (Whitaker 1973) it is not only possible, but also practical, to assess accurately the degree of obstruction and hence make a logical decision as to management.

Essentially, a single cannula is introduced into the renal pelvis percutaneously or during operation and a fast perfusion of 5 or 10 ml/min is commenced. During perfusion the pressures in the pelvis and in the bladder are measured. The latter subtracted from the former produces a "relative pressure" or pressure gradient across the pelvi-ureteric junction at the fixed and steady perfusion rate. Most information is obtained if these pressure-flow studies are performed with contrast medium so that at the same time the pelvic pressure and the radiographic picture can be followed.

As judged by the results in over 120 such studies (Whitaker 1973) in a variety of conditions both with and without obstruction it seemed clear that this relative pressure at 10 ml/min should not exceed 10-12 cm. $H_2O$. If the decision has been made on clinical and radiographic grounds to perform a pyeloplasty in the certainty that an obstruction is present, clearly such a test is superfluous, but nevertheless a perfusion study with the kidney exposed just before the pyeloplasty produces documentary evidence of obstruction and a baseline against which to compare the pressure on perfusing the kidney via a nephrostomy on the 10th postoperative days. Such studies also provide a standard against which the difficult cases can be compared.

The cannula needle is inserted into the renal pelvis away from the pelvi-ureteric junction and before this region is dissected. The kidney is allowed to lie in its natural position. In the equivocal case the study is performed before surgery and helps with the decision as to whether or not an operation is necessary. The technique is the same but the cannula is introduced percutaneously under fluoroscopic control after an intravenous injection of contrast medium. It is usually possible to enter the pelvis via a dilated calyx. In the majority of patients, including older children the procedure is very well tolerated under local anaesthesia.

The perfusion test, however, is not very modern because in 1908 Lucas performed perfusion experiments. He found that if the ureter is obstructed below a cannula, the pressure is raised and the number of peristaltic contractions increased.

In a more recent publication, Whitaker (1979) presented an evaluation of 170 diagnostic pressure flow studies of the upper urinary tract. He concluded that it can be valuable in patients of all ages. The complication rate (transient haematuria, extravasation, urinary tract infection) is low and there are few patients, accordingly to him, in whom these studies do not provide a clear-cut answer on the degree of obstruction.

### 7.6. <u>Renography</u>.

Radioisotope renography was introduced in 1956 by Taplin as a diagnostic tool to estimate renal function. The principle of this test is based on the external detection of the behaviour of a radioactive tracer in the kidney region. The introduction of $^{131}$I-o-iodohippurate (Hippuran-R) in 1960 was an important advance. O-iodohippurate has a high extraction rate (90 per cent) by the kidneys with a glomerular filtration component of 20 per cent and a tubular secretion component of 80 per cent. Assuming under normal

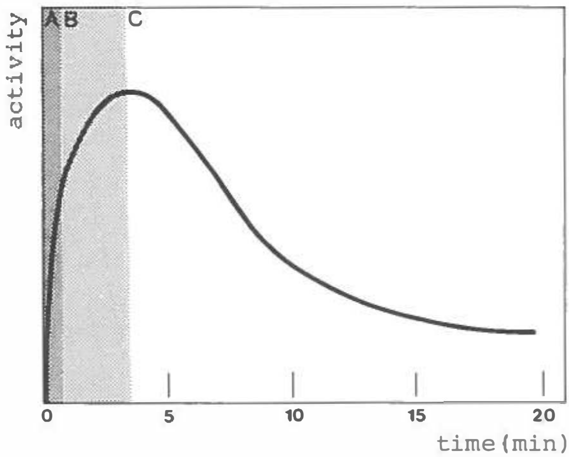



Fig. 7.1. The normal renogram curve.

circumstances a renal blood flow of 20 per cent of cardiac output and an extraction of 90 per cent, rapid accumulation in the kidneys, a brief renal passage and quick delivery into the urinary tract will result.
In 1967 Stevens published a thesis on this subject.

7.6.1. The renogram curves.
Intravenously injected o-iodohippurate quickly mixes with the blood and diffuses into the extracellular space. Blood levels decrease, even in the absence of renal function, but this decrease is much faster if renal accumulation and excretion occur. Immediately after injection a rapid rise in count rate over the kidney occurs (phase A), due to arrival of the tracer in the field of view of the detectors. About 30 seconds later an inflection point can be seen, which is the result of the rapidly falling background component and the rising kidney component. Accumulation in the kidney area is represented in a steep rise of the time-activity curve (phase B), reaching a peak 2-5 minutes after injection. At this moment the disappearance of tracer from the kidney begins to overrule the rapidly declining accumulation. The result is a downward slope of the curve, reaching a plateau near the base-line about 20 minutes after injection (phase C). A normal renographic curve is represented in Fig. 7.1.

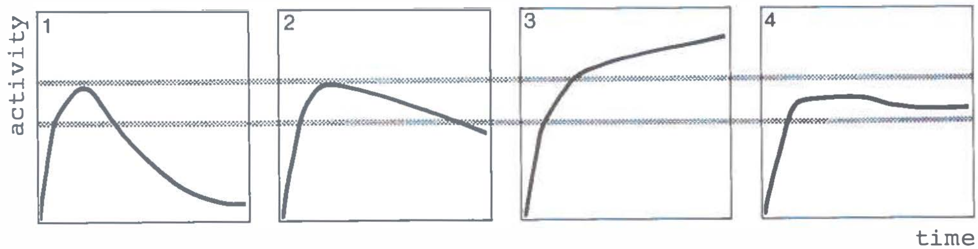



Fig. 7.2. Progressive obstruction of one ureter; schematic presentation of the effects on the renogram curve.

In a theoretical attempt to analyse the function of the kidney, three elements can be distinguished: an uptake, a transit and an excretory function. The uptake is related to the supply rate and the extraction efficiency, i.e. it depends on renal blood flow and glomerular and tubular function. The transit function is a reflection of the performance of the integral nephron population. The excretory function is primarily connected with the patency of the urinary tract. In practice, these functions are closely interrelated: the following sequence of alterations in a renogram is an example (Fig. 7.2.). Partial obstruction of a ureter leads to disturbed excretory function, resulting in delayed disappearance of the tracer (Fig. 7.2.2.). If the obstruction is progressive disappearance deteriorates further and an upward slope in the C phase is recorded (Fig. 7.2.3.). The first part of the curve remains unaltered but, when the obstruction persists, the transit and uptake are affected, leading to diminished accumulation in the early phase of the renogram. At this moment the C phase shifts downward, not because the obstruction is removed, but simply because the diminished kidney function causes a sharp decrease in the amount of tracer delivered in the urinary tract (Fig. 7.2.4.). Parallel with the deterioration of the affected kidney, the contralateral kidney takes over part of the function and becomes hypertrophic, resulting in an exaggerated accumulation on the unaffected side. It is the complexity of factors contributing to the shape of the curves that precludes a diagnosis solely based on renography. It is only in the complete clinical investigation that the renogram can be an useful aid in the care of the patient.

7.6.2. Obstruction of urinary flow.

Renography can provide meaningful information in cases of urinary obstruction, provided the function of the kidney is sufficient. If renal function is seriously disturbed, the radioisotope is not accumulated and excreted in the renal pelvis, and no conclusion can be made concerning the flow in the urinary tract. Providing that there is good renal function, reliable information on the patency of the urinary tract can be obtained. The gamma camera can be very useful for localising obstruction. An obstruction at the pelvi-ureteric junction, e.g., reflected by a continuously rising curve of the renogram, reveals marked accumulation in the pelvis area. Lower ureteric obstruction may give the same curve, but in this case an area of increased radioactivity in the pelvis and proximal (dilated) ureter is demonstrated by the gamma camera. Hampered urinary passage due to prostate hypertrophy can result in bilateral curves of the obstructive pattern, and on the images in visualization of both, dilated, upper urinary tracts. Once urinary tract obstruction is recognized, kidney function can be monitored at regular intervals by renography to select the optimal time for intervention. After correction of an obstructive lesion, renography can be helpful in evaluation of the recovery of kidney-excretion.

Especially in urological problems in childhood, renography is a valuable tool because of its ability to present functional information with a high sensitivity, combined with good patient acceptance and a relatively small radiation dose.

It should be remembered that the gamma camera images have to be regarded as a visual adjunct to the curves; because of the low geometric resolution, they should not be used for detailed morphological information.

Otnes et al (1975) evaluated 28 patients (29 kidneys) clinically by urography and by background subtracted renography performed preoperatively and up to 65 months after surgical correction of hydronephrosis due to pelvi-ureteric obstruction. Clinically 24 patients were improved. Urography showed regress of hydronephrosis and/or improved urinary pelvic drainage in 22 patients, whereas the kidney excretory function as judged from renography was improved in only 8 patients. Their evaluation of radiological improvement was based partly on the state of the calyces and papillae, partly on a visual evaluation of the pelvi-ureteric junction. Others have based their evaluation on the degree of calyceal dilatation only. Their criteria of improvement may have been slightly accomodating, but they considered that the irreversibility of calyceal and papillary changes may mask a technically successful result of the operative correction performed at the pelvi-ureteric junction and that visual evaluation of this function must be included in the evaluation of the results. Evaluation by renography gave far fewer positive changes. Only 8 kidneys were improved, both clinically and radiologically. Of the 3 kidneys with deteriorated renograms, one was radiologically improved, the others were unchanged. The discrepancy in the findings obtained with radiological and renographic evaluation may of course be interpreted as due to shortcommings in the radiological evaluation, and the clinical evaluation is similarly open to criticism. They felt, however, that the patients reported as improved by these criteria have benefited from their operation. In most of the clinically improved patients there was radiological improvement as well while the function of the operated kidneys as assessed by renography remained unchanged in the majority of cases.

Clinical evaluation, urography and renography cannot be directly compared as they give answers to different questions. Clinical evaluation combined with urinalysis tells whether pain and infection is abolished; neither urography nor renography can give this information. Urography is ideal for demonstrating a regression in renal pelvis size, while neither clinical examination nor renography is capable of giving this morphological information. Urography also permits evaluation of urinary drainage. Renography, on the other hand, permits assessment of relative distribution of effective renal plasma flow between the two kidneys, and neither clinical nor radiological methods can do this with reasonable reliability. It is disappointing that renography quite often evidently fails to disclose improved drainage. They believe the reason for this is, that renography in their cases fell outside the normal working range of the method l.e. 20 minutes.

Renography is very sensitive to changes in urinary drainage in the near normal range, but the method has low discriminatory value in extreme, pathological cases. Even after pyeloplasty a hydronephrotic pelvis is very capacious compared with a normal pelvis and therefore renography shows gross pathology with no fall in activity within the 20 minutes usually used for registration. It is almost sure that prolonged monitoring would have disclosed post-operative improvement in more cases. In their material, improvement in renograms was seen most often when the contralateral kidney was abnormal or absent. This may be explained by a greater tendency for regeneration and functional improvement in the operated kidney, or the method may be more sensitive to detect improvements when the radiohippuran is not rapidly eliminated from the circulation by a normal, contralateral kidney. Similar results have been reported by others in animal experiments as well as clinically (Joekes 1972). It would have been advantageous if the comparatively simple method of renography could be a substitute for urography at follow-up after hydronephrosis surgery. It appears that an improvement in renography is always confirmed radiologically, while an unchanged renogram does not exclude radiological and clinical improvement. In their material reliance on renographic improvement could have saved follow-up urography in less than one third of the patients. This saving is not sufficient to warrant the choice of renography in the form used as the main follow-up method for hydronephrosis surgery. Renography is best suited to estimate effective renal plasma flow, which in most cases does not improve even after a successful surgical procedure on the renal pelvis.

7.6.3. Diuresis-renography.

O'Reilly (1978) and Lupton (1979) introduced the diuresis-renography as a method to evaluate patients with equivocal pelvi-ureteric obstruction. It involves the performance of a standard $^{131}$iodine-hippuran renogram followed by a second renogram 3 minutes after an intravenous injection of the diuretic frusemide. On the basis of the response seen on the 2 renograms taken together or the single curve before and after diuresis, there are four different reactions possible (Fig. 7.3.).

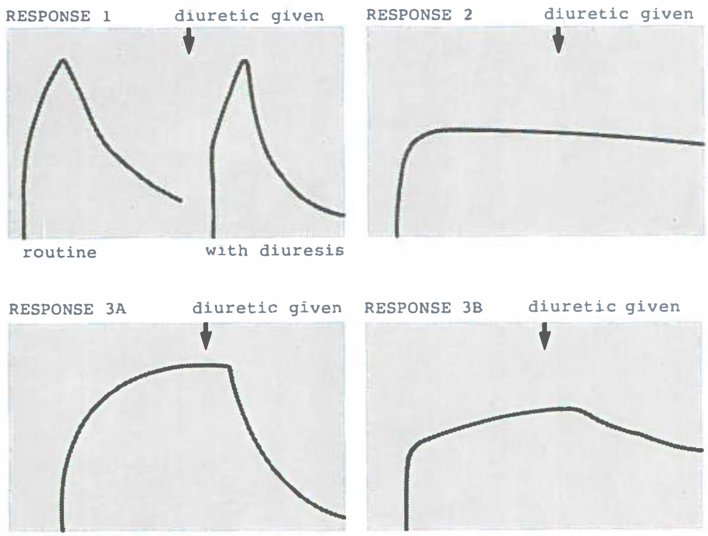



Fig. 7.3. Response 1:normal initial and diuretic renograms. Response 2:initial and postdiuretic renogram with significant obstruction. Response 3A:initially obstructive with rapid excretion after diuretic. Response 3B:initially obstructive with only partial improvement in excretion after diuretic.

Response 1: The initial and postdiuretic renogram are normal which effectively excludes a significant obstruction.

Response 2: The initial and postdiuretic renogram show significant obstruction.

Response 3A: Initial renography shows obstruction which during diuresis becomes converted to a rapid and complete elimination of radioactivity from the apparently obstructed upper tract. This is the pattern of a hypotonic, distended but non-obstructed system, in which the initial flat curve represents a "mixing chamber effect" of the isotope in the capacious renal pelvis. By increasing the urine flow rate the capacity of the pelvis becomes relatively insignificant in comparison with the urine flow and excretion proceeds uninhibited in response to the diuresis.

Response 3B: the initial renogram shows obstruction, which is altered by diuresis but less dramatically than in the 3A response. The elimination is only partial as the third phase of the renogram is still slow and prolonged. Although this group may be said to show a somewhat equivocal response it almost certainly repre-

ACADEMISCH ZIEKENHUIS GRONINGEN

ISOTOPEN LABORATORIUM

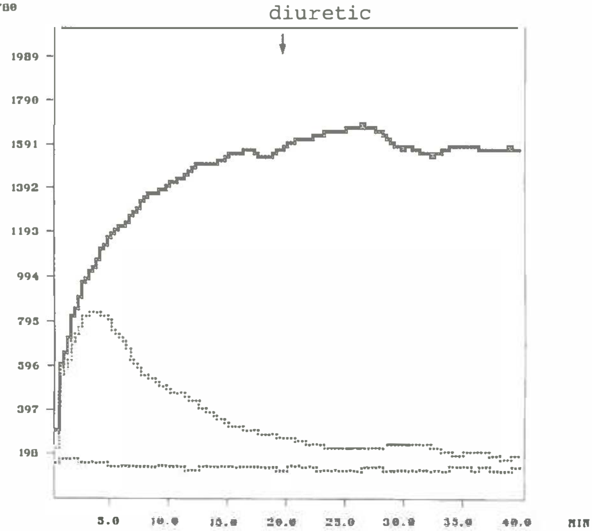
COMPUTER: MODUMED

PATIENT NAME: J. WOLTJER
PATIENT ID NUMBER: 000231207
STUDY: RENOA
DATE OF STUDY: 06/08/80

+=CURVE #1

□=CURVE #2

×=CURVE #3




CURVE SPECIFICATION:
1:RE
2:LI
3:BC

COMMENTS:

RENOGRAM

GRONINGEN 12/08/80

Fig. 7.4

ACADEMISCH ZIEKENHUIS GRONINGEN

ISOTOPEN LABORATORIUM

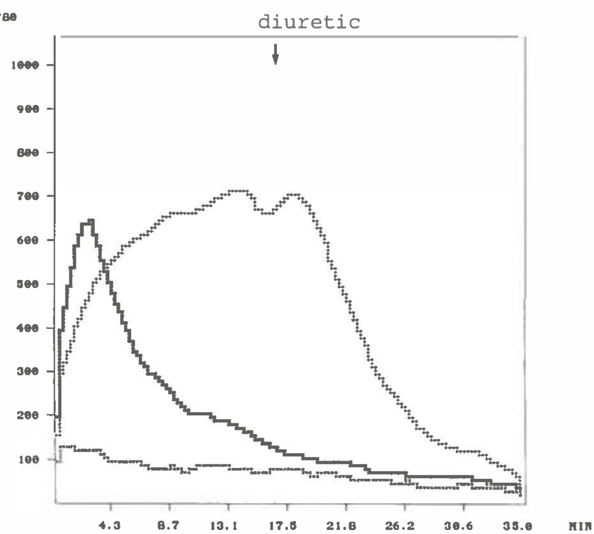
COMPUTER: MODUMED

PATIENT NAME: DONKER
PATIENT ID NUMBER: 000000000
STUDY: RENOA
DATE OF STUDY: 09/01/80

+=CURVE #1

□=CURVE #2

×=CURVE #3




CURVE SPECIFICATION:
1:RE
2:LI
3:BC

COMMENTS:

RENO

GRONINGEN 01/09/80

Fig. 7.5

sents a degree of subtotal obstruction.
Examples of patients with response 2 and 3A are shown in Fig. 7.4. and Fig. 7.5..
O'Reilly (1979) examined 50 patients with dilatation of the upper urinary tract. Of these patients 37 were suspected of PUJO while 13 had persistent dilatation 6 months or more after an Anderson-Hynes pyeloplasty. The results of the diuresis renography were as follows:

| Response | 1 | 2 | 3A | 3B | Total |
|---|---|---|---|---|---|
| PUJO ? | 10 | 12 | 11 | 4 | 37 |
| post-pyeloplasty | 6 | 2 | 5 | - | 13 |

In all patients (12) with suspected PUJO, who showed response 2, the diagnosis was confirmed at operation. Response 3A was found in 11 patients with suspected obstruction and in 5 with post-pyeloplasty dilatation.
Although the diuresis-renography is an easy and non-invasive method to evaluate patients with equivocal PUJO some errors may occur. Aaronson (1980) reported three children with only slightly dilated pelves that emptied well with posture change or diuresis, but in whom there was disproportionate dilatation of the calyces. Diuresis-renography would certainly have shown a non-obstructive curve. However pressure-flow studies showed normal basal pressures (10 - 20 cm $H_2O$) together with vigorous contractions producing rapid increase in pressure up to 100 cm $H_2O$ which resulted in emptying of the renal pelvis. In all 3 cases a pyeloplasty was performed.
The behaviour of the renal pelvis in this group of patients appears to be analogous to the high voiding pressures in the partially obstructed but compensated bladders. The muscle of the renal pelvis retains its tone on the IVU, but the repeated high peak pressures result in progressive dilatation of the less muscular calyces. This may be a mechanism for the urographic appearance described as megacalicosis. As the definition of obstruction ultimately depends on pressure-flow relationships, it seems probable that there will continue to be a place for their direct measurement by pressure-flow studies.
From the present material it seems that standard renography and

diuresis-renography are valuable supplementary methods for estimating the result of surgical correction of hydronephrosis. Renography exposes the patient to minimal radiation and causes only minor discomfort. Since the investigation may be repeated several times it is of significant value in the follow-up of patients with urological disease. In the first postoperative control, renography might replace urography, which may be reserved for those cases in which renography failed to demonstrate definitive improvement.

### 7.7. Renal scintigraphy.

DMSA (dimercapto-succinic acid) labeled with 99mTc (Technetium) is now the isotope of choice for renal scintigraphy. After intravenous injection it accumulates intensively in the renal cortex. With normal kidney function, good morphological information concerning the renal parenchyma can be obtained after two hours. With impaired function it takes sometimes four hours. Also the relative "function" of each kidney can be determined with the use of computer registration. The overall kidney function is reflected in the amount of isotope accumulation in both kidneys. If we want to perform renography and renal scanning on the same day the examination starts with renography because Hippuran $^{R}$ is excreted completely in a short time if there is no obstruction, so it will not disturb the scanning. One hour after the renography the isotope for the renal scanning can be injected.

### 7.8. Renal function studies.

Obstruction in the kidney outflow can produce renal damage and a progressive deterioration of renal function. For a good follow-up adequate information about renal function by estimation of the creatinine clearance or the glomerular filtration rate (GFR) using a radioisotope is necessary.

To obtain information about the renal function, Mayor (1975) studied 24 children with obstructive uropathy. He divided them in 3 groups, that were operated upon before 1 year of age (12 patients), between 1 and 2 years (6 patients) and after the age of 2 years (6 patients). Twenty out of 24 patients had radiologically evident bilateral hydronephrosis. In his study he came to the conclusion, that surgical relief of chronic urinary tract obstruction was followed by a lasting improvement of renal function only in those patients operated upon before one year of age. When patients were operated upon between 1 and 2 years of age, renal function did not improve but remained stable at a lower than normal level. Finally, when patients were operated upon after 2 years of age, a slow and progressive deterioration of renal function occurred postoperatively. The lack of any improvement in kidney function when corrective surgery is performed after 1 year of age indicates the need for early intervention before an irreversible state has developed. It thus appears essential to diagnose and to correct chronic hydronephrosis associated with renal failure before 1 year of age if an improvement in renal function is to be expected.

7.9. Computerized tomography (CT).

The CT-scan is a comparatively new non-invasive diagnostic method by which an image is created by passing a small monoenergetic X-ray beam in many directions through a plane of the body and using a computer to recreate the pattern of tissues produced by the observed attenuation of the beam. The technique is limited because only transverse sections of the body can be studied.
In hydronephrosis due to PUJO it can give information about the parenchymal thickness and the dilatation of calyces and renal pelvis. In general, however, it is not necessary to use the CT-scan because other diagnostic methods are available (IVU, ultrasound, renal scintigraphy) which are less expensive and give the information wanted with less radiation.

7.10. Ultrasound.

B-mode ultrasound can have a place in the diagnosis of hydronephrosis due to PUJO. Ultrasonography can demonstrate a dilatation of the collecting system and can give information about the thickness of the parenchyma. Especially in small children it can be of great value because it is non-invasive, simple and harmless to the patient.

7.10.1. Antegrade pyeloureterography.

Ultrasound is a useful technique in combination with percutaneous puncture of the renal pelvis which permits antegrade pyeloureterography, pressure-flow studies or temporary pyelostomy (see chapter 8).

7.11. Conclusions.

If a patient is suspected of having a PUJO an IVU should be performed. Because the IVU could be almost "normal" this investigation should be performed during an attack of pain or after a diuretic has been administered.
When pelvicaliceal dilatation is demonstrated on an IVU the presence of pelvi-ureteric junction obstruction can be determined by subsequently performing a diuretic-IVU and/or a diuresis renography.
Retrograde ureteropyelography is only necessary if the proximal ureter is not visualized on IVU and should be performed just prior to exploration of the kidney.
There is hardly any remaining indication for angiography. Only in cases of horseshoe kidney it would be useful to be informed about the vascular pattern if one decides to transect the isthmus.
Renography is a very sensitive test that gives information about renal function and excretion. It can be very useful before as well as after operative correction of the PUJO. The diuresis-renography can be used as a method to evaluate patients with equivocal PUJO.
The most reliable test in PUJO is the pressure-flow study which can be performed during operation or by percutaneous puncture of the renal pelvis.
There is hardly any indication for computerized tomography because other diagnostic procedures are available with less radiation and less costs. Ultrasound is a "non-invasive" investigation, which can be of great value. It is simple and harmless to the patient.

# 8. Therapy

8.1. Introduction.

The only cure for hydronephrosis lies in the alleviation of the flow resisting factor. In order to conserve a hydronephrotic kidney some type of surgical procedure is required to relieve the patient of discomfort and to stop further damage to the kidney. Numerous surgical operations have been advocated. The ideal operation in PUJO would be one which produces an adequate pelvi-ureteric outlet, allowing the kidney to function free from any resistance and infection and relieve the patient of all symptoms.

In 1923 Hunner stated: "In dealing with a mechanism as delicately balanced as the ureteropelvic junction, and particularly when that mechanism has been badly disarranged by disease, one hesitates to lay down hard and fast rules. Each case differs from the preceeding one in the problems presented and the surgeon should approach these problems with an open mind, ready to adopt the course that seems best fitted for the individual case". These sound remarks are still applicable even today. Certain facts must be borne in mind in considering the conservation of renal parenchyma. When an individual is born he/she has a fixed number of nephrons. They may be divided equally between two kidneys, or the total number may be limited to one kidney. Once the number of nephrons is determined, hyperplasia of the kidney by increasing the number of nephrons is impossible. After birth any hyperthrophy is accomplished by an increase in the size of the existing units. It is our duty to preserve as many of those units as possible. No singular operative technique is suitable for the repair of all types of hydronephrosis. The technique to be used should be suited to the particular defect, which can not be completely known until after the surgical exposure. It is therefore imperative, when approaching such a problem, that the urologist should have an adequate knowledge of the alternative methods available. Various procedures for relief of pelvi-ureteric junction obstruction have been described. Some of these were adoptions of plastic surgery principles. Their application in the field of urology did not contribute anything fundamentally new but represented a gradual evolution. End-to-end anastomosis of viscera had been employed in various ways before the application in the "uretero-pyeloneostomy" by Küster in 1891. Transverse suture of a longitudinal incision as applied to the pylorus in the Heineke-Mikulicz (1890) operation was adopted for use in the pelvi-ureteric junction by Fenger (1894). The continuous side-to-side union was used in plastic procedures on the skin before it was used as a pelvi-ureteric plasty by Finney (1898). The simple Y-V plasty differs from the Heineke-Mikulicz principle only in detail: one end of the longitudinal incision is split but essentially it is a transverse suture of a longitudinal incision. Durante (1895) applied this simple form of Y-V plasty to relieve a pyloric stenosis before its application to the pelvi-ureteric junction by Schwyzer (1923).

The degree of hydronephrosis and kidney function should be determined as accurately as possible, to help decide whether or not conservative treatment is indicated. Sharp (1961) thought that excretory urography provides the most reliable means of estimating renal function. He advocated the use of an indwelling ureteric catheter for a few days. It demonstrates the ability of the kidney to recover its function and gives a reliable indication of the improvement of the hydronephrosis, which might be expected when the obstruction is permanently relieved by surgery. He stated that generally, if the affected kidney has less than 25 percent of normal function, nephrectomy is preferable. This rule cannot always be followed; for instance in cases with impaired function of the contralateral kidney. The presence and type of infection are frequently important factors, but final judgment rests on the appearance and volume of the renal parenchyma at the time of operation. Any kidney parenchyma should be salvaged, if possible, without future risk to the patient.

It is a long established fact that hydronephrosis due to pelvi-ureteric obstruction is often bilateral. Removal of one kidney sometimes may result in marked progression of hydronephrosis in the remaining kidney, because of increased flow of urine.

If one decides to conserve the kidney another phase in the diagnosis of obstructive lesions that has not been overly stressed, is their recognition at the time of operation. Culp (1957) advocated careful study for evidence of obstruction during renal surgery for other conditions, especially calculi. Unless the pelvi-ureteric region is funnel shaped, he considered that potential obstruction was present and that a corrective procedure was indicated. Eberhart and Rieser (1953) called attention to the fact that the obstruction usually is not so evident at operation as it appeared to be on the urogram. Foley's (1937) method of injecting fluid with a syringe and needle before opening the pelvis is a reliable means of determining the location and degree of obstruction. Once the repair is completed, this test will then reveal how well the fluid drains down the ureter and how efficient the anastomosis is.

The therapeutic possibilities of hydronephrosis due to PUJO can be divided in several groups:

1. Nephrectomy
2. Drainage of the kidney
    - -Nephrostomy
    - -Pyelostomy
3. Non-dismembered procedures
4. Dismembered procedures

The terms non-dismembered and dismembered mean operation with and without transection of the PUJ. In some dismembered pyeloplasties the PUJ is resected.

## 8.2. Nephrectomy.

In 1937 Schulhof warned against Hinman's theory of counterbalance which said: "The healthier side will gradually undergo compensatory hypertrophy, which may be so capable of counterbalance as to render the work of its weak assistant unnecessary, disuse of which will presently occur".
Many writers concluded that there was a remarkable return of renal function after removal of the obstructing lesion. Many so called functionless kidneys are valuable and should be preserved.
In the years around 1900 the mortality rate for most operations was very high. In those days one could make a nephrostomy and the

surgeon was happy if his patient survived a nephrectomy. Trendelenburg in 1886 made the first deliberate attempt to widen an obstructed pelvi-ureteric junction. Unfortunately his patient did not survive. In 1952 Schwartz published his series of 54 patients with hydronephrosis due to pelvi-ureteric obstruction. In 56% of these patients, the condition had progressed to such a point that nephrectomy was considered the procedure of choice. Zincke (et al. 1974) found 20-25% of all cases basically no longer suitable for conservative surgery. Eckstein (1971) had a primary nephrectomy rate of only 3% and Johnston (1977) of 10%.

Though usually unilateral when first discovered, pelvi-ureteric obstruction may be either actually or potentially bilateral. Therefore, the effort is justified to preserve the damaged kidney rather than remove it and run the risk of causing a subclinical process on the opposite side to "blossom out". After nephrectomy, the functional load on the remaining kidney may accelerate or even initiate the development of hydronephrosis given the proper setting, so a more lengthy follow-up and repeated urography are required.

One should not hesitate to remove a hydronephrotic sac, but should always keep in mind that large hydronephrotic kidneys may recover very well. The parenchyma may be thin but the total volume can be considerable. It is now easier to obtain information about the function of a kidney thanks to the tests available. Saving the patient however, will continue to be more important than saving a few extra nephrons. Two factors warrant serious consideration when there is a good contralateral kidney:

1. Rehabilitation. Too frequently urologists forget that the patient should again be happy, healthy and a useful citizen. One should look farther ahead than the day the patient can leave the hospital. Technical triumphs do not necessarily assure the most practical results. Multiple operations on the same kidney have created many urologic cripples. Nephrectomy will continue to be prudent in many instances.
2. Age. Although chronological age can be most deceiving, one should be reluctant to perform any type of pyeloplasty if the patient is more than 60 years of age. Indeed, the virtues of such procedures after the age of 50 remain doubtful, if the other kid-

ney has a good function.

## 8.3. Drainage of the kidney.

### 8.3.1. Nephrostomy.

### 8.3.2. Pyelostomy.

As mentioned before a permanent nephrostomy or pyelostomy was frequently made in the early days because other possibilities were not available. These procedures cause infection and often stone formation. Nowadays a temporary nephrostomy is only necessary in exceptional cases and should be avoided if possible, because it makes a pyeloplasty more difficult later.

Temporary urinary tract drainage was advocated by Barbaric (1976) in cases of infection in the obstructed urinary tract system. His method of choice was a percutaneous nephro(pyelo)stomy.

## 8.4. NON-DISMEMBERED PROCEDURES.

### 8.4.1. Pelvi-ureterolysis.

Rolleston (1957) was impressed in many cases by the presence of a broad fascial band extending from the lower pole of the kidney, crossing the region of the pelvi-ureteric junction and then merging with the coverings of the aorta and caval vein. Often this fascia contained abnormal lower pole vessels. He found that, after removing this fascial band, cutting any associated abnormal vessels and freeing the secondary adhesions between ureter and pelvis, calibration of the pelvi-ureteric junction and upper ureter revealed an ample lumen. Nothing further was required except fixation of the kidney to prevent new adhesions of the ureter to the pelvis or the lower pole of the kidney.

### 8.4.2. Dilatation of the pelvi-ureteric junction.

For a long time many patients with hydronephrosis due to pelvi-ureteric obstruction have been treated by dilatation. This dilatation was performed in a retrograde manner by cystoscopy or operatively in a orthograde manner via a pyelotomy.
Mc.Iver (1939), Soley (1946) and Mathé (1954) were convinced that dilatation by a catheter introduced at cystoscopy was the treatment of choice.
This way of treatment, of course, will not improve the drainage of the hydronephrotic kidney. On the contrary, because of oedema, drainage will deteriorate. Moreover, there is a great danger of infecting the hydronephrotic kidney.

### 8.4.3. Ligation of aberrant vessels.

The significance of aberrant vessels passing to the lower pole of the kidney in the pathogenesis of pelvi-ureteric obstruction remains a controversial subject. Bibus and Hohenfeller (1958), and others claimed that such vessels, by compression of the ureter, may be primarily responsible for hydronephrosis. In a study of 71 cases of pelvi-ureteric obstruction, Jewett (1940) found lower polar vessels to be the only aetiological factor in 24 patients. On the other hand, the facts that accessory renal vessels at the lower pole are frequently encountered when no obstruction exists (Brosig, 1961,

Jewett, 1940) and that in addition hydronephrosis is chiefly observed in the second decade of life (Boeminghaus, 1977) indicate that a combination of factors may be involved.
The majority of urologists agrees with Boeminghaus, Brosig, Campbell, Gibson and others that aberrant vessels act as a secondary obstruction to an already enlarging pelvis.
Renal arteries are terminal arteries. Therefore, some risk is always involved in their ligation, as necrosis of renal tissue can result. Many authors (Bibus and Hohenfellner (1958),Bischoff (1953), Engel (1951), advised ligation of lower polar vessels, if their obstructive function is obvious, if the calibre is small, if the ischaemic area on temporary occlusion does not exceed 25% of the kidney surface, if the patient is young or if a partial nephrectomy is considered. Simon (1940) has emphasized that temporary occlusion of the vessel as a test to show the amount of renal tissue involved, may be misleading. The same is true of the injection of indigocarmine into the artery as suggested by Khoury (1950). Compression of a capsular artery will produce cyanosis, whereas compression of an artery supplying central parts of the parenchyma will not. In 332 cases of ligation of lower polar vessels Simon found the incidence of tissue necrosis, requiring secondary nephrectomy to be 2,4%. Most authors agree that veins can be ligated safely.
In search of a parenchyma conserving operation which would cure hydronephrosis without sacrificing the obstructing vessels Stewart (1947) introduced the nephroplication, and Young (1932) and Hellström (1934) advised transposition of aberrant vessels.

8.4.4. Partial pelvectomy or pelvic plication.
For many years and even in 1946 by Hinman, a partial pelvectomy or pelvic plication was advocated if after pelvi-ureterolysis a substantial degree of pyelectasis remained.

8.4.5. Nephropexy.
Because some writers thought that nephroptosis was the main cause of obstruction at the pelvi-ureteric junction they only performed a nephropexy after pelvi-ureterolysis. The kidney is fixed in such a position that the ureter is stretched, so preventing the rede-

velopment of kinks.

8.4.6. Vessel transposition.

Young (1932) and Hellström (1934) used transposition of aberrant vessels, in combination with a resection of the enlarged pelvis. Brosig (1961) and Casey (1959) agreed that in cases of moderate hydronephrosis, the renal pelvis will shrink to normal size and regain its tone if the obstruction is relieved. They believed that if no organic stenosis of the pelvic outlet is present, the transposition of aberrant vessels will in many instances alleviate the symptoms of pelvi-ureteric junction obstruction. On the basis of his experience , however, Brosig did not feel justified to state that aberrant vessels alone could cause hydronephrosis, although their transposition may result in clinical cure.

Technique.

The obstructing aberrant vessels are mobilized from the renal pelvis by careful dissection and placed at a higher level on the renal pelvis close to the main artery and attached to the medial border of the kidney parenchyma by encasing them in a flap cut from the perirenal fat overlying the anterior pelvic wall (Brosig, 1961). Hjort (1942) made an anastomosis of the renal pelvis around the vessels, without operating on the PUJ.

8.4.7. Renal sympathectomy.

In 1935 Harris stated that since 1926 renal sympathectomy had been carried out for the relief of pain on increased intrarenal tension, in cases of urinary stasis arising from neuromuscular dysfunction of the calyces, renal pelvis and upper portion of the ureter, a definite type of obstructive nephropathy to which he five years before affixed the title of "renal sympathico-tonus". Renal sympathectomy may be employed according to Harris in cases of this type with a certainty of success which is exceeded by few other operations. After a complete operation, in addition to a careful denudation of the renal artery or its main branches and of the renal vein, the renal pelvis on both aspects as far as the hilum, also the pelvi-ureteric junction and the first inch of the ureter will have been cleaned up, the superior ureteric nerve being divided in the process. Finally the kidney will be attached solely by its denuded vessels and ureter.

### 8.4.8. Trendelenburg.

The first and very simple plasty was published by Trendelenburg in 1886. He opened the hydronephrotic sac widely and divided the spur which was formed by the parallel course of the ureter with the wall of the renal pelvis. The pelvis and ureter were split down to the point where the ureter left the pelvic sac. The mucosa of the pelvis and ureter were then united by catgut. Unfortunately, the patient died of intestinal obstruction.
Von Lichtenberg (1921) presented his lateral uretero-pyeloanastomosis, allied to the Finney gastroduodenostomy (pyloroplasty).

### 8.4.9. Fenger.

In 1894 Christian Fenger described his technique. In those days the mortality of lumbar nephrotomy for pyonephrosis was 23%. For primary lumbar nephrectomy it was 34%. The disadvantage of nephrotomy as compared with nephrectomy for pyonephrosis was that a fistula remained in 45% of the cases. He found that in all cases where a stone was the cause of obstruction, passage is possible when the stone is removed. When there is no stone, simple nephrotomy will leave the impediment in all cases and a permanent draining fistula will result, if in both calculus and noncalculus pyonephrosis, where drainage via the ureter could be reestablished, a lower percentage of permanent fistulas was to be expected.
Technique as described by Fenger (Fig. 8.1.).
A stenosis at the pelvi ureteric junction can be treated by a plastic operation on the plan of the Heineke-Mikulicz operation for pyloric stenosis. A longitudinal incision of the stenosis and transverse closure is done.
His opinion was that this method seemed preferable to resection of the stenotic part of the ureter (Küster) for the following reasons: "it is a more economical operation and preferable when, after excision of the stenosis, the length of the ureter is insufficient to permit the two cut ends to come in contact, thus allowing closure and invagination without stretching".
A variation of the Fenger operation was done by Gibson (1940), who made a longitudinal incision both on the anterior and posterior

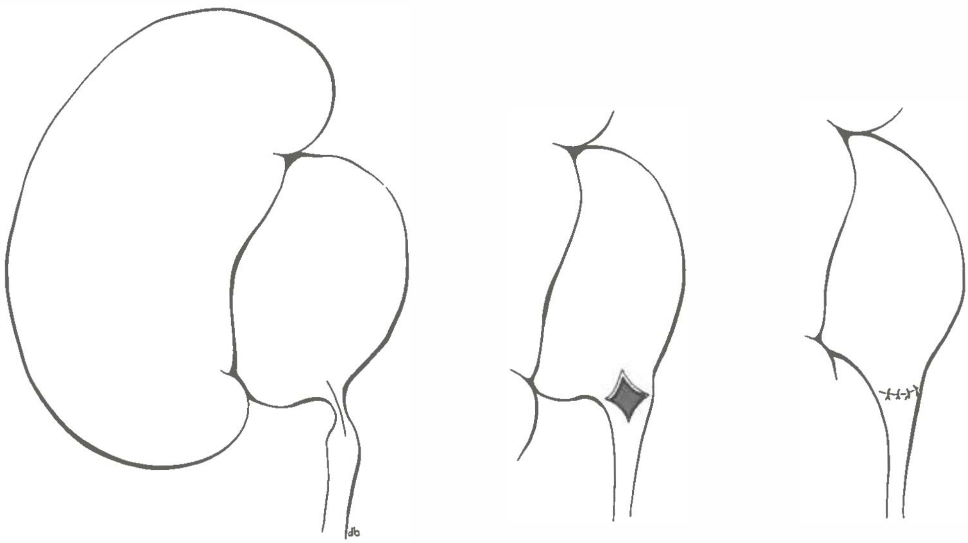


Fig. 8.1. The Fenger pyeloplasty.

sides, closing these transversely.

8.4.10. Albarran.

Albarran stated that he was the first to perform a lateral anastomosis in 1888, although he reported it in 1898. It was like Wölfler's gastroenterostomy. In 1898 he also described his "resection orthopedique pyelorenale", in which he excised the lower pole and lower lateral renal pelvis, extending the incision to the lateral wall of the pelvi-ureteric junction. The aim of the operation was to transform the hydronephrotic kidney and renal pelvis into a funnel at the expense of the lower pole of the kidney.

8.4.11. Schwyzer Y-V plasty.

In 1923 Arnold Schwyzer described his technique. Because the results of some operations had been unsatisfactory he apologised for offering another method. It was different in one essential point, in that he tried to avoid the difficulty encountered in linear division. With the transverse suture of the longitudinal incision, the part of the wall opposite the suture always tends to produce a valve-like fold. Also a good deal of puckering occurs

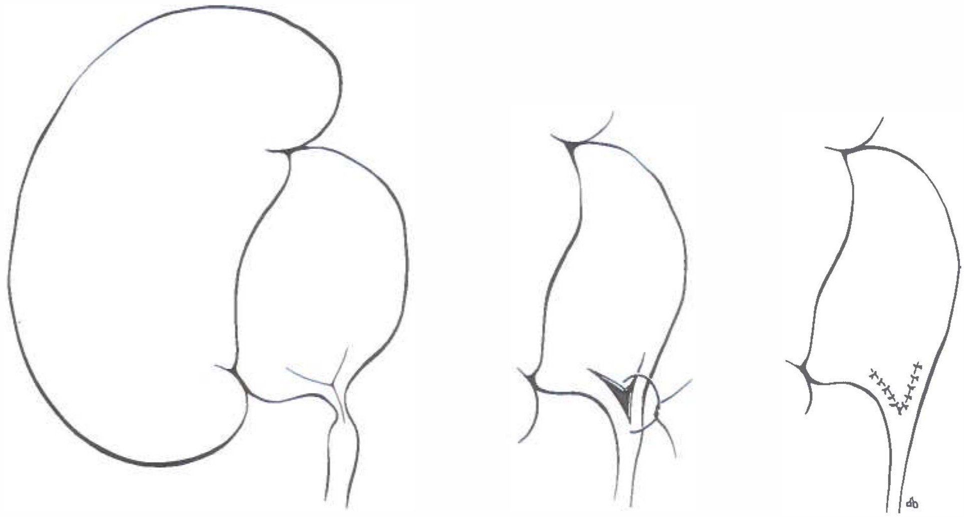


Fig. 8.2. The Schwyzer pyeloplasty.

at the site of the new pyelo-ureteral union (Fig. 8.2.).
Technique (as described by Schwyzer).
The pelvis and proximal ureter are dissected. An Y-shaped incision is now made with its center about ½ cm. above the PUJ. From here one leg runs downward into the ureter which is split for a distance of about 1 cm.. The two other legs of the incision run upward into the hydronephrotic sac with an angle of about 60 degrees between them. Each of the three branches of the incision is about 1½ cm. long. The tip of the triangular flap in the kidney pelvis is united by catgut with the lower end of the slit in the ureter, avoiding the mucosa. On each side sutures approximate the cut edges in such a manner that the folds, which always occur, are well up in the wide portion of the pelvis, while at the pelvi-ureteric junction the parts are smooth. The upper end of the ureter thus becomes funnel shaped. Two catheters are now inserted from the convexity of the kidney, one into the ureter, the other only into the pelvic sac. The former is removed after two days, the one in the kidney pelvis after three. Schwyzer mentioned three essential points:
1. the mucosa is not sutured, but brought into exact apposition;

this reduces the danger of formation of concrements.
2. at the junction of the pelvis with the ureter the parts are in linear approximation.
3. the bulges and folds which are unavoidably produced by sliding the flap downward to the end of the ureteric slit are adjusted at the upper end of the pelvic incisions, so that the pelvi-ureteric junction becomes neither kinked nor puckered.

8.4.12. Foley Y-V plasty.
In 1937 Frederic E.B.Foley published his paper: "A new plastic operation for stricture at the uretero-pelvic junction". Already in 1923 he had devised this new method. He withheld the first description of the operation until he could give a report of some long term results. Foley considered another technique because he was unsatisfied with the results of several procedures which he had used. From the technical standpoint all these procedures had one or more of the following faults:
1. undesirable puckering or folding at the suture line.
2. persistence of high insertion of the ureter.
3. absence of gradual funneling of the pelvis into the ureter.
The last is common to all of them except Schwyzer's Y-V plasty. Conversely absence of puckering, correction of high insertion and gradual funneling, all accomplished by one procedure would appear most desirable. Foley thought his technique met all these requirements. The Foley Y-V plasty differs from the Schwyzer operation in that in the Schwyzer operation the incision is made in one plane with distortion of the incision by suturing whereas in the Foley operation the incision is made in two planes with direct opposition of both planes for approximation and suturing without distortion. Correction of the usual high insertion of the ureter should be considered an important detail in any operation for pelvi-ureteric junction. Failure to correct this abnormal relationship leaves a segment of ureter below the junction lying in contact with the pelvis and the PUJ remains high. A one-way membrane valve effect is thus produced similar to the uretero-vesical valve. Under certain conditions of distension and pressure, passage of urine from the pelvis will be prevented in the same way that prevents regurgitation (reflux) of urine from the bladder into the ureter.

Technique (as described by Foley).

A large incision with adequate exposure and complete freeing of the kidney are essential. It is folly to undertake a procedure technically so exacting under the handicap of insufficient room. By careful examination the exact anatomic relations present and responsible for obstruction are determined. Particular attention is paid to the vascular arrangement and discovery of anomalous vessels playing a part in the obstruction. If such vessels are found they are held out of obstructing contact with the ureter while pressure on the pelvis determines its freedom of evacuation and the presence or absence of intrinsic obstruction. A relatively high insertion of the ureter is usually present so that the lateral wall of the ureter is opposite to or in contact with the medial wall of the pelvis. Almost regularly connective tissue or fibrous tissue adhesions are present between the pelvis and the segment of ureter in contact with it. Adhesions present between the pelvis and ureter are completely severed thus accurately exposing the pelvi-ureteric junction. The latter is carefully examined by inspection and palpation and if necessary by instrumental exploration through a small pyelotomy opening. By these means the presence or absence of a "stricture" and the need for a plastic operation are determined. The kidney and ureter are held in position to give facility in accurately placing the Y incision in the pelvis and ureter. The stem of the Y is placed in the lateral wall of the ureter and thus will face the pelvis when the normal position if restored. The incision is carried through the uretero-pelvic junction and downward in the medial wall of the pelvis, an appropriate distance below the uretero-pelvic junction. From this point the incision continues as two diverging limbs in the lower medial wall of the pelvis in the form of an inverted V. The incision in the pelvis plus the length of the V shaped flap are equal in length. The triangular opening in the pelvis and the triangular shaped flap of pelvic wall when turned down, face directly the incision in the ureter and the apex of the flap fits directly into the lower angle of the ureteric incision. Using closely spaced interrupted sutures of 4/0 chromic catgut embracing only the muscularis with careful avoidance of the mucose, the edges of the ureteric incision are approximated directly to the

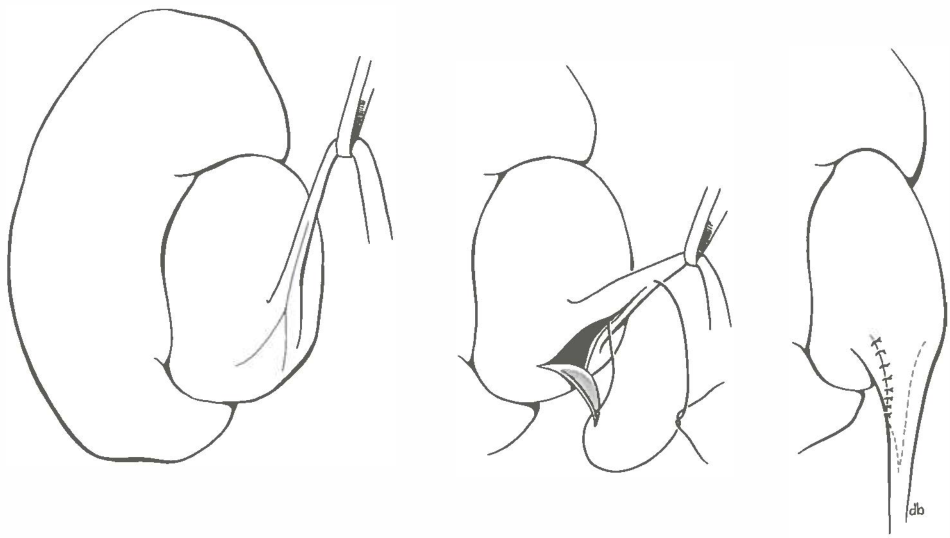


Fig. 8.3. The Foley pyeloplasty.

edges of the triangular defect in the pelvis, the tip of the flap fitting neatly into the lower end of the ureteric incision. Upon completion of the suture a soft rubber catheter of size 10F or 12F is introduced through a small stab opening on the posterior surface of the pelvis and is directed into the ureter for a distance of 6 or 8 cm.. A number of small fenestrations are cut in the intrapelvic portion of catheter. The catheter serves to splint the sutured segment and provides for drainage of urine from the pelvis. It is left in place for about one week. A second catheter extending only into the pelvis is also introduced for through and through irrigation. Upon removal of the splinting catheter this second catheter may be used to test the efficiency with which a coloured solution such as mercurochrome will pass downward into the bladder.

8.4.13. Davis. Intubated ureterotomy.

In 1943 David M. Davis described his new technique for correction of pelvi-ureteric and upper ureteric narrowings. In 1948 he wrote that he believed the first person to perform this type of operation was E.L.Keyes Jr. in 1915. A few other attempts at similar operations escaped his attention, amongst which should be mentioned Ormond (1936) and Mc Iver (1939). Davis referred to a case 10 years previously when he was faced with a dense, fibrous, thick walled stricture of the upper ureter. He successfully applied the principle of the Rammstedt operation for pyloric stenosis and divided the stricture longitudinally, passing through all the layers of the ureteric wall except the mucosa.

The question of splinting after pelvi-ureteric plastic operations arose with every operation but he had the impression that the results were better in the splinted cases. Another aspect of the problem appeared as a result of experiences with urethral strictures. Twenty years previously Davis had treated a patient with a severe urethral stricture by incising the stricture and splinting the urethra with a 24F. catheter which was left in situ for 3 weeks giving an excellent result.

In 1940 Davis was confronted by a patient with a narrow, thin walled stricture of the upper ureter just at the point where the ureter disappeared into the kidney, with a completely intrarenal pelvis. An ureterotomy was made from the kidney downwards through the stricture. A 12F rubber catheter, with fenestrations to drain the pelvis was introduced through a nephrotomy into the ureter. The ureter was closed loosely around it with a suture of 3/0 plain catgut. The tube was removed on the 14th day with an excellent result. In the same paper he described four other patients. The second patient was identical except that he used no ureteric sutures and that the tube was accidentally pulled out on the 10th postoperative day . This result was also good. The third case was somewhat different. There was a markedly distended extrarenal pelvis with a stenotic area 1¼ cm in length just below the pelvi-ureteric junction. The stenotic area was incised longitudinally and a 14F. rubber tube was passed down through the pyelotomy into the ureter to a point about 3,5 cm below the incision in the ureter. Openings were cut in the tube to drain the pelvis. No sutures were used in the ureterotomy. The tube was pulled out on the 15th day. The result was good. The fourth patient had a narrowing just below the pelvi-ureteric junction. There were bands of adhesions joining this part of the ureter to the pelvis, and the lower portion of

the pelvis was rounded and projected a little below the pelvi-ureteric junction (high insertion). Via a pyelotomy it was impossible to pass a probe into the ureter, it always pushed out the lower portion of the pelvis. The ureter was therefore incised, beginning at the point where the narrowing began. The incision was carried upward until one could see within the ureter the tip of the clamp covered by a thin membrane, evidently a congenital valve! (the pictures is his paper show a classic high insertion). This was seized with forceps and excised with scissors. The clamp then passed freely down into the ureter. A 14F rubber tube was then passed through the pyelotomy down the ureter to a distance of about 5 cm. below the ureterotomy. A pyelostomy drain was left behind. On the 16th day the ureteric tube and the pyelostomy was removed. The result was good. The fifth patient had a long stricture of the ureter of about 12 cm. which was incised longitudinally. A 16F T-tube was used. The ureteric wall was held in close approximation to the tube by some 3/0 plain catgut sutures. On the 31st postoperative day the T-tube was pulled out. The result was good.
Davis came to the conclusion that intubated ureterotomy is an extremely valuable procedure. In the intubated ureterotomy, no effort is made to draw the tissues into a new form, and no sutures are used. The operation depends upon the physiological repair process of the tissues. The splint is a mould upon which the tissues, by their own proliferation, reconstruct the ureteric channel with a normal size and shape. At that time Davis had no idea what really happened and only later this became clear. He thought that the use of an ureteric or pelvi-ureteric splint, the size of the splint, its shape (and later the material) and the length of time it is left in place were the most important points. A tube used for this purpose should be the largest that will enter the uncut, or presumably normal, part of the ureter without fitting so tightly that it will cause ischaemia of the wall. If a splint is withdrawn too soon, it will fail of its purpose. The allowance of time for the tissues to reconstruct themselves about it should be generous, erring on the longer rather than on the shorter side. Three weeks may be enough, but should be regarded as a minimum. Davis believed it would seldom be necessary to leave a splint in place more than

4 or 5 weeks. The provision of fully adequate, continous drainage for the urine during the period that the splinting tube remains in place is essential for success.
In 1948 Davis answered to the following questions most frequently posed concerning his procedure:
1. What is the best size for the splinting tube?
2. How are calcareous deposits in the tubes to be overcome or prevented?
3. How long should the splint be left in place?
4. How does the ureter and particularly its muscularis heal around the tube?
5. Is the healed, reconstructed ureter capable of peristalsis?
6. Will there be adynamic dilatation of the ureter?
7. Does infection interfere with good results?
8. Will there be late strictures, so that good original results deteriorate?
His answers were:
ad.1. The splint tube should be as large as possible; experience shows that even if it fits the ureter fairly tightly, ischaemic necrosis does not occur.
ad.2. Calcareous deposits are combated by irrigation with acid solution.
ad.3. Experiments in 6 dogs showed that it is safe to assume that healing will occur in 4 weeks.
ad.4. The experiments showed that probably the muscle does grow around the entire ureter.
ad.5. The experiments showed that the reconstructed ureter is capable of peristalsis.
ad.6. Adynamic dilatation of the ureter had never been observed.
ad.7. Infection apparently did not prevent good results unless the kidney was so greatly dilated that infection persisted even after the ureteric obstruction was relieved. Of 10 cases infected before operation, 8 became sterile afterward.
ad.8. In this series there was one case in which there was a stenosis of the ureter occurring 2 years after operation; but the stenosis was not at the site of the original stricture, but was opposite the point at which the lower end of the splint tube had lain; as a result of this finding he had tended more and more to increase

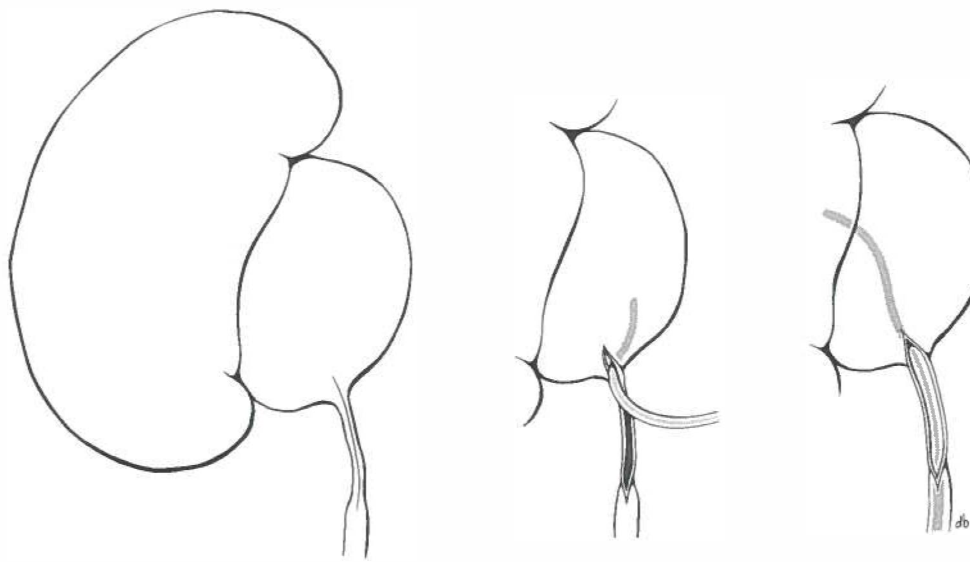


Fig. 8.4. The Davis pyeloplasty.

the length of the splint tube, preferably so that it will extend in every case over the pelvic brim into the pelvic ureter.
In the discussion concerning this paper Henline (1948) remarked that:
ad.1. Clinical experience and animal experimentation had proven that the use of a large splint in the ureter is never followed by pressure necrosis in the ureter.
ad.2. The greatest hazard with prolonged nephrostomy or pyelostomy drainage with splinting of the ureter is the tendency to the formation of renal calculi; in his series of 45 patients in which a nephrostomy tube and splinting ureteric catheter had been allowed to remain in position for 6 weeks, 11 per cent of the patients developed renal calculi.
ad.3. Kimbrough published his series of 7 cases in 1950. He removed the splints 14-35 days postoperatively. The results were equally satisfactory in patients from whom the tubes were removed after 14 days as in those retained for 35 days. There appeared to be little advantage in retaining tubes for long periods.
In 1951 Davis summarized the advantages, or as he called them, the "points of superiority" :

1. The operation is equally applicable to all cases, regardless of the length, location or multiplicity of the strictures.
2. It is simple and rapid to perform.
3. No sutures whatever are used, so that no dependence needs to be put on the holding of sutures.
4. Since the splinting tube can be left in place as long as desired, good results have been obtained in many cases even in the presence of gross infection.

Moreover he mentioned that some surgeons had had difficulties and failures, including himself. He believed that in such instances the difficulties had been due to errors in technique and he had attempted to remove the causes of imperfect results by modifying the method of performing the operation.

Schwartz (1952) preferred to bring the splinting and drainage tubes out through a nephrostomy while Davis always used pyelostomy drainage where possible. Schwartz did not agree with Deming's (1943) argument that this induces infection and renal scarring, with hypertension as a later possibility. He had come to favour the use, in general, of polyethylene tubing, which ran the entire length of the ureter and out of the urethra. The upper end emerged through the lower pole of the kidney alongside a Foley catheter, which drained the kidney pelvis. When a simple stenosis of the pelvic outlet existed, multiple short linear incisions through the stenotic area down to the mucosa were sufficient. When the stenosis was more extensive, a single vertical incision was made extending through all coats of the ureter for the length of the involved portion. The diameter of the splinting tube should conform closely to the size of the normal part of the ureter without causing pressure on its walls. The purpose of the splint was to act as a scaffolding and not as a dilating medium. Schwartz thought that a tight splint was likely to cause eventual fibrosis and constriction. The splint was pulled down the ureter by being fastened to an ureteric catheter, which had been passed up the ureter cystoscopically prior to operation. Because in some cases the tubing caused urethral irritation when it was left in place for several weeks, the tube as it emerged from the urethra was cut off and the end was drawn back into the bladder.

In 1955 Lapides published his experiments to investigate the factors involved in failure of Davis type intubated ureterotomy. He came to the conclusion that in dogs complete regeneration of the mucosa was present by the end of the third week. The defects in the ureters were not bridged by smooth muscle until the sixth postoperative week. The evidence obtained in his study suggested strongly that ureteric smooth muscle regenerates to a marked degree. The experimental findings indicated also that periureteric fibrosis is the most important factor in the failure of the Davis procedure. This complication can be avoided partially by enclosing the incised portion of the ureter in retroperitoneal fat and by preventing prolonged leakage of urine into the operative area.

Oppenheimer and Hinman (1956) undertook important research concerning the repair of ureteric defects and the ureter after transection. In their excellent paper: "The effect of urinary flow upon ureteral regeneration in the absence of a splint", they come to the following conclusions:

1. Continued urinary flow through experimental ureterotomies increased periureteric fibrosis but did not significantly affect the degree of healing of the defect. Urinary flow did not greatly change the pattern of regeneration, but the process took longer.
2. Reconstruction of all layers of the ureteric wall was hindered if the edge was forced to lie free in the retroperitoneal space. The role of the splint was to act as a guide for epithelial regeneration. Without a splint, primary epithelialization was deranged so that an abnormal muscular coat was laid down, resulting in incomplete ureteric regeneration.
3. The principal sequel to nonsplinting of an ureteric incision was derangement of primary epithelialisation, made worse by urinary flow.

Their experimental work showed that first epithelialisation can take place and that complete reconstitution of the muscular coat occurs by actual smooth muscle regeneration, arising mainly from the cut edges of normal muscle.

There are some factors that influence epithelialisation. Hinman (1957) concluded that the damage from urinary flow was greater than any beneficial hydraulic effects, such as Johanson (1953) described for urethral healing. Moreover, healing against peritoneum progressed more readily, with more nearly normal primary epithelialisation, than against fascia. His experiments tended to show that a rigid fibrous bed is hostile to the reformation of an epithelial lined tube and hence to adequate regeneration of the ureteric wall.

Creevy (1956) advocated intubated ureterotomy in patients who had been operated upon previously and had dense scar formation. The period of intubation may profitably be extended for as long as a year, as was done in a patient he described.

8.4.14. Stewart. Nephroplication or nephroplasty.

In 1947 H.Hamilton Stewart published his paper called: "A new operation for the treatment of hydronephrosis in association with a lower polar (or aberrant) artery". Encouraged by his initial success (10 years earlier) he used the operation at first for cases similar to the original one with large polar arteries, but in 1947, as these continued to give uniformly successful results he extended its use to all cases judged worthy of conservative surgery. Only later he realized that he had been copying and attempting to re-establish the anatomical relationship of infancy. Kelly and Burnam (1942) had shown that in the infant, the kidney is arched upon itself to such an extent that the two poles approach each other very closely over the enclosed pelvis. If a lower polar artery is present in the infant, it will lie in close relation to the main renal artery, and in this position, he thought, is unlikely to produce outflow obstruction. As the child grows, the kidney opens out rather like a bud developing into a flower. The poles diverge markedly from each other and in this straightening out process the lower polar artery becomes separated from the renal artery, and is now in a lower position and is, as he thought, capable of producing obstruction. After the operation the "infant" relationships are re-established. Because lower polar arteries from the aorta or main renal artery are fairly common and obstruction by such a vessel is relatively rare, Stewart thought, that an additional factor or factors must be present. He wished to demonstrate, in his paper, that whatever the precise factor may be, the operation described cured the pathological condition. Stewart did not believe that a congenital stricture (or neuromuscular defect at the pelvi-ureteric junction) played an important part and that the aberrant artery was a minor factor. He thought, and the uniform success of the operation suggested it, that the presence of a stenosis in association with an aberrant renal artery must be rare. He mentioned the disadvantages and dangers of the old operations: infarction, infection, loss of renal tissue, imperfect drainage with the risk of persistant infection introduced through drainage tubes, stenosis of the ureter with fistula formation etc.. Stewart mentioned that the operation described can be used for all cases deemed worthy of conservative surgery. The bloodsupply is not interfered with nor is the pelvi-ureteric continuity disturbed. As a drainage tube is not inserted into the kidney pelvis or ureter, there is no risk of introducing infection into the urinary tract from the skin and provided the operation is carefully performed, there is no risk of fistula formation. The main underlying principle of the operation is the "moulding" of the kidney so that the lower polar or aberrant renal artery comes into close relationship with the renal artery. In this position it is no longer capable of causing obstruction. The poles of the kidney are brought together as in the infant. The anterior surfaces of the poles are brought together so that a broad and secure grip is obtained and the kidney is thus held permanently in its new shape.

Technique (as described by Stewart).

1. Exposure of kidney. Any of the recognized loin incisions may be used. The exposure of the kidney is followed by a dissection displaying the lower polar or aberrant artery and the pelvi-ureteric junction.

2. Relief of renal distension. In the majority of cases, once the pelvis and ureter have been dissected free from the lower polar vessels (artery and vein), and many minute vessels or adhesions maintaining the kink (whether situated in the ureter or at the pelvi-ureteric junction or in the pelvis) have been divided, the distension of the pelvis and kidney can be relieved. The prolapsed pelvis is raised over the obstructing vessels and at the same time gentle traction is exerted on the ureter in its long axis. The urine flows rapidly down the ureter. If the hydronephrosis is gross and the tension in the kidney considerable, a needle

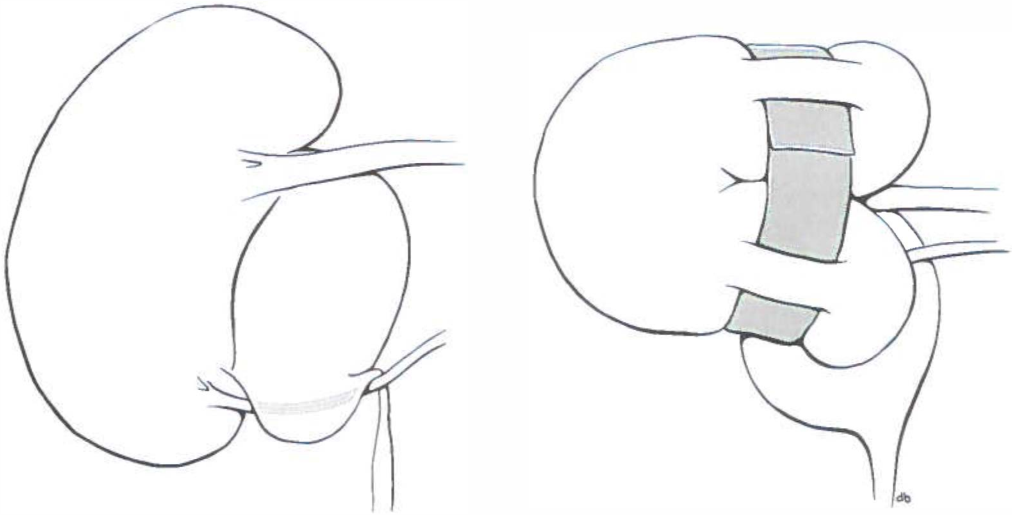


Fig. 8.5. The Stewart pyeloplasty.

connected with a suction pump is passed obliquely through a relatively normal part of the kidney tissue into the pelvis and the urine aspirated. This procedure should be carried out with all aseptic precautions, particular care being taken if the urine is infected.

3. Mobilisation of the lower polar vessels and renal pelvis. The lower polar vessels (artery and vein) should now be freed from the sheet of connective tissue in which they lie, so that they can without difficulty be raised to a higher level. The testicular or ovarian vein may require division on the left side. The pelvis should be dissected free on its inner aspect from the same sheet of connective tissue as above so that the pelvis now becomes free and is in a suitable condition for plication if necessary at a later stage in the operation. Any adhesions retaining the kink should be divided.

4. Remodelling of the shape of the kidney. The capsule is reflected from the front of the upper and lower poles of the kidney and is left attached at the convex margin. A dura mater elevator facilitates separation of the capsule. The kidney is grasped in

both hands, and the upper and lower poles are brought together. Owing to the fact that renal distension has previously been present, this position and the subsequent position are easily obtained. The anterior aspects of the upper and lower poles are then brought together so that the kidney now becomes ballformed.

5. Retention of the kidney in its new shape. Plain catgut sutures are now placed through the upper and lower lobes, the sutures being so placed that when tied they will help to retain the kidney in the new shape. Catgut tape (hardened) is now threaded under the capsule along the new convex border of the newly shaped kidney rather like a rim round a wheel. The hoop of catgut is fixed at the front with sutures. Care must be taken that the tape lies quite flat. The plain catgut sutures (about five in number) are now tied lightly. The two pieces of reflected capsule are brought together and sutured. It will thus be realized that the kidney is retained in it new shape by: 1. The hoop of catgut tape; 2. The sutures in the kidney tissue apposing the anterior surfaces of the poles; 3. The overlapping and suture of the capsule which has been seperated from the poles of the kidney. Traction is now made in the long axis of the ureter and if dissection has been adequate the pelvis will come to lie mainly below the aberrant artery, which should now lie in close proximity to the renal artery.

6. Plication of the pelvis. The pelvis is plicated at the front and back by the use of interrupted 6/0 catgut. Care should be taken that the sutures do not pass into the lumen of the pelvis.

7. Replacement of the kidney. The kidney is now replaced and the renal space is drained for 48 hours. No attempt is made to perform a nephropexy.

Adams (1951) called Stewarts operation nephro-plication and found it a somewhat elaborate procedure. Instead of ribbon catgut he preferred a fascial strip from the thigh as an encircling band and threaded it through slits in the capsule, which was otherwise left intact. Adams conclusion about nephroplication was: 1. A clinical cure is usually achieved; 2. The reduction of stasis is startling in the postoperative urography, and the normal calyceal pattern, a vertical fan, changes to a horizontal cluster; 3. There is surprising adaptability of circulation and satisfactory survival of excretory function despite the increased tension of a drasti-

cally altered pose.
In 1957 Stewart himself called his operation nephroplasty and mentioned that the hydrodynamics of the hydronephrotic kidney are improved and renal residual urine is eliminated or reduced. He wrote: "When observing the results of operations for the treatment of hydronephrosis uncomplicated by stone I have been struck by the superior results obtained after nephroplasty (nephroplication) operations for the relief of lower polar vessel obstruction as compared with those obtained after excision of a ureteropelvic stricture. At first I was inclined to explain this observation by the fact that an anastomosis had been performed in the latter operation which would interfere, at least temporarely, with normal peristalsis. This explanation did not, however, make it clear why the ultimate results should be different. I was fortunate in having the opportunity of putting the above observation to the test and finding the explanation. A case of hydronephrosis due to stricture of the upper end of the ureter had been treated by excision of the stricture and partial excision of the pelvis followed by anastomosis. Two years later some dilatation of the calyces persisted, although ascending ureterograms showed a satisfactory lumen at the site of the anastomosis. I operated upon the kidney again and absolutely avoided any interference with the site of the anastomosis and performed a nephroplasty. The result of this procedure was very gratifying. The calyces decreased in size and many of those which had been dilated previously now had a normal cupped appearance. Other cases have verified this finding. It thus appears that when a nephroplasty is performed the hydrodynamics of the kidney become more efficient, the calyceal capacity reduced, and the renal function improved. The "moulding" of the kidney is more difficult if the calyces are not dilated, the pelvis being principally involved. Provided the surgeon, however, carries out the various movements slowly, splitting of the kidney along its convex border should not occur. On those rare occasions when a slight split has occured, nothing has been done and no ill-effects have resulted. In these latter cases, as the tension on the tape may be above average, it is advisable to pass the tape around the kidney twice".
Although nephroplasty seemed a rather traumatic procedure to the

kidney and never established a prominent place in the surgical management of pelvi-ureteric obstruction, Smith presented a series of 17 patients in 1979. All patients were treated by pyeloplasty (7 Anderson-Hynes and 5 Culp) and nephroplasty . The aim of the nephroplasty was to reduce the intrarenal dilatation and to improve drainage by elevating the lower pole calyx.

8.4.15. Culp - De Weerd. Pelvic flap operation.
In 1951 Osmond S. Culp and James H. de Weerd published their paper: "A pelvic flap operation for certain types of ureteropelvic obstruction". They had obtained their best results with the Foley Y-V operation. This was designed primarily for kidneys with a high insertion of the ureter on a large extrarenal pelvis. It was their procedure of choice in such cases, but only about 66% of their cases of stenosis and "achalasia" had been associated with high insertion of the ureter. Adequate treatment in the remaining cases had been a major problem. Dependent obstructions were treated by reimplantation of the ureter in the pelvis. Long segments of constricted ureter had required intubated ureterotomy as described by Davis (1943). Since many of their results had been rather disappointing, they were stimulated to try to devise some solution other than intubated ureterotomy when they encountered 4 cm. of narrow ureter below a dependent pelvi-ureteric junction.
Technique (as described by Culp and De Weerd).
Converging incisions from a broad, slightly oblique base adjacent to the original ureteropelvic juncture are joined after following the spherical contour of the dilated renal pelvis for sufficient distance to assure a flap longer than the constricted segment of ureter. Since the enlarged pelvis is much like a ball poised on the end of a narrow spindle, the flap falls parallel to the upper end of the ureter without angulation. The ureter is incised beyond the lower limit of the constriction and corresponding edges of split ureter and pelvic flap are united with interrupted sutures of size 3/0 chromic catgut. A splinting tube of appropriate caliber and a separate nephrostomy tube are inserted through one of the calyces in the lower pole, after which the splint is passed down the ureter for several centimeters. The remaining edges of the flap and ureter are sutured over the splint and the defect in the

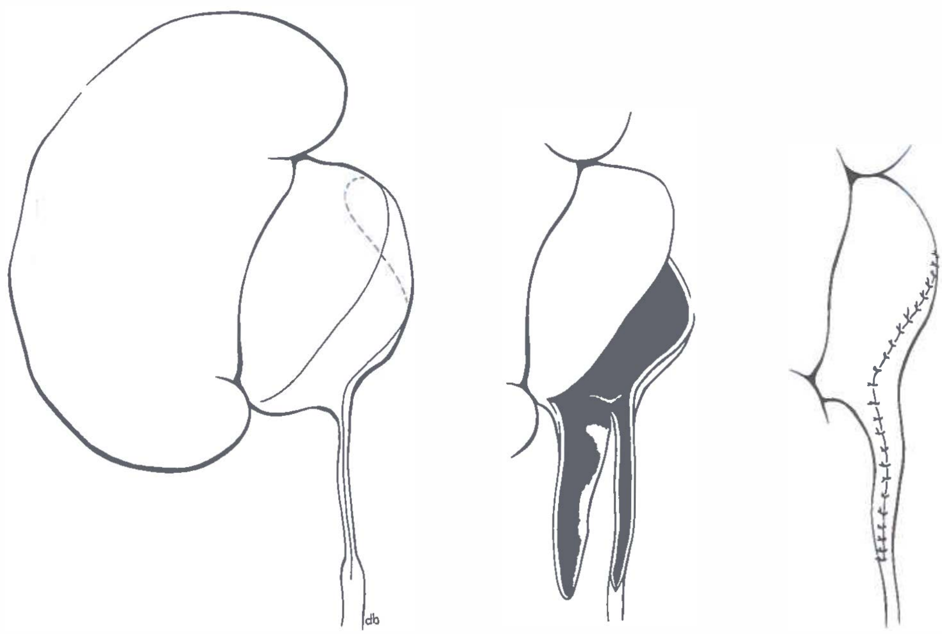



Fig. 8.6. The Culp- de Weerd pyeloplasty.

pelvis is closed. They usually removed the ureteric splint at the end of two weeks and took out the nephrostomy tube twenty-four to forty-eight hours later.

This operation has been used only when the obstructed pelvi-ureteric junction has been dependent. The length of the flaps varied from 2 to 8 cm.. In some cases it was impossible to construct a flap long enough to compensate for unusually extensive ureteric narrowing and the flap operation was combined with the Davis intubation ureterotomy.

8.4.16. Renal capsule pyeloplasty.

An alternative way of reconstruction of the pelvi-ureteric junction after resection of part of the pelvis and the pelvi-ureteric junction by using pedicle grafts of renal capsule was advocated by Thompson et al (1963) and Michalowski (1964). The information derived from Thompson's study would appear to warrant the following conclusions:

1. The renal capsule is an abundant and readily available prosthe-

sis for upper urinary conduit repair.
2. It is feasible to cover extensive pelvi-ureteric defects with hinged pedicle flaps of renal capsule.
3. Despite reports referable to faulty transport of urine through reconstructed ureteral conduits, use of the fibrous renal capsule as a replacement for large portions of the upper urinary tract in dogs did not appear to be harmful to the renal function or urine transport.
4. Although smooth muscle regeneration may contribute to ureteric repair in many instances, such regeneration was not evident in any of the animals in his experiment.
In 1969 Thompson published a series of 14 patients with excellent results. However, he felt that the renal capsule flap should be used only when other techniques did not appear to be suitable.

8.4.17. Pyeloplasty by a free graft of peritoneum.
Kouwenhoven (1969) discussed 16 patients with pelvi-ureteric obstruction corrected by using a free peritoneal graft. Nine patients were operated for the first time, while seven patients had secondary operations. The results in the first group were better but the overall results were good. A splint via a pyelotomy was used for 3 weeks. Kouwenhoven refered to Lutzeyer et al (1964) who described a case where multiple ureteric defects caused by excision of small granulomatous tumors were successfully repaired with free grafts of peritoneum. The successful use also of a free peritoneal graft covering a defect in the abdominal part of the ureter in dogs was described by Post (1979).

8.4.18. Pyeloplasty by a free graft of renal pelvis wall.
Macauley et al (1970) advised in certain cases of pelvi-ureteric obstruction, surgical correction with a free graft of tissue from the wall of the renal pelvis. Certain requirements must be met:
1. The kidney must have a dependent pelvi-ureteric junction, or one that can be made dependent.
2. The renal pelvis must be large enough to allow for a graft of adequate size.
This procedure is contraindicated when the wall of the renal pelvis is markedly thickened and inflamed or when the pelvi-ureteric

junction is badly scarred and avascular. This operation is technically easy to perform. The graft, which may be precisely tailored to correct the obstruction, is free of limitations of a pedicle and may be used to repair more extensive obstructions involving the upper ureter. Macauley reviewed 15 patients operated in this way with good results.

## 8.5. DISMEMBERED PROCEDURES.

### 8.5.1. Küster, 1892.

Küster advocated resection of the upper end of the ureter and implantation of the distal end into the pelvis. His method was to split and unfold the end of the ureter, and to implant it into the dependent portion of the pelvis, to which it was united with sutures.

### 8.5.2. Bazy.

In 1897 Bazy used a modification of Küster's operation. In some instances he cut the ureter off obliquely instead of splitting it, in others he excised part of the pelvis, including the pelviureteric junction. He anastomosed the ureter to the lower part of the defect and closed the remainder.

### 8.5.3. Lubash. Uretero-pyeloneostomy.

In 1935 Samuel Lubash published his paper on a modification of the Küster operation (1892). Because Fenger's operation gave many failures, other methods were devised with the hope of eliminating puckering of tissue at the suture line and at the same time correcting the high insertion of the ureter. Quinby and Walters (1937) became the protagonists of this technique. The wish to make a good anastomosis without leakage was the basis of the Lubash method.

Technique (as described by Lubash).

The ureter is removed from its original site as near to its insertion to the pelvis as possible, as the strictured area is utilized at reimplantation. From this point on, the technique is almost identical with the method of Küster, popularized by Bazy as uretero-pyeloneostomy. The difference lies in the method of anastomosis. The ureter is incised downward on its anterior and posterior surface for a distance of 2 or 2.5 cm. and after insertion into the new orifice at the most dependent portion of the renal pelvis, the straps of the ureter are then drawn outward laterally from the pelvis through 2 very small stab incisions on either side of the new neostomy opening and a mattress suture is employed to fix them in position. The knots are placed outside the renal pelvis. From this point on, a resection of the redundant pelvis and a trans-renal drainage are carried out. A catheter used to splint the new anastomosis and a second catheter to drain the kidney are brought out through the same nephrostomy wound. Nephropexy is employed if the kidney was mobilized. He hoped that this technique would be an improvement based on the following points:

1. Little or no tension at the site of anastomosis.
2. The true diameter of the ureteric orifice remains intact, as there are no sutures through the edges giving rise to scar formation and shrinkage.
3. The two straplike projections are brought outside the newly established pelvis, thereby preventing any possibility of an obstructing valve-like formation.
4. At the same time the tension is reduced from the point of anastomosis.
5. No puckering or buckling can occur.

8.5.4. Wilhelm. Uretero-pyeloneostomy.

In 1943 Seymour F. Wilhelm described his method of uretero-pyeloneostomy, in which to prevent obstructive valve formation a technique was planned, whereby the pelvis is implanted into the ureter.

Technique (as described by Wilhelm).

The upper end of the ureter is split for a distance of 1 cm. into 2 straps. These straps are placed and sutured outside the pelvis. The anastomosis is made over a splinting catheter and a nephrostomy and nephropexy are also done. If the externally sutured ureteral straps should loosen, they would not obstruct the newly made stoma.

8.5.5. Neuwirt - Ureterocalycostomy.

In 1948 Neuwirt described this technique which he performed for the first time in 1932 on a patient with a solitary kidney which had been operated upon several times because of stones. There was so much scar formation in the renal hilum that reconstruction was thought to be impossible. The lower calyx was considerably dilated, reaching very deep and merely separated from the capsule of the kidney by a very thin layer of parenchyma. The thin wall

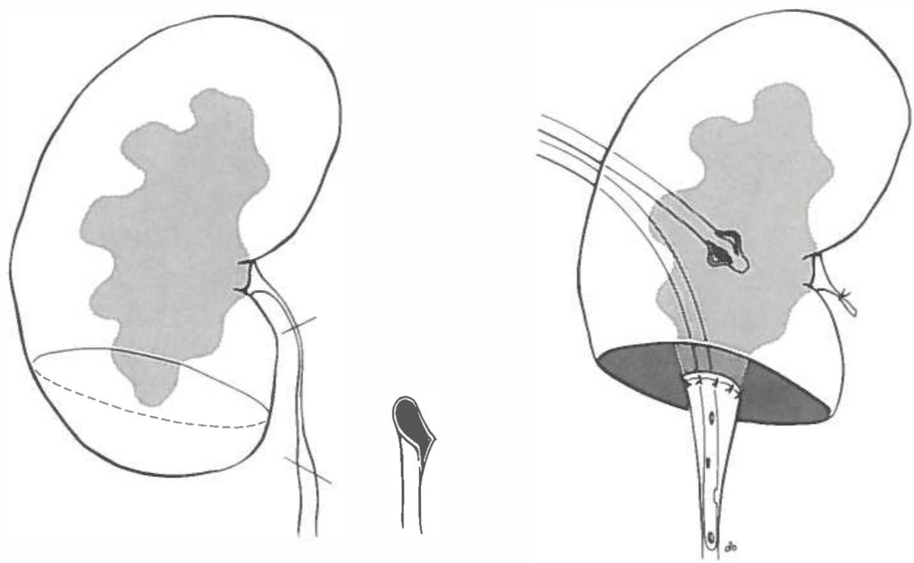


Fig. 8.7. The Neuwirt pyeloplasty.

of the calyx at the lowest level was pierced and the ureter was pulled into the renal pelvis with a catheter. The ureter was fixed to the capsule of the kidney. Then the ureteric catheter was pulled out through a nephrostomy and the pelvis was drained by a De Pezzer catheter.

Jameson (1957) also described a patient with a solitary hydronephrotic kidney caused by obstruction at the pelvi-ureteric junction. Reconstructive surgery in the hilum was considered impossible, so an anastomosis was made between the lower calyx and the ureter. Several mattress sutures were taken through the parenchyma closing the nephrostomy of the lower pole of the kidney over that portion of the ureter coursing through it. Later on a lower pole amputation and a new ureterocalycostomy had to be performed because the ureter was compressed by scarring of the parenchyma. The polyvinyl splint was removed on the 36th day, the nephrostomy on the 63rd.

Michalowski (1970), who published his experience with 10 patients, and also McLoughlin (1976) advised that in this procedure adequate removal and tapering of the surrounding renal tissue is required to prevent scarring and stenosis.

8.5.6. Anderson-Hynes pyeloplasty.

In 1949 J.C.Anderson and Wilfred Hynes from Sheffield, England, described their technique that is nowadays probably the most widely used procedure for correction of pelvi-ureteric obstruction. Originally the operation was used in a case of retrocaval ureter. They felt, that an anastomosis between the ureter and the pelvis would be more satisfactory than an anastomosis between two segments of the ureter as was done before and which had led to a stricture.

Technique (as described by Anderson and Hynes).

With the patient supine, the kidney is approached through an oblique incision commencing at the tip of the twelfth rib and extending to the outer border of the rectus sheath. If the twelfth rib is long, the anterior portion can easily be resected. Sometimes the rectus sheath is opened. The approach is extraperitoneal and it gives an excellent exposure of the pelvi-ureteric junction; this is necessary if the procedure is to be carried out under optimal conditions. In cases of pelvic hydronephrosis the upper end of the ureter, uretero-pelvic junction, and the upper redundant part of the renal pelvis are resected. Anatomical relationships are maintained by means of a silk stay-suture in the upper ureter. A pelvic flap is turned down from the lower part of the pelvis. The upper two thirds of the opening thus created in the renal pelvis are closed by a continuous plain 4-0 catgut suture through all layers. The upper end of the ureter is split downwards for a distance of 2.5 to 3 cm. and its edges are anastomosed to the edges of the aperture in the lower third of the kidney pelvis and to the edges of the pelvic flap by a continuous plain 4-0 catgut suture through all the layers. The fact that the lower part of the renal pelvis is turned down as a flap ensures that the pelvis is drained at its most dependent part. The method also ensures that the new pelvis, which consists of the pelvic flap and the upper split portion of the ureter, drain into a ureter which has scar tissue at only one point of the circumference and which is not encircled by a circumferential scar. Subsequent contraction of the anastomotic scar cannot cause stenosis

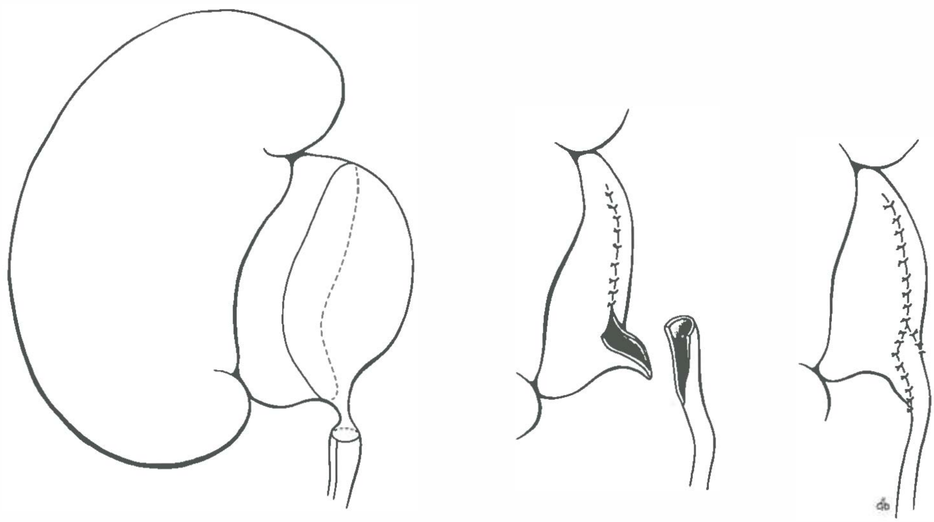


Fig. 8.8. The Anderson-Hynes pyeloplasty.

of the lumen of the ureter and thus interfere with drainage of the pelvis. Stenosis and stricture formation are inevitable if the ureter is cut straight across and anastomosed directly to a small aperture of similar size in the renal pelvis.
In the cases recorded the anastomosis was not "splinted" by an indwelling catheter nor was a nephrostomy established. Despite the fact they had had no trouble in a few cases in which the nephrostomy was omitted, they later employed it as a safety valve for a few days only.

8.5.7. Nesbit - Elliptical flap ureteroneopyeloplasty.
Nesbit (1949), dissatisfied with the constrictive tendency of the anastomosis with the transverse cut ureter, advised the elliptical anastomosis. For correction of hydronephrosis he proposed two possibilities: 1. Without excision of the redundant pelvis and 2. with excision of the redundant pelvis, the operation then being almost similar to the procedure of Anderson-Hynes.

8.5.8. Tube-flap pyeloplasty.
In 1972 Sand and Connolly described this method and referred to

Benady (1968). This procedure can be performed in cases of a dilated renal pelvis with the obstruction at the pelvi-ureteric junction or proximal ureter.

Technique (as described by Sand and Connolly).

After dissection of the region involved the site of the obstruction is inspected. The length of the tube required is determined and the limits of the pelvic flap are outlined. The base of the flap should be at the lowest part of the pelvis so that no pocket of residual urine will remain. The pelvi-ureteric junction is transected and the defect in the pelvis is closed. If one is dealing with an upper ureteric stricture in the vicinity of the pelvi-ureteric junction, the diseased segment can be removed if feasible or the flap can be used to bypass the area. An area of normal ureter is selected for anastomosis and at this site the ureter is transected and the stoma is spatulated. The anastomosis is made and the tube is fashioned and sutured with 3-0 chromic catgut. A ureteric catheter (5 F), as a splint, is brought out along with a pyelostomy tube. The defect in the pelvis is closed. The splint is removed after 10-14 days. If there are no contraindications the pyelostomy tube is removed the following day.

## 8.6. Effect of transection of the ureter.

This chapter would not be complete if the effects of transection of the ureter on peristalsis were not discussed. In all dismembered pyeloplasties the continuity is interrupted, so it is of great importance to know what happens to the peristaltic activity. By considering the different theories of myogenic and neurogenic ureteric peristalsis, the significance and effect on peristalsis of surgical interruption and healing of the pelvi-ureteric junction can be discussed. A great deal of available information originates from animal experiments but is borne out by clinical experience.

Simple longitudinal incision into the wall of the ureter or through the pelvi-ureteric junction elicits minimal interruption of ureteral activity. Postoperative management of such incisions often consists simply of providing ready access of extravasated urine to the surface by the use of drains. Primary repair of the urete-

ric wall is not necessary and could be detrimental of the blood supply were to be compromised by the placement of sutures. Urinary leakage ceases within a few hours provided there are no secondary inflammatory changes in the ureteric wall. On the other hand, circular or spiral incisions, particularly those that circumscribe the conduit system, disrupt completely ureteric peristaltic activity at that point and are accompanied by extravasation of larger quantities of urine over a longer periode of time.
The natural response to urine outside the urinary tract is fibrosis and the delay in conduction time of a peristaltic wave may be directly proportional to the degree of fibrosis.
Using laboratory animals, Butcher et al (1957), and others have shown that peristalsis below an anastomotic site is dependent upon the presence of activity above the junction. Excision of portions of the renal pelvis, the pelvi-ureteric junction, and the upper ureter disrupts normal activity across the anastomotic site for a prolonged period of time. This combined with a long suture line means that leakage of urine around the site of repair is quite common. Furthermore, complete resection of a portion of the conduit system provides a barrier to the transmission of activity from one muscle cell to another, whether it being mechanical, electrical, neurally mediated activity or otherwise. In contrast to complete excision of the ureteropelvic junction, maintenance of a continuous ridge of the original conduit wall provides an avenue for propagation of peristaltic activity from the proximal to the distal portion of the system. In animal experiments, recovery of normal peristaltic activity following excision of a segment of the conduit system and reanastomosis has required as much as 28 days. This could contribute to the development of the hydronephrosis one often encounters in the first weeks after the operation. There is a functional defect in the peristaltic conduction mechanism at the anastomosis.
Butcher and Sleator (1956) have described the action potentials of the transected and anastomosed ureter in carefully detailed experiments. They observed that a discrepancy exists in the rate of peristalsis above and below the transverse section of the ureter.They asserted that after healing has occurred, a lag in conduction is still maintained across an anastomotic site.

However, Weinberg and Siebens (1958) were able to demonstrate a uniform frequency of peristalsis through the length of the healed ureter after transverse section and anastomosis. This discrepancy may be due to a difference in surgical technique. Whereas Butcher and Sleator performed a circular end-to-end anastomosis, they used in their experiments a proximal linear ureterotomy allowing for urine diversion and an oblique end-to-end anastomosis, obtaining a very fine scar that normal peristalsis was not interrupted, making it more likely that they produced in this way less disturbance of transmission of peristaltis. It is evident, however, that immediately after transection of the ureter, different rates of peristalsis can exist at either side of the transverse section. Stasis and extravasation of urine is inevitable, unless this effect is minimized by urine diversion (above the anastomosis). Iselin (1929) noted that peristalsis proximal to an anastomosis was much impaired for a week and perhaps longer. Benjamin et al (1956), by cineradiographic observation found that peristaltic contractions distal to the anastomosis were about one third of the total above, and were not synchronous. Hamm (1957) postulated delay in resolution of hydronephrosis on the basis of this behaviour. Hinman (1970), Butcher and Sleator (1956) concluded that it is evident that complete severance of the pelvi-ureteric junction with reanastomosis significantly decreases peristaltic continuity and urinary flow past the suture line for approximately 4 weeks.

8.7. Urinary drainage and splinting.

The perfect operation would be one requiring neither drainage nor splinting. Unfortunately, this ideal appears to be unattainable in the majority of cases. Opinion is divided on this point between the "splinters" and the "non-splinters".

Peck (1926) came to the conclusion, that splinting of the ureter was an useful adjunct to operative procedures for relief of upper ureteric obstruction with hydronephrosis and "forms of painful obstruction, without dilated pelvis". This was usually done in conjunction with probe dilatation of a ureteric "stricture" and nephropexy. Several patients with pelvi-ureteric obstruction were treated only by passing a ureteric catheter via a stab wound in the cortex to the bladder. The splint was removed on the fifth day. He started using splints in 1910.

Gibson (1939) stated that it should be axiomatic that the urologist uses ureteric splinting following operation in all cases of ureteric and renal calculi in which dense adhesions or other types of obstruction to free drainage, either intrinsic or extrinsic, exist about the ureter or renal pelvis. According to Gibson the same principle applies to plastic operations on hydronephrosis.

McIver (1939) introduced a new way of drainage and splinting. He had devised a self-retaining catheter for nephrostomy drainage with an extension tube for ureteric splinting, and a distensible bag.

Peck (1926) felt that the splint should be removed in 5 to 6 days. Priestly (1939) recommended splinting up to three months. McIver (1939), Gibson (1939) and Henline (1943) recommended the use of splints for varying periods between these two extremes. Sharp (1943) and Gibson (1939) reported a series of cases and considered the ureteric splint to be essential following ureteric surgery. On the other hand, Deming (1943) felt that the use of a splint was contraindicated unless infection already existed, because its use predisposes to infection. Davis, Strong and Drake (1948) have shown in their work on intubated ureterotomy, that healing of the ureter after excision of two-thirds of its circumference takes place in approximately four weeks. They did not feel that the presence of infection contraindicated the use of ureteric splints, or that it altered the successful expectancy of the procedure.

Cordonnier and Roane (1950) did experimental work on dogs. They splinted the ureters for periods of three days up till seven weeks. They found thickening of the ureteric wall, with definite muscle hypertrophy . This muscle hypertrophy is probably a compensatory factor due to increased ureteric peristalsis, brought on by the presence of a foreign body in its lumen. Since these findings were minimal up to about five weeks they concluded, that the optimal time for ureteric splinting would be three to four weeks, and that prolonging it beyond that time could lead to permanent changes in the ureteric wall.

Weaver and Henderson (1954) did experimental work on ureteric regeneration. They found that the ureter showed a marked ability to regenerate all its components. The mucosa is rapidly replaced, with the muscular filling in more slowly up until six weeks, when nearly normal components were present. In dealing clinically with an injured or diseased ureter they came to the following conclusions:

1. the ureter should be splinted.
2. the splint should be left in place for six weeks.
3. the ureter will reform with all its component structures and it will function adequately.
4. no resultant strictures were found.

Protagonists of splints have advocated its use to prevent obstruction from developing at the pelvi-ureteric junction. Hamm and Weinberg (1955) thought that an obstruction probably develops as the result of two principal causes. The first is due to kinking. The kidney, having been mobilized and consequently freed from its normal attachments to the perirenal fat, tends to occupy a lower position when replaced, resulting in redundancy of the upper ureter. This can be eliminated by placing the kidney high in the fossa and supporting it by nephropexy. The second possible cause was thought to be faulty repair of the apex of the V-shaped piece of renal pelvis as it is sutured into the pelvi-ureteric junction. They found that excessive suturing increased the tendency to fibrosis. Only a minimal number of fine chronic catgut stitches were used. No attempt was made to obtain a watertight closure. Drainage in the absence of the nephrostomy tube was porvided by either leaving a space of 1½ cm. unsutured in the renal pelvis or making a stab opening at another site.

Hamm and Weinberg concluded that pyeloplasties may be successfully done without the use of splinting or nephrostomy tubes. Adequate drainage can be provided by leaving a vent in the renal pelvis. Elimination of tubes produces satisfactory results because of the following points: 1. a short period of postoperative hospitalization; 2. a relative absence of infection; 3. relief of obstruction; 4. preservation of renal function.

Gibson (1956) also found the idea of a simple vent in the pelvis as a safety valve more logical than a nephrostomy or pyelostomy drainage tube because one thereby avoids the presence of a foreign

body in the urinary tract. He stated furthermore, that: "nature is a better judge of how long drainage should continue than the surgeon who arbitrarily maintains drainage for a certain number of days wondering whether it is too short or too long".
Experimental work on the effect of large caliber splints on ureteric healing was done by Weaver (1957). On the basis of his observations on dogs he came to the following conclusions:
1. a splint which must be forced into the ureter produces severe stricture formation, most severe at its distal end.
2. marked periureteric and perirenal fibrosis follow pyonephrosis.
3. a small splint, which is introduced with ease into the ureter drains adequately, produces no stricture formation and leaves a more than adequate lumen in the regenerated segment.
4. a large soft splint causes damage while a small firm one does not.
Smith et al (1960) also advocated pyeloplasties without diversion or splinting. They thought there were obvious advantages in avoiding tubes:
1. possible infection associated with the use of a tube is prevented; when active infection was present at the time of surgery, it seemed to clear more rapidly without tubes.
2. ureteric injury possibly due to splinting catheters is obviated.
3. parenchymal damage by nephrostomy catheters and possible associated vascular injury or haemorrhage are avoided.
4. hospitalization time is decreased.
Drake et al (1962) did an evaluation of the materials that can be used as ureteric splints. He compared the reaction in the dog ureter of latex rubber, red rubber, polyethylene and polyvinyl. In all cases there was thickening of the intubated ureter. Microscopically, this was due to a marked increase in both the submucosal connective tissue and the muscular layers. The submucosal zone thickening after one week was apparently due to oedema, fibroblastic proliferation and new vessel formation. Slight fibrosis was present at the end of 2 weeks. There was a massive increase in muscular substance. The irritative response which produces fibrosis and chronic inflammation is less with polyethylene.Silas-

tic is least irritative.
From his experiences and evaluation of the literature Crowel et al (1973) thought that the anastomosis of a dismembered pyeloplasty should be done over a snug splint and then replaced by a smaller one. He believed splints and nephrostomy tubes definitely should be used in cases of reoperation or where small caliber ureters, calculi and infection of atonic pelves are involved.
Stadie (1974) advocated the use of a so called "endoprothese". After pyeloplasty a PVC-splint is left in the ureter. The proximal end has extra holes for proper drainage of the pelvis. The distal part lies in the bladder. The splint can be pulled out by cystoscopy, after 10 days. One disadvantage is the somewhat higher pressure in the pelvis at micturation because of reflux. An advantage was the fact that he found less infections than with the drainage by nephrostomy or pyelostomy.
Because Bard et al (1974) had several patients with unsplinted pyeloplasty who needed prolonged hospitalization and further instrumentation for prolonged postoperative urinary drainage, they came to the conclusion that the unsplinted procedure incurred an excessive postoperative morbidity rate and should be abandoned for more conservative surgical repairs including adequate nephrostomy drainage and/or splinting across the repaired pelvi-ureteric junction. The experience of Crowell et al (1973) in a series of 17 cases strongly supported this view.
Dalley et al (1976) did investigations by light and electron microscopy about smooth muscle regeneration in pig ureters. After intubated ureterotomy ureteric wall replacement occurred within 3 months after the operation and included all tissue layers. Epithelialization of the wound surface occurred in the first week and was accompanied by a connective tissue proliferation. Smooth muscle bridged the defect within 5 weeks. The margins of the muscularis were thickened and showed cellular infiltration in early stages: cells were elongated and extended towards the defect from the muscular remnant. Primitive smooth muscle cells were present at defect margins. This evidence indicates that smooth muscle was replaced by hyperplasia.
Smith and Butler (1976) published their series of 129 patients randomly selected for splinted or unsplinted pyeloplasties. Of

these groups, the patients with splinted pyeloplasties had a lower incidence of postoperative complications. The longterm results however, were similar in both groups. It is interesting to note that theoretically the presence of a splint and nephrostomy should lead to an increased incidence of urinary tract infection. In their series however, the incidence of postoperative infection was slightly lower in the splinted group whereas in a number of unsplinted cases urinary tract infection developed postoperatively despite sterile urines in the preoperative phase. Nephrostomy and splinting is an easy and safe procedure in the patient with a thin renal cortex. However, brisk haemorrhage may be encountered occasionally in patients whose kidneys have a substantial cortex. Usually this settles spontaneously, but in their series one patient required nephrectomy within 48 hours due to persistent haemorrhage which was directly attributed to the nephrotomy. The period of hospitalization reflects the postoperative complication rate. In the unsplinted group , the stay in hospital tended to be short when there were no complications. However, when complications did occur they tended to be of a degree which required long-term treatment. Over-all the results suggested that despite a longer stay in hospital due to the splinting technique involved, those in the splinted group were discharged in a predictable shorter period. In conclusion they believed, that splinting at pyeloplasty is indicated because of many advantages afforded in the immediate postoperative period. There is a lower incidence of leakage, a reduction in the number of kidneys lost due to complications, as well as an over-all shorter period of hospitalization. There appears also to be a slightly lower incidence of postoperative urinary tract infection in the splinted group. The increased risk of stricture as reported by some authors does not appear to be substantiated. On the contrary they believed that splinting of the anastomosis combined with nephrostomy is a safe and reliable procedure with satisfactory results.
Hanley (1977) considered that the dangers of oedema or obstruction at the new pelvi-ureteric junction far outweigh the risk of infection and prefers to leave only a small bore pyelostomy or nephrostomy tube in situ for a few days. This can be removed when the new junction is known to be draining satisfactorily but

not before.
When Anderson (1963) commented that he did not drain the renal pelvis or use a trans-anastomotic splint, it was his belief that patency of the anastomosis was best ensured by encouraging urine to pass through it from the beginning. However, it has been feared that in infants and children only a little oedema at the anastomosis will completely occlude the lumen of the ureter and that therefore drainage of the renal pelvis plus a trans-anastomotic splint is essential.
Rickwood (1978) came to the conclusions that:
1. extra-anastomotic drainage is the method of choice following pyeloplasty in children over 2 years of age.
2. in infants under 2 years of age pyelostomy drainage probably should be combined with a trans-anastomotic splint.
In his series of 63 Anderson-Hynes pyeloplasties in infants and children he saw fewer postoperative complications in the 40 cases that had extra-anastomotic drainage than in the 23 that had pyelostomy drainage.
The rationale of pyelostomy drainage is to allow free drainage of the kidney and early healing of the anastomosis during the period when post-operative oedema might compromise the lumen of the ureter. It may be objected that this is an inherently unsatisfactory compromise because, if urine is being drained entirely by a pyelostomy in the immediate postoperative period, the two sides of the anastomosis may fall together and become united by a film of fibrin . This may indeed occur as evidenced by the difficulty in persuading urine to pass through the anastomosis after leaving the pyelostomy on free drainage for as short as 2 days postoperatively and by patients requiring retrograde catheterisation of the anastomosis to open it up long after any postoperative oedema should have subsided.
Drake et al (1978), however, in their series of 88 infants and children, never used ureteric splints. They found use of a corrugated, extra renal drain sufficient and most satisfactory. Nephrostomy drainage was reserved for patients with massive dilatation of the pelvis.
In conclusion one could say that adjunctive use of nephrostomy or pyelostomy tubes and splints (stents) has been a subject of

considerable debate. Many urologists have used these routinely as safeguards for repair and to aid in maintaining alignment during healing. However, others have popularized the use of pyeloplasties without splints or nephrostomies and have indicated that the length of hospitalization is considerably reduced (Hamm and Weinberg, 1955; Webb et al , 1957). They further stress that these pyeloplasties result in a quicker return to an infection-free state postoperatively. Most urologists agree, however, that nephrostomy tubes and splints should be used whenever the repair is compromised by any of the following factors: (1) previous pyeloplasty or other surgery on the same kidney; (2) significant inflammatory changes in the pelvis and upper ureter or in the surrounding tissue; or (3) if the repair form any reason is less than ideal. The ureteric splint should be a soft, nonreactive tubing, such as Silastic tubing or a polyethylene infant feeding tube. A size is selected which will fit easily into the ureter. It is then brought out alongside the nephrostomy tube and can be held firmly in position by a ligature tied around the splint and the nephrostomy tube, securing it snugly enough to prevent dislodgment without occluding the lumen of the nephrostomy. The end of the splint can be completely occluded so that no urine will be draining through it. At times it is possible, through an anterior transabdominal incision, to perform a pyeloplasty without mobilizing the kidney to any significant extent. However, when the kidney is entirely mobilized, a nephropexy at the conclusion of the repair may be performed at the discretion of the surgeon in order to help maintain proper alignment. The length of time before removal of the splint and nephrostomy tube depends on the circumstances involved in each case. When a good repair is obtained, the splint is removed in 10 to 14 days. In selected cases, when the repair is difficult, the splint may be left in place for six weeks. After removing the splint, pyeloureterography and a pressure-flow study can be done. If this reveals no evidence of leakage and shows good propagation of contrast material down the ureter, the nephrostomy tube is clamped and opened at periodic intervals to check the residual urine. The nephrostomy tube is also immediately opened if there is flank pain or chills and fever. If the patient tolerates having the tube clamped, and the residual urine in the pelvis is small, the nephrostomy may be removed. A nephrostomy tube and splint are always required in a Davis intubated ureterotomy. In these instances both the nephrostomy tube and the splint are left in place for six weeks and a similar procedure is followed for their removal.

After performing a pyeloplasty there are the following methods of drainage and/or splinting: 1. nephrostomy; 2. nephrostomy plus ureteric splint (one or two); 3. McIver type of nephrostomy-ureteric splint; 4. pyelostomy; 5. pyelostomy plus ureteric splint; 6. McIver type of pyelostomy-ureteric splint; 7. ureteric splint fenestrated to drain the pelvis (via pelvis or cortex); 8. pelvi-ureteric splint that ends in the bladder; 9. pelvic vent; 10. T-tube; 11 in situ pelvi-ureteric splint.

All pyeloplasties should be drained. Some prefer the use of large soft Penrose drains brought through a generous stab wound below the incision. In a well-performed pyeloplasty the urinary drainage should be minimal. The drain should be placed in the region of the pyeloplasty, but care should be taken that they do not lie directly against the suture line. This is especially important if anything other than a soft Penrose drain is used, as the rigidity of the tubing, for instance of a vacuum drain, could quite easily interfere with healing. Care should be taken to bring the drain out in such a position that the patient will not be lying on it. The drain site should be located so that the drain can be "bagged" with an ileostomy appliance of considerable urinary drainage occurs. This both quantitates the amount of drainage and keeps the patient dry. If no drainage occurs, the drain may be removed in seven days. If drainage is copious and persistent, an intravenous urogram with delayed films should be obtained to assess the region of the repair. If it appears favourable, the drain should be moved away from the site of the pyeloplasty to see if the drainage decreases. If it does not, and if the amount of leakage appears to be a significant portion of that kidney's output, then consideration should be given to cystoscopy and retrograde placement of an ureteric catheter. If an ureteric catheter can be inserted up the renal pelvis, its position should be confirmed radiographically by injecting a small amount of contrast material. The catheter is then anchored to an urethral Foley catheter. When it has been necessary to insert an ureteric catheter, the urinary drainage through the flank drain will frequently decrease almost immediately. If the drainage remains small or stops completely, radiographic control by injection of contrast material through the ureteric catheter is necessary. Enough contrast is injected to fill the collecting system, and if no extravasation of contrast material is demonstrated the stent may then be safely removed. If a leak persists, the ureteric catheter should be left for several more days before another radiographic examination is performed. At times, of course, the catheter becomes dislodged by ureteric peristalsis, but it must be promptly replaced if the patient is still leaking. If properly drained, urinary leakage does not interfere with proper healing of the pyeloplasty. Certainly urinary leakage which is not properly drained, may at times set up a dense fibrotic reaction around the pyeloplasty with subsequent failures of the repair. If leakage of urine persists, an urinoma may form, which will require subsequent drainage.

8.8. Pyeloplasty in cases of duplicated renal pelvis or ureter.
Pelvi-ureteric obstruction in this anomaly can be surgically relieved by a variety of established techniques. However, references to this conditions are scarse. Culp (1961, 1962), Amar (1970, 1976), Marx (1974) and Lifland (1975) performed a lateral anastomosis between the two pelves and partially duplicated ureters, where one of the PUJ showed obstruction.

Amar (1970) performed a pyelo-uretero-stomy. A 2 cm. longitudinal incision in the lower obstructed renal pelvis was made and a similar one in the corresponding area of the non-obstructed upper-segment ureter, after which the anastomosis was made.

Lifland (1975) corrected it in another way. He transected the common ureter and its bifurcation. The spatulated ureter was anastomosed to the obliquely sectioned lower pelvis. The upper segment ureter was then joined to the lower segment pelvis as an ureteropyelostomy. Both anastomoses were made watertight using interrupted 4-0 chromic catgut. Intubation was not carried out.

Amar (1976) described the possibilities to correct hydronephrosis of the lower segment in a duplicated system: 1. Pyeloplasty of the lower segment; 2. Side-to-side pyelo-ureterostomy; 3. Lower

segment nephrectomy.
In cases of bifid renal pelvis there are the following possibilities: 1. Plastic widening; 2. Excision of the narrow segment and end-to-side anastomosis.

8.9. Massive hydronephrosis.
The occurrence of hydronephrosis containing more than 1000 ml. of fluid is comparatively rare. In a complete review of the literature Stirling (1939) found 74 cases. Since then many other cases have been reported. The size of the hydronephrotic sac in the cases reported varied from 1000 ml. to 30 gallons. The latter figure, frequently mentioned in the literature (Hinman, Papin) was an autopsy finding reported by Glas in the 18th century. This report appears to be greatly exaggerated, since it is inconceivable that this amount of fluid could be accommodated in the retroperitoneal space of a human body. The largest hydronephrosis reliably reported contained 17 litres, according to Stirling; however Papin believed that Dumreichers case (36 litres) as well as Franck's case (30 litres) represented trustworthy reports.

8.10. Pelvi-ureteric obstruction in the horseshoe kidney.
The best surgical approach in these kidneys is transperitoneal because it permits identification of the renal vessels. Surgery of horseshoe kidneys is facilitated by obtaining preoperative renal arteriograms. These kidneys usually have multiple, abnormally located renal arteries, and the preoperative determination of the number and location of these vessels is most useful. The renal pelvis is more accessible through this approach since, in these kidneys, it is in an anterior position.
Montague (1976) stated that pelvi-ureteric obstruction is usually secondary to compression of the pelvi-ureteric junction by an aberrant lower pole renal vessel against the portion of parenchyma extending to the midline (isthmus) which may be combined with a high insertion of the ureter in the pelvis. The type of pyeloplasty to be employed depends upon the exact pathology encountered but according to him usually a dismembered pyeloplasty is the procedure of choice if the pelvi-ureteric junction has to be reconstructed in front of the aberrant vessels. In selec-

ted patients the isthmus of the horseshoe kidney could be divided as an adjunct to the pyeloplasty. The isthmus may be merely a fibrotic band joining the lower poles of the two kidneys; however, in most instances, it contains a considerably amount of functioning renal tissue. Once the lower poles of the kidneys have been divided, they are positioned laterally and a modified nephropexy may be performed to maintain the new alignment. Hendren (1978) never encountered a case in childhood where obstruction of the pelvi-ureteric junction in a horseshoe kidney appeared to be due to stretching over the isthmus of the kidney. A simple nondismembered pyeloplasty sufficed to correct the problem without disturbing the isthmus where important vessels may lie.

8.11. General remarks concerning the pyeloplasty technique.

Regardless of the approach, certain general considerations for the performance of a pyeloplasty should be followed. The upper ureter is identified and is dissected upward to its insertion into the pelvis. All adhesions between the ureter and the renal pelvis are severed. At the start of the dissection it will often seem that the ureter inserts into the lower portion of the renal pelvis, but after completely freeing the adhesions between the ureter and renal pelvis the actual insertion of the ureter will sometimes be found to be considerably higher in the pelvis than was initially thought. After completely dissecting the renal pelvis and upper ureter, the type of pyeloplasty best suited for the individual patient is selected. Because in some cases the pelvis is collapsed the "true" condition can be seen after injecting saline into the pelvis with a small needle. The proposed incisions in the renal pelvis and upper ureter may be marked with methylene blue or stay sutures. The incision into the renal pelvis should be started with a knife, then completed with fine, sharp scissors. The cut edges of the ureter and pelvis should be handled by traction sutures, not with forceps or other crushing instruments. Small bleeders can be lightly fulgurated and larger bleeding vessels should be suture ligated with fine catgut or Dexon®. The electrocautery should be avoided on tissues which are going to be incorporated in the repair. The repair should be carried out with

Dexon® (polyglycolic acid) sutures, usually 4-0 or 5-0 depending upon the thickness of the renal pelvis. The sutures should be precisely placed through the full thickness of renal pelvis and ureter, and should be close enough to attain a watertight closure. The knot should be laid down squarely, but not so tightly as to strangulate tissue, and the sutures should be placed so that the knots are on the outside of the urinary tract. A combination of running sutures in the area of the renal pelvis and interrupted sutures in the area of the ureter is often utilized. A water-tight closure is obtained by very careful placement of interrupted sutures beginning at the apex of the V-flap, while an 8 or 10 FR. splint temporarily rests in the ureter. Upon completion of the repair it can be tested for watertightness, and the pelvi-ureteric junction can be tested for patency by compressing the upper ureter externally and injecting the renal pelvis with saline through a fine needle or a diuretic. If leaks are observed at this time, the repair should be reinforced by additional sutures. Upon release of the upper ureteral compression the pelvis should promptly empty.

It is important to recognize the limitations of the various operative principles employed in repair of pelvi-ureteric obstruction and to utilize that technique which is best suited for the particular situation encountered in each patient. The urologist should be able to make the best choice out of all the various operative procedures for correction of pelvi-ureteric obstruction. In chapter 9 is shown that from 1970 the Anderson-Hynes pyeloplasty was performed more and more and is now our first choice of operation.

The requirements for a successful procedure for correction of pelvi-ureteric obstruction are:

1. preservation of adequate bloodsupply.
2. formation of a funnel shaped pelvis.
3. avoidance of a circular suture line.
4. absence of tension and pressure at the suture line.
5. prevention of postoperative distension of the renal pelvis.
6. prevention of infection.
7. sufficient reduction in the size of the enlarged pelvis.

8.12. Surgical approach.

The surgical approach potentially influences the pyeloplasty in a number of ways. In situ plasty enables the surgeon to see the operative field without distorsion. A displaced kidney on the other hand makes the approach shorter but conceals tension which may interfere at a later stage. The more the kidney is displaced, the greater the local trauma which involves the adrenal gland and its vascular supply. The necessity for completing the operation with a nephropexy is likewise increased.

The anterior extra peritoneal (Anderson-Hynes 1949) or the anterior transperitoneal Kocher subcostal incision (Eckstein 1971) and the dorsal approach permit an entire in situ operation. Most urologists and surgeons prefer the lumbotomy incision, when they want to operate on the kidney pelvis or proximal ureter with the patient lying on his side, while some paediatric urologists are inclined to use a ventral incision. Sigel (1977) pointed out that the younger the child, the more advantageous the ventral approach becomes. Eckstein (1971) in his series of 24 children had 5 children with bilateral pelvi-ureteric obstruction which were operated upon at the same session through a long transverse incision. Drake et al (1978) in his series of 88 children and infants used the anterior transperitoneal approach in 73 procedures. The remaining 29 urinary tracts were exposed via an extraperitoneal approach, using either a flank or an anterior incision. The 11 bilateral simultaneous pyeloplasties were performed transperitoneally, using an upper abdominal transverse incision. Two of this last group had intestinal obstruction two months postoperatively and required laparotomy for division of intraperitoneal adhesions.

8.13. Complications.

1. Leakage of urine at the anastomosis síte still remains the most common problem associated with pyeloplasties.

Smith and Butler (1976) published their series of 82 splinted and 50 nonsplinted pyeloplasties. In the non-splinted group, leakage occurred in 16 (32%), and of these, 9 required ureteric catheterisation for periods up to forty-eight hours to improve drainage of the renal pelvis. Three of these patients required recatheterisation of the ureter as the leakage of urine recurred when the ureteric catheters were removed on the first occasion. Secondary surgery was required subsequently in 3 of the 16 cases with postoperative leakage, because of increasing infection and progressive obstruction. These cases eventually required nephrectomy. Although leakage of urine occurred in 9 cases (11%) in the splinted group all settled within forty-eight hours, and there was no nephrectomy in this group due to leakage. However, one patient required nephrectomy for massive haemorrhage in the postoperative period (the splint was brought out through the renal parenchyma alongside a nephrostomy tube). One unusual complication was a fracture of the splint, which required reexploration.

2. Infection.

In the series of 129 patients of Smith and Butler (1976) the preoperative infection rate was 15 cases (11,5%). Of these, 10 had sterile urine postoperatively, and 5 continued to have infection. Of the 10 sterile cases, 7 were splinted and 3 were unsplinted. As well as the 5 cases which remained infected postoperatively, in 9 other cases, sterile before surgery, an urinary infection developed postoperatively, making a total of 14 cases. Of the 9 sterile cases which became infected postoperatively, only 3 had splints at operation and 6 were in the nonsplinted group. Although the over-all infection rate was small, postoperative urinary infections seemed to be more common in unsplinted patients.

3. Stone formation.

A stone in the renal palvis may lead to secondary hydronephrosis. A pelvi-ureteric obstruction may be the cause of stone formation because of stasis of the urine or secondary infection with urea-splitting bacteria like proteus. If one does perform a pyelolithotomy one should think of the possibility that the stone is secondary to a pelvi-ureteric obstruction.

An infection of the urine caused by urea-splitting bacteria, is a particular hazard for a patient and strenuous efforst must be made to sterilize the urine in the postoperative period otherwise it may lead to stone formation. This effort should be started 24 to 48 hours before the operation.

Slade (1967) reported in his series of 200 cases that some surgeons used non-absorbable suture material (nylon) which led to stone formation in 4 patients. Two of them underwent secondary nephrectomy.

4. Stricture at the anastomosis.

A secondary stricture at the site of the anastomosis may be treated by an ureteric catheter for several days but if not successful an exploration and a second pyeloplasty must be done if possible.

5. Secondary nephrectomy.

In some cases of a non-functioning kidney or in a difficult re-exploration nephrectomy may be necessary.

6. Ileus.

If a transperitoneal approach is used a secondary ileus is possible.

The fact that initial complications do develop should not discourage the urologist or lead to the abandonment of his technique. Most of these initial complications can be handled quite easily and even the need of reintervention does not preclude excellent long-term results.

## 8.14. Is surgical intervention always indicated?

When renal function is excellent and the calyces are well preserved and if the patient has no pain, pyuria, or calculi it is foolhardy to tamper with the pelvi-ureteric region (Culp 1967). When in doubt, it will be prudent to "watch" the kidney with periodic urographic, renographic and urinary studies. Some obviously obstructed kidneys without cortical damage may never change.
An especially tempting situation is the case of bilateral obstruction in which the more advanced symptomatic side has been repaired successfully. Despite an overwhelming desire to correct the quiet, incipient, contralateral pelvi-ureteric obstruction, it is wise to wait and be sure that such measures are justified.

## 8.15. Pelvi-ureteric obstruction in the solitary kidney.

A single hydronephrotic kidney may be present in patients showing contralateral agenesis, whose other kidney was previously removed for disease or trauma, or is virtually nonfunctioning. There even is a good chance that the kidney was removed because of damage due to pelvi-ureteric obstruction. Major surgery on a solitary kidney is not to be embarked upon lightly and the hazards of infection must be avoided.

8.16. The symptomless pelvi-ureteric obstruction.

Many kidneys with PUJO are found in the course of routine examinations, some at autopsy and several more present with mild symptoms not in themselves indications for surgery.

Some authors have thought that the early pelvi-ureteric obstruction causing few or no symptoms is unlikely to develop further and can safely be left untreated. It is true that in some instances no complications ensue but that slow deterioration and loss of parenchyma seems inevitable is shown by 30 patients in the series of Slade (1967) in which a gross hydronephrosis, unsuspected during life, was discovered at autopsy. Some patients suffer either a slow or a sudden unpredictable deterioration of the hydronephrosis leading to a radiological non-functioning kidney, pyonephrosis or exacerbation of symptoms; in some instances nephrectomy is necessary when earlier conservative surgery would have preserved the kidney. However, late treatment of some longstanding cases can be surprisingly effective.

8.17. Bilateral pelvi-ureteric obstruction.

An exhaustive study of renal function as outlined by Pieretti et al (1974) is appropriate to determin the percentage of functional contribution by each kidney and to plan the management of the patient. If the general condition and metabolic status of the patient are stable, bilateral pyeloplasty through a midline or transverse transperitoneal approach can be accomplished safely.

If it appears to be safer to stage the operation, one can use the following as a rough guide:

If one kidney is severely impaired and contributes less than 20 per cent of the total renal function, operation on the better side first is appropriate to improve the general condition of the patient.

The poorer side may be operated four to eight weeks later to allow recovery of the better kidney from the operative trauma and to avoid further deterioration of the worse side.

If the functional difference between the two kidneys is 20 per cent or less, the conventional approach would be to treat the worst side first, and the other side after 2 weeks (Johnston 1977).

# 9. Data of operated patients

## 9.1. PREOPERATIVE DATA.

In 1959 de Boer published in his thesis 55 patients (58 kidneys) with PUJO, operated in the University Hospital in Groningen from 1912 till 1959.
The following series of 152 patients (157 kidneys), described in this thesis, was operated in the same hospital from 1959 till 1980.
The 152 patients can be divided in five groups: (see table page 140)

A. Unilateral PUJO
B. PUJO in congenital solitary kidney
C. PUJO, first operated in an other hospital
D. Bilateral PUJO, operated (nephrectomy) on the contralateral kidney, in an other hospital
E. Bilateral PUJO.

### 9.1.1. Incidence.

This series consists of 90 male and 62 female patients (= 152 total) of whom 11 had been operated before (14 operations totally). In 4 patients with bilateral PUJO a nephrectomy of the contralateral kidney had already been performed. Because 4 female and 1 male patient were operated on bilaterally and one female patient was operated on twice in the same kidney (152 + 6 =) 158 kidneys were operated totally. Three patients had a horseshoe kidney (1.9%), one patient had a congenital solitary kidney (0.6%) and the remaining 148 patients had two kidneys at birth.
The male-female ratio in this series was 90:62. There have been many series published with a predominance of females (Deming, 1943), males (Notley, 1973; Smith, 1976; Drake, 1978) and an even distribution (Roberts, 1964; Deming, 1964). In the series of de Boer

| PREOPERATIVE DATA | | | | |
|---|---|---|---|---|
| A. 135 patients | | 135 | | |
| B. 1 patient | | 1 | | |
| C. 7 patients | | | | |
| a. one operation | 5 | | | |
| -pyelolithotomy | 1 | | | |
| -pyeloplasty | 2 | | | |
| -adhesiolysis | 1 | | | |
| -ligation of vessel | 1 | | | |
| b. two operations | 1 | | | |
| -pyeloplasty | | | | |
| -pyelolithotomy | | | | |
| c. three operations | 1 | | | |
| -adhesiolysis (2x) | | | | |
| -pyeloplasty (1x) | | 7 | 7 | 10 |
| D. 4 patients | | 4 | 4 | 4 |
| E. 5 patients | | 5 | | |
| Total of patients | | 152 | | |
| Total of patients previously operated | | | 11 | |
| Total of operations previously performed | | | | 14 |

A. Unilateral PUJO

B. PUJO in congenital solitary kidney

C. PUJO, first operated in an other hospital

D. Bilateral PUJO, operated (nephrectomy) on the contralateral kidney, in an other hospital

E. Bilateral PUJO

(1959), there were 39 male and 16 female patients. The fact that both series from the same hospital have a clear predominance of male patients is probably a coincidence.
The incidence of bilateral PUJO varies widely. Anderson (1953) has recorded an incidence of 50%, while Hanley (1959), Roberts (1964) and Drake (1978) believed it to be 13%. The incidence of bilateral PUJO in this series (9 patients) was 6% (de Boer 5.4%). During the first years of life, PUJO has been reported to be bilateral in approximately 30% of the patients (Jonhston, 1977). Others have reported a higher incidence in patients less than 6 months old (Williams, 1966). In our study there were only 2 patients in this age group (both 2 years old).

9.1.1.1. <u>Age of the patients at operation</u>.
Table 1 shows the age of the patients at the time of the operation in periods of 5 years.

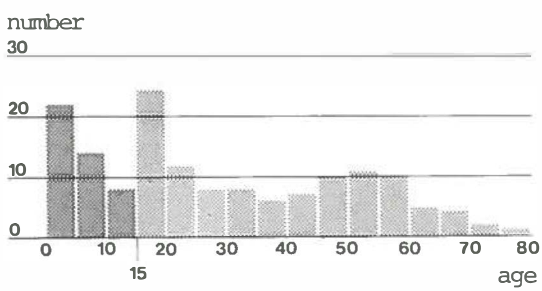



Table 1: The age of patients at the time of operation in periods of 5 years.

As far as the age is concerned, almost half (45%) of the patients were operated in the first and second decade of life. As is mentioned in chapter 6 it is supposed to be characteristic for this condition that the patient in most cases begins to have trouble in the first and second decade of life (Sunderland, 1963). However, an even distribution of the time of presentation in the different age groups has also been published (Roberts, 1964; Balfour, 1964). In the series of de Boer (1959) 58% of the patients was in the 0-20 years of age group. In our 152 patients 44 (29%) fell in the so called paediatric age group (0-15 years), while 108 patients (71%) were older.

9.1.1.2. Number of operated kidneys.

Table 2 shows the number of operated kidneys with PUJO per year.

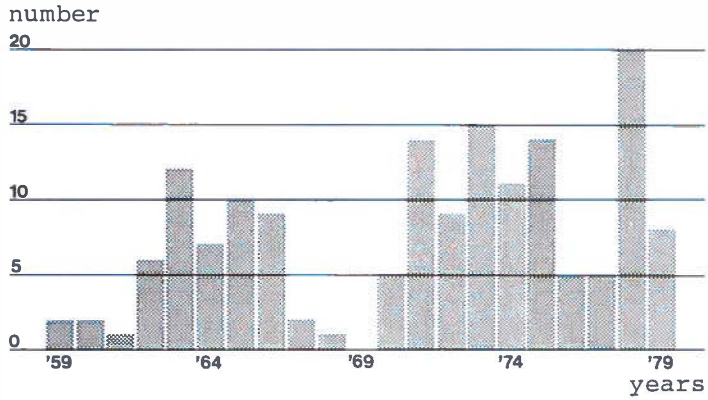



Table 2:The number of operated kidneys per year.

The decrease in the year 1968 and 1969 was caused by the absence of an urologist in our hospital. The mild decrease in 1976 and 1977 was due to a forced reduction of hospital admissions.
Over a period of 21 years 152 patients with PUJO were operated, this is an average of 7,2 patients per year.

9.1.2. Symptomatology.

9.1.2.1. Presenting symptoms.

The 152 patients with PUJO presented with the following main symptoms:

| | 0-15 years | | >15 years | | Total | |
|---|---|---|---|---|---|---|
| Pain | 12 | 27% | 87 | 81% | 99 | 65% |
| UT-Infections | 17 | 39% | 4 | 4% | 21 | 14% |
| Gross Haematuria | 6 | 14% | 7 | 6% | 13 | 9% |
| Palpable Tumour | 4 | 9% | 1 | 1% | 5 | 3% |
| GI-Symptoms | 2 | 4% | 1 | 1% | 3 | 2% |
| Coincidence | 3 | 7% | 8 | 7% | 11 | 7% |
| Total | 44 | 100% | 108 | 100% | 152 | 100% |

It is possible for a patient with a PUJO to have pain with haematuria or pain with gastrointestinal complaints, so combinations of symptoms are not uncommon. The incidence of all symptoms together was:

| | | | |
|---|---|---|---|
| 1. Pain<br>Pain on increased diuresis | 86<br>11 | 97 patients | 61% |
| 2. Urinary tract infections | | 39 patients | 24% |
| 3. Gross haematuria | | 24 patients | 15% |
| 4. Gastrointestinal complaints | | 9 patients | 5% |
| 5. Palpable tumour | | 9 patients | 5% |

In a group of 11 patients the PUJO was found during examinations indicated by different pathology:

- routine ultrasound investigation of the uterus of a pregnant woman showed unilateral hydronephrosis in the foetus; an IVU performed after birth revealed a PUJO which was confirmed at operation (nephrectomy);
- angiography because of a cardiac defect showed a PUJO in 1 child;
- an IVU was performed for the following reasons:
  - hypertension 6 patients
  - lymphoedema of a leg (idiopathic) 1 patient
  - sterility 1 patient
  - myelomeningocèle 1 patient

In 7 patients the symptoms of pain and/or gastrointestinal complaints were wrongly interpreted and a false diagnosis was made which led to the following operations:

- appendicectomy (3 patients)
- cholecystectomy
- exploration of the testis
- laparotomy for salpingitis
- hernia epigastrica correction

Urinary tract infections (UTI) were noticed in the history of 39 (24%) patients (25 females and 14 males). In the female patients these were infections of the lower urinary tract in 88% (22 patients). In only 3 patients (12%) there might have been a relation between the UTI and the PUJO because of a history of pain on the side of the hydronephrotic kidney with chills. Nine (64%) of the male patients with UTI in their history had infections of the lower urinary tract and 5 infections (36%) were kidney-related.

| UTI in history | Lower UTI | Kidney related UTI |
|---|---|---|
| 25 female patients | 22 | 3 |
| 14 male patients | 9 | 5 |
| Total 39 patients | 31 | 8 |

Thirteen patients had an UTI at the moment they were admitted to the hospital. This group consisted of 9 female and 4 male patients. The nine female patients had also UTI in their history. Three of the 4 male patients had UTI in their history.

| UTI at admission | UTI in history | No UTI in history |
|---|---|---|
| 9 female patients | 9 | 0 |
| 4 male patients | 3 | 1 |
| Total 13 patients | 12 | 1 |

As has been discussed in chapter 6, the presenting symptoms in children are different. Urinary tract infections, a palpable abdominal mass, pain and failure to thrive are more common. In the 0-15 years of age group (17 girls and 27 boys) UT-infections were the main presenting symptom (39%).
In this group of 44 children there were two patients with bilateral reflux (complete without dilatation). Both children also had UT-infections. After a pyeloplasty and long term treatment with antibiotics the reflux disappeared.
By far the most common symptom in all series is pain. The pain may be induced by increased diuresis. Gross haematuria is an important presenting symptom and is often seen at some stage of this condition. Seven of the 13 patients with gross haematuria as the presenting symptom had nephrolithiasis.
As is shown, PUJO is sometimes found by coincidence during investigations for other reasons such as angiography for cardiac defects. The finding of a PUJO while performing an IVU for hypertension might not be a complete surprise because the relationship

between hypertension and PUJO is well known.
If a patient presents with a vague sensation of pain or gastro-intestinal complaints, a wrong diagnosis may be made with subsequently even an unnecessary operation, as was the case in 7 (4,6%) of our patients.
Urinary tract infections play an important role as presenting symptom, especially in children (39%). These infections are mainly located in the lower urinary tract. Only 3 female and 5 male patients had urinary tract infections that were kidney-related. Three out of these 8 patients had nephrolithiasis, one of them in combination with an urinary infection with urea-splitting bacteria (Proteus). The low incidence of preoperative kidney-related infections, despite the obvious urinary stasis, is rather surprising in the face of the established teaching that infection is an almost inevitable sequel to obstruction.

9.1.2.2. Duration of symptoms.
The duration of the symptoms (pain, urinary tract infection, gross haematuria, gastrointestinal complaints and a palpable tumour) before the patient was examined by a physician was as follows:

| | | |
|---|---|---|
| no symptoms | 15 patients | 10% |
| < 1 month | 20 patients | 13% |
| 1-6 months | 48 patients | 31% |
| 7-12 months | 23 patients | 15% |
| 13-24 months | 16 patients | 11% |
| 25-36 months | 8 patients | 5% |
| > 36 months | 22 patients | 15% |
| Total | 152 patients | 100% |

The time between the onset of symptoms and the establishment of the diagnosis in the 0-15 years age group varied from 1 day to 5 years.
Gross haematuria was in all patients, presenting with this symptom, an indication for performing an IVU.
Patients with urinary tract infections were sometimes treated with antibiotics for periods from several weeks to 18 months before an IVU was performed and the PUJO was found.
It is quite remarkable that in many cases of PUJO the duration

of symptoms is so long before the right diagnosis is made. Twenty-two patients ( 15 %) had symptoms for more than 3 years and 9 of them ( 6 %) even for more than 8 years. There was 1 patient with a dull ache in his loin for 20 years. Ten patients had no complaints at all and 5 patients with bilateral PUJO had symptoms on one side, while the contralateral PUJO was found by coincidence. As is shown there was a large number of patients with complaints for many months and even years before they were treated. It is possible that they had only minor complaints with long intervals or also the physician might not have suspected the presence of a PUJO and did not perform an IVU during an attack of pain.

9.1.2.3. Nephrolithiasis.

In this series of 152 patients with PUJO, nephrolithiasis was observed in the hydronephrotic kidney in 25 patients (16%). This was in 11 patients on the right side and in 14 patients on the left side.

| Nephrolithiasis | 0-15 years | > 15 years |
|---|---|---|
| 9 female patients | 0 | 9 |
| 16 male patients | 4 | 12 |
| Total 25 patients | 4 | 21 |

Nephrolithiasis in the 0-15 years of age group (44 children) was observed in 4 male patients of whom 2 had UT-infections in their history (one Proteus infection). In this age group 3 patients of the 4 with nephrolithiasis presented with gross haematuria.
The 25 patients with nephrolithiasis presented with these symptoms:

| | |
|---|---|
| pain | 9 patients |
| pain + gross haematuria | 5 patients |
| pain + UTI | 3 patients |
| gross haematuria | 4 patients |
| UTI | 3 patients |
| none | 1 patient |
| Total | 25 patients |

The IVU-picture in this group was as follows:

| | |
|---|---|
| moderate hydronephrosis | 13 patients |
| severe hydronephrosis | 10 patients |
| no excretion | 2 patients |
| Total | 25 patients |

Nephrolithiasis in the hydronephrotic kidney was observed in 25 patients. Because of urinary stasis a higher incidence might have been expected. In only three patients in this series nephrolithiasis was probably caused by urea-splitting organisms with the formation of struvite stones. In one patient the stone formation may have been caused by hypercalciuria.

There is a great variety in the incidence of nephrolithiasis in PUJO as reported in the literature:

- 0,5 % in 200 patients (Roberts, 1964)
- 10 % in 525 patients (Balfour, 1964)
- 15 % in 33 patients (Notley, 1963)
- 36 % in 78 patients (Weber, 1970)

These series are good comparable because they consist of patients of all ages. However, there is no explanation for the striking difference in incidence of nephrolithiasis in PUJO, as found in the above mentioned studies. In the series of de Boer (1959) only one patient had a kidney stone.

### 9.1.3. Diagnostic procedures.

#### 9.1.3.1. Number of IV-urograms.

The number of IV-urograms that was performed before the diagnosis was made, was as follows:

| | |
|---|---|
| - one IVU in 103 patients | 67% |
| - two IVU in 35 patients | 23% |
| - three IVU in 9 patients | 6% |
| - four IVU in 5 patients | 4% |
| Total 152 patients | 100% |

The group of 14 patients with three and four IV-urograms had the following grades of hydronephrosis:

- mild 3 patients
- moderate 9 patients
- severe 2 patients

The number of IV-urograms performed before the right diagnosis was made, has been surprisingly high in several patients in our study. This might be due to the technique of urography. Another possibility could be that the IV-urograms were not performed during an attack of pain. There were 2 patients with severe hydronephrosis who fell in this intermittent type of hydronephrosis group. These patients had a moderate hydronephrosis with a funnel shaped renal pelvis which changed to a severe hydronephrosis during an attack of pain.

9.1.3.2. IVU-pictures.

This series consists of 152 patients, but the 5 patients with bilateral PUJO and the patient who was operated on twice in the same kidney will be mentioned separately (152-6=146). There were 5 patients with one kidney. One patient had an aplasia of one kidney and in 4 patients a nephrectomy was performed. This makes the total number of kidneys in this group 2 x 146-5=287.

The criteria were:

- Mild hydronephrosis = dilated renal pelvis, normal papillae
- Moderate hydronephrosis = dilated renal pelvis, atrophy of papillae
- Severe hydronephrosis = severe dilatation of renal pelvis, large globular calyces, thinning of renal cortex
- No excretion = no contrast visible in the collecting system

The division of the IVU-picture of the 287 kidneys was as follows:

| | | |
|---|---|---|
| - funnel pelvis | 102 | 35% |
| - closed pelvis | 39 | 14% |
| Total | 141 kidneys | |
| - mild hydroneprhosis | 17 | 6% |
| - moderate hydronephrosis | 65 | 23% |
| - severe hydronephrosis | 51 | 18% |
| - no excretion | 13 | 4% |
| Total | 146 kidneys | |
| Total | 287 kidneys | 100% |

This division consists of two groups. The first concerns the funnel shaped pelvis and the closed pelvis. The funnel shaped pelvis is physiologically the ideal collecting system. The drainage of the closed type of renal pelvis is less effective and may eventually lead to a PUJO. The second group represents the different grades of PUJO.

If the hydronephrotic kidneys alone are considered, the percentage of the various grades of dilatation was:

| | | |
|---|---|---|
| - mild hydronephrosis | 17 | 12% |
| - moderate hydronephrosis | 65 | 44% |
| - severe hydronephrosis | 51 | 35% |
| - no excretion | 13 | 9% |
| Total | 146 kidneys | 100% |

The IVU-picture of the 5 patients with bilateral PUJO and the patient (no. 6) who was operated twice on the same kidney was as follows:

| | Sex | Age | Symptom | Hydronephrosis |
|---|---|---|---|---|
| 1 | ♀ | 2 | UTI | R severe<br>L moderate |
| 2 | ♂ | 2 | Haematuria | R no excretion<br>L moderate (+ stone) |
| 3 | ♀ | 37 | UTI<br>urosepsis | R moderate<br>L moderate |
| 4 | ♀ | 66 | pain | R no excretion<br>L no excretion |
| 5 | ♀ | 77 | pain | R no excretion<br>L no excretion |
| 6 | ♀ | first opera-<br>tion 29 | pain | R moderate |
| | | second opera-<br>tion 33 | pain | R severe |

9.1.3.3. Renography.

Because renography is of great value in PUJO, it has been performed in increasing frequency in the last ten years.

In this series preoperative renography was performed in 89 patients. In unilateral PUJO the renogram showed an obstructive curve on one side in 75 patients. An afunctional curve on one side and a normal curve on the other side was observed in 10 patients. In these patients a nephrectomy was performed. An obstructive curve on both sides was seen in 2 patients with bilateral PUJO and an obstructive one on one side and an afunctional one on the other side in 2 patients with bilateral PUJO.

A. Unilateral PUJO -obstructive curve 75 patients
-afunctional curve 10 patients

| | | |
|---|---|---|
| B. Bilateral PUJO | -obstructive curves on both sides | 2 patients |
| | -obstructive on one and afunctional on the other side | 2 patients |

In 26 patients with unilateral PUJO a closed type of renal pelvis was observed on the contralateral side. In 22 patients the renogram showed a normal and in 4 patients a slightly obstructive curve. However, in all cases of a closed type of renal pelvis, a PUJO might eventually develop.
In all patients with a mild, moderate or severe hydronephrosis due to PUJO an obstructive curve was found on renography.
Preoperative renography has been of increasingly great value in this series. The renogram curve gives good information about the renal parenchyma and the excretion. In all cases of PUJO the renogram showed an obstructive curve. In all patients with an afunctional curve of a kidney, nephrectomy was performed. All these kidneys were not worth conserving, because there was no viable parenchyma left.
As has been discussed in chapter 5, the closed type of renal pelvis is supposed to have e less effective way of drainage, compared with the funnel shaped pelvis. The renogram of 26 kidneys of the 39 with a closed type of renal pelvis could be examined and showed a complete normal curve in 22 patients and only a slightly obstructive curve in 4. However, it is still possible that the closed type of renal pelvis is a potential PUJO, which, at some time, may lead to a real obstruction.

9.1.3.4. Retrograde urography.

Retrograde urography was not performed in 50 patients (32%) because the IVU gave sufficient information. A retrograde urogram was performed in 102 patients. In 37 patients (24%) this investigation was performed on the day of the operation and in 65 patients (43%) before the day of the operation. In all cases of retrograde urography a normal ureter was found below the PUJ.
In 37 patients retrograde urography was done on day of the operation, which is the time we prefer, because this investigation is not without danger. If the ureteric catheter is placed in the renal pelvis, it may cause oedema of the PUJ which may lead to increased obstruction. Moreover, the hydronephrotic kidney

may become infected. If the ureter has many kinks at the PUJ, a false passage is possible.
By performing a retrograde urogram, a (normal or bulb) ureteric catheter should be placed just below the PUJ, before the contrast is injected. In this way good pictures can be made of the PUJ and the distal ureter without interfering with the PUJ itself. It can also give some additional information about the length of the stenosis and the place of entrance of the ureter in the renal pelvis.

## 9.2. OPERATIVE AND POSTOPERATIVE DATA.

A. Unilateral PUJO
B. PUJO in congenital solitary kidney
C. PUJO, first operated in an other hospital
D. Bilateral PUJO, operated (nephrectomy) on the contralateral kidney, in an other hospital
E. Bilateral PUJO

| PREOPERATIVE DATA | | | | |
|---|---|---|---|---|
| A. 135 patients | | 135 | | |
| B. 1 patient | | 1 | | |
| C. 7 patients | | | | |
| a. one operation | 5 | | | |
| -pyelolithotomy | 1 | | | |
| -pyeloplasty | 2 | | | |
| -adhesiolysis | 1 | | | |
| -ligation of vessel | 1 | | | |
| b. two operations | 1 | | | |
| -pyeloplasty | | | | |
| -pyelolithotomy | | | | |
| c. three operations | 1 | | | |
| -adhesiolysis 2x | | | | |
| -pyeloplasty 1x | | 7 | 7 | 10 |
| D. 4 patients | | 4 | 4 | 4 |
| E. 5 patients | | 5 | | |
| Total of patients | | 152 | | |
| Total of patients previously operated | | | 11 | |
| Total of operations previously performed | | | | 14 |

| THERAPY | | |
|---|---|---|
| nephrectomy | 23 | |
| adhesiolysis | 10 | |
| ligation acc.vessel | 1 | |
| pyeloplasty | 102 | 136 |
| pyeloplasty | 1 | 1 |
| a. pyeloplasty | 4 | |
| nephrectomy | 1 | |
| b. pyeloplasty | 1 | |
| c. nephrectomy | 1 | 7 |
| pyeloplasty | 4 | 4 |
| pyeloplasty | 9 | |
| adhesiolysis | 1 | 10 |
| Total of operations | | 158 |

9.2.1. Side of operation.

Five patients with bilateral PUJO were operated upon on both kidneys. One patient was operated upon twice on the same kidney. The (152-6=) 146 patients with PUJO on one side at the time of operation were divided as follows:

| Side of operation | | |
|---|---|---|
| Right kidney | 80 patients | 55% |
| Left kidney | 66 patients | 45% |
| Total | 146 patients | 100% |

In almost all series the left side is affected more frequently. If the series of Roberts (1964), Smith (1970), Rickwood (1978) and Drake (1978) are taken together the division is approximately 60% on the left and 40% on the right side. There is no explanation for this phenomenon, neither for the fact that in our series the right side was affected more often.

9.2.2. Type of operation.

In our study of 152 patients with PUJO, the following 158 operations (first operation in our hospital) were performed:

| | | |
|---|---|---|
| 1 nephrectomy-primary 23<br>-secondary 2 | 25 kidneys | 15% |
| 2 adhesiolysis | 11 kidneys | 7% |
| 3 ligation of an accessory vessel alone | 1 kidney | 2% |
| 4 pyeloplasty | 121 kidneys | 76% |
| Total | 158 kidneys | 100% |

Five different types of pyeloplasties were performed:

| | | |
|---|---|---|
| - Anderson-Hynes | 77 kidneys | 64% |
| - Culp- de Weerd | 18 kidneys | 15% |
| - Foley | 13 kidneys | 10% |
| - Fenger | 12 kidneys | 10% |
| - Davis | 1 kidney | 1% |
| Total | 121 kidneys | 100% |

In 23 patients a primary nephrectomy was found necessary because the kidney was too much damaged by the PUJO (15%). In two other patients who had been operated once and three times respectively for PUJO in an other hospital, nephrectomy was also necessary.
In 11 cases a secondary operation was necessary after the operations we performed, which makes the total number of operations performed by us 158 + 11 = 169. These 11 operations were 2 pyeloplasties, 7 nephrectomies and 2 p.o. explorations because of woundbleeding.
The various types of operations, performed in this series of patients have been discussed in detail. Primary nephrectomy was found necessary in 23 patients. Secondary nephrectomy of patients first operated in an other hospital, was performed in 2 cases, secondary nephrectomy of patients, first operated by us, in 7 cases.
The incidence of primary nephrectomy in patients with PUJO has changed considerably in the past decades:

- 48% in 82 patients Deming (1943)
- 44,8% in 55 patients de Boer (1959)
- 21% in 100 patients Sunderland (1963)
- 14% in 525 patients Balfour (1964)
- 81% in 32 patients Maurer (1969) 1936-1946
- 37,2% in 56 patients 1946-1956
- 17,7% in 96 patients 1956-1962
- 15% in our own series of 152 patients

These were studies of patients of all ages. The following 2 series only consist of children (0-1 years):

- 12,6% in 63 children Smith (1976)
- 3,9% in 102 children Drake (1978)

In our group of 44 children (0-15 years) we performed 7 primary (16%) and 4 secondary nephrectomies (see 9.2.8.).
From these data it can be seen that less primary nephrectomies are performed because of improved diagnostic procedures and a stronger tendency to preserve as much renal parenchyma as possible, and the experience and knowledge that even severely damaged kidneys can function well after the obstruction has been relieved.
The next table gives the various types of operations that were performed each year from 1959 to 1979.

| | Nephrectomy | Adhesiolysis | Accessory vessel ligation | Davis | Fenger | Foley | Culp-de Weerd | Anderson-Hynes | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1959 | 2 | | | | | | | | 2 |
| 1960 | 2 | | | | | | | | 2 |
| 1961 | 1 | | | | | | | | 1 |
| 1962 | | 2 | | | 1 | 1 | 2 | | 6 |
| 1963 | 3 | 1 | 1 | | 4 | | | 3 | 12 |
| 1964 | | 1 | | | 2 | 3 | | 1 | 7 |
| 1965 | 2 | | | 1 | 4 | 1 | 1 | 1 | 10 |
| 1966 | | 4 | | | | | 3 | 2 | 9 |
| 1967 | | | | | 1 | | 1 | | 2 |
| 1968 | | | | | | | | 1 | 1 |
| 1969 | | | | | | | | | 0 |
| 1970 | 1 | | | | | 2 | 1 | 1 | 5 |
| 1971 | 1 | 1 | | | | 4 | 5 | 3 | 14 |
| 1972 | 1 | | | | | 1 | 2 | 5 | 9 |
| 1973 | | | | | | 1 | 1 | 13 | 15 |
| 1974 | 1 | 1 | | | | | 1 | 8 | 11 |
| 1975 | 2 | | | | | | 1 | 11 | 14 |
| 1976 | 1 | | | | | | | 4 | 5 |
| 1977 | 2 | 1 | | | | | | 2 | 5 |
| 1978 | 5 | | | | | | | 15 | 20 |
| 1979 | 1 | | | | | | | 7 | 8 |
| Total | 25 | 11 | 1 | 1 | 12 | 13 | 18 | 77 | 158 |

The table that gives the various operations per year in this series, shows the present preference for the Anderson-Hynes pyeloplasty instead of the Culp, Foley , Fenger and Davis procedures during the last 7 years.
Adhesiolysis alone, for correction of PUJO, is now considered as insufficient unless a pressure-flow study, during the operation, excludes the presence of an obstruction.
In this study 9 patients had bilateral PUJO. In 4 patients nephrectomy of the contralateral kidney had already been performed in an other hospital. Five were operated by us on both sides. At the moment of the first operation, it was decided to operate on the most damaged (obstructed) kidney in all 5 cases. Although the reason for this decision was not well recorded, the rationale might have been, to try to save the most endangered kidney first.

9.2.3. Bilateral PUJO.

Of the 152 patients in this study, 9 had bilateral PUJO. In 4 patients a nephrectomy of the contralateral kidney had already been performed in an other hospital. There were 5 patients in whom a pre- and postoperative evaluation of both kidneys was possible.

| | | Sex | Age | Symptoms | Hydronephrosis | Operation | Final result (IVU) |
|---|---|---|---|---|---|---|---|
| 1 | R | ♀ | 2 | UTI | severe | Anderson-Hynes | good |
| | L | | | | moderate | Anderson-Hynes | good |
| 2 | R | ♂ | 2 | Haematuria | no excretion | Culp | good |
| | L | | | | moderate (stone) | Foley | good |
| 3 | R | ♀ | 37 | UTI urosepsis | moderate | Culp | good |
| | L | | | | moderate | Culp | good |
| 4 | R | ♀ | 66 | pain | no excretion | Anderson-Hynes | fair |
| | L | | | | no excretion | adhesiolysis | fair |
| 5 | R | ♀ | 77 | pain | no excretion | Anderson-Hynes | good |
| | L | | | | no excretion | Culp | good |

In this group only patient number 1 had UTI in her history. In all operations some method of urinary drainage was used and the total renal function improved in all patients. All were free of symptoms after the operations.

There were four patients with bilateral PUJO, while on one side a nephrectomy already had been performed in an other hospital:

| | Sex | Age | Symptom | Hydronephrosis | Operation | Final result (IVU) |
|---|---|---|---|---|---|---|
| 1. | ♀ | 3 | UTI | moderate | Anderson-Hynes | fair |
| 2. | ♂ | 13 | GI uraemia | severe | Anderson-Hynes | good |
| 3. | ♂ | 63 | pain | severe | Anderson-Hynes | good |
| 4. | ♀ | 71 | UTI | severe | Anderson-Hynes | good |

There were 2 patients (number 1 and 4) with UTI in their history. In 3 patients (1, 2 and 3) some method of urinary drainage was used. The total renal function improved in all patients and they were all free of any symptoms.
The incidence of bilateral PUJO in this series is 9 in 152 patients (= 6%).

9.2.4. Secondary operations.
There were 8 patients in this study who had been operated before on the same kidney, 7 of them in an other hospital. The operations had been performed because of PUJO, but this condition was not recognized in some cases and the pyeloplasty failed in others. Patient number 8 in this group was operated upon twice in our hospital. The patients number 3 and 6 had kidneys which were severely damaged by prolonged obstruction and had much scar tissue because of previous operations. It was therefore decided to perform a nephrectomy. The secondary operation (Culp pyeloplasty) in patient number 2 failed because of persistent obstruction and a nephrectomy was found to be necessary.

| | Sex | Age | First operation | Symptoms | IVU after first operation<br>Hydronephrosis | Second operation | Final IVU |
|---|---|---|---|---|---|---|---|
| 1 | ♂ | 63 | nephropexy + adhesiolysis | pain | severe | Anderson-Hynes | good |
| 2 | ♀ | 54 | pyelolithotomy | p.o. IVU | moderate | Culp | poor; sec. nephrectomy |
| 3 | ♂ | 46 | 2x adhesiolysis 1x pyeloplasty | pain | severe | Nephrectomy | - |
| 4 | ♀ | 35 | Fenger | pain | moderate (+ stone) | Anderson-Hynes | good |
| 5 | ♂ | 23 | Fenger | pain | no excretion (+ stone) | Nephrectomy | - |
| 6 | ♂ | 40 | 1x Fenger 1x pyelolithotomy | pain | severe | Anderson-Hynes | fair |
| 7 | ♂ | 48 | ligation of access. vessel | pain | moderate | Anderson-Hynes | good |
| 8 | ♀ | 33 | adhesiolysis | pain | moderate | Culp | good |

9.2.5. Accessory vessels.

Accessory vessels were found in 39 of the 158 operations performed for PUJO. Of the 39 accessory vessels found, 18 were ligated because they were at that time thought to be a causative factor of the PUJO or they interfered with the adequate performance of the pyeloplasty.

| Accessory vessels | Present: Ligated | Present: Not ligated | Absent |
|---|---|---|---|
| 158 operated kidneys | 39 | | 119 |
| | 18 | 21 | |

For decades accessory vessels have been thought to play an important causative role in PUJO. Because accessory vessels are, at present, not considered to be the cause of PUJO, they should not be ligated. Accessory vessels are only a secondary, sometimes aggravating factor in PUJO.

9.2.6. Urinary drainage.

When a pyeloplasty (121 kidneys) was performed, the following ways of urinary drainage were chosen:

| | | |
|---|---|---|
| - nephrostomy | 8 kidneys | 7% |
| - nephrostomy + ureteric splint | 43 kidneys | 36% |
| - combinationsplint | 21 kidneys | 17% |
| - none | 49 kidneys | 40% |
| Total | 121 kidneys | 100% |

A combinationsplint is a Silastic® tube which can be used as a nephrostomy or a pyelostomy, with on the tip a splint for the ureter. An ureteric splint was used in 53% of the operations. In all operations a vacuum drain was used.

The final result of the operations with or without urinary drainage, as judged on the IVU picture after 3 months or longer, was as follows:

A- without urinary drainage:

| | | |
|---|---|---|
| - good | 36 kidneys | 73% |
| - fair | 8 kidneys | 17% |
| - poor | 2 kidneys | 4% |
| - no follow-up | 3 kidneys | 6% |
| Total | 49 kidneys | 100% |

B- with urinary drainage:

| | Nephrostomy | | Nephrostomy + ureteric splint | | Total | |
|---|---|---|---|---|---|---|
| - good | 5 | 62% | 46 | 72% | 51 | 71% |
| - fair | 2 | 25% | 10 | 15% | 12 | 16% |
| - poor | 1 | 13% | 1 | 2% | 2 | 3% |
| - no follow-up | - | - | 7 | 11% | 7 | 10% |
| Total | 8 | 100% | 64 | 100% | 72 | 100% |

There are many different views about urinary drainage after pyeloplasty operations. Over the years, the opinions have changed several times, always, never, or sometimes using urinary drainage. From the moment urinary drainage was started there has been the fear of infection. Infection may be damaging to the kidney, it may lead to nephrolithiasis and it may jeopardize the patient's life. However, we now have a large number of antibiotics available, to eradicate the infection. Therefore the dangers of urinary drainage are now less realistic than they were in the past. The use of some method of urinary drainage may prevent complications of urinary leakage, obstruction and even urinary tract infection because of improved drainage. It may therefore shorten the duration of hospitalization. Moreover, a drain in the renal pelvis gives the opportunity to perform a control pressure-flow study or antegrade pyelo-ureterography.
The data of this series show that the results of operations with and without urinary drainage are almost the same. In other words, using some way of urinary drainage does not have any negative effect on the final result and because it is safer to use urinary drainage, our conclusion is, to recommend pyeloplasties with urinary drainage.
It is our policy to use urinary drainage in all children and adults unless the local conditions, like the proximal part of the ureter , the anastomosis and the quality of the tissues in general, during the operation are so good that a successful outcome may be expected.

9.2.7. Postoperative urinary tract infections (UTI).

In 28 patients a postoperative UTI was observed. Two (female) of these patients had an UTI at presentation before operation and 8 had UTI in their history (6 females, 2 males), while UTI were the main symptom in all cases. In 23 of the patients with a post-operative UTI some form of urinary drainage was used.

| P.O. UTI | UTI in history | UTI at admission | Urinary drainage |
|---|---|---|---|
| 28 patients | 8 | 2 | 23 |

The incidence of postoperative UTI after using some form of urinary drainage was as follows:

| P.O. Urinary drainage | P.O. UTI | | No P.O. UTI | |
|---|---|---|---|---|
| With U.D. 72 kidneys | 23 | 32% | 49 | 68% |
| Without U.D. 49 kidneys | 5 | 10% | 44 | 90% |

Because 23 of the 28 patients (82%) with a p.o. UTI had been operated with urinary drainage, the relation between p.o. UTI and urinary drainage looks obvious. However, one should keep in mind that of the 23 patients with p.o. UTI in this series, 10 had already UTI as main presenting symptom.

All patients with p.o. UTI were treated with antibiotics and the urine of all patients became sterile eventually.

9.2.8. Postoperative complications.

The complications after the operation for hydronephrosis due to PUJO in this series can be divided in pyeloplasty-related complications (10) and general complications (13).

A. Pyeloplasty related complications.

Non functioning of the anastomosis.

A. Introduction of an ureteric catheter.

- male, 28 years. 1952 ligation of an accessory vessel. 1971 Anderson-Hynes pyeloplasty; no urinary drainage; p.o. urinary leakage; an ureteric catheter was introduced, which stopped the leakage definitively: good result.

B. Secondary pyeloplasty.

1. male, 24 years. Moderate hydronephrosis. Fenger pyeloplasty; urinary drainage; p.o. urinary leakage; secondary pyelo-

plasty (Anderson-Hynes): good result.

2. male, 20 years. Severe hydronephrosis. Foley pyeloplasty; no urinary drainage; p.o. severe hydronephrosis; secondary pyeloplasty (Anderson-Hynes): good result.

C. Secondary nephrectomy.

1. male , 1 year. Moderate hydronephrosis. 1965 Davis procedure; splint pulled out by patient on the 26th day; nephrostomy removed on the 78th day; p.o. non functioning of the anastomosis: secondary nephrectomy 6 months after operation.
2. male, 1 year. Severe hydronephrosis. 1973 Anderson-Hynes pyeloplasty; nephrostomy removed on the 21st day; p.o. non functioning of the anastomosis: secondary nephrectomy.
3. male, 9 months. Moderate hydronephrosis with stones. 1962 Fenger pyeloplasty; ureteric catheter fell out on the 6th day; nephrostomy tube was removed on the 23rd day; p.o. non functioning of the anastomosis: secondary nephrectomy.
4. male, 13 years. Severe hydronephrosis. 1963 Foley pyeloplasty; nephrostomy removed on the 15th day; p.o. non functioning of the anastomosis: secondary nephrectomy.
5. male, 50 years. Severe hydronephrosis. 1970 Culp pyeloplasty; no splint; one year p.o. pain and severe hydronephrosis: secondary nephrectomy.
6. female, 53 year. Mild hydronephrosis. 1964 Foley pyeloplasty; ureteric splint; splint removed on the 14th day; nephrostomy on the 21st day; one year p.o. pain and severe hydronephrosis: secondary nephrectomy.
7. female, 54 years. Moderate hydronephrosis. 1969 pyelolithotomy (other hospital); 1971 Culp pyeloplasty; no splint; non functioning of the anastomosis: secondary nephrectomy 1 month p.o..

B. General complications.

| | | |
|---|---|---|
| -woundbleeding: | 3 patients | - 2 needed exploration |
| | | - 1 was treated conservatively |
| -other : | 10 patients | - 3 urinary retention |
| | | - 1 deep vein trombosis |
| | | - 1 pulmonary embolism |
| | | - 1 myocardial infarction |

- 1 ileus (paralytic) + respiratory tract infection
- 1 allergic reaction on Tegretol®
- 1 wound dehiscence
- 1 woundseroma

The most important postoperative complication is the non-functioning of the anastomosis. If the complete urine production is drained by a nephrostomy and no splint is used, the 2 sides of the anastomosis may fall together and become united by a film of fibrin . Sometimes a retrograde catheterisation is required to open it up. In 2 patients the first pyeloplasty (1 Foley and 1 Fenger) failed but a secondary pyeloplasty (Anderson-Hynes) was successful. In these secondary operations urinary drainage was used.

9.2.9. Postoperative IVU.

In general it is our policy to perform a 20-30 minutes IVU before the patient leaves the hospital because we want to be sure that the kidney is functioning.

The criteria were:

- poor = compared with the preoperative IVU, means poor excretion and more dilatation
- fair = the picture is almost the same or somewhat better and the ureter may be filled with contrast
- good = less dilatation and good excretion.

The results of the postoperative IVU within 3 weeks after the operation could be evaluated in only 92 kidneys and was as follows:

| IVU within three weeks p.o. | | |
|---|---|---|
| - poor | 18 kidneys | 20% |
| - fair | 35 kidneys | 38% |
| - good | 39 kidneys | 42% |
| Total | 92 kidneys | 100% |

The results of the postoperative IVU after approximately 3 months was as follows:

| IVU at three months | | |
|---|---|---|
| - poor | 6 kidneys | 5% |
| - fair | 29 kidneys | 23% |
| - good | 89 kidneys | 72% |
| Total | 124 kidneys | 100% |

Because in 25 patients a nephrectomy was performed there was no IVU at 3 months and in 9 cases an IVU was not available.
The change from one category, soon after the operation, to another category, 3 months postoperatively, was as follows:

| | | Final IVU | | |
|---|---|---|---|---|
| IVU at three weeks | | poor | fair | good |
| - poor | 15 kidneys | 3 | 4 | 8 |
| - fair | 34 kidneys | 1 | 10 | 23 |
| - good | 37 kidneys | 0 | 0 | 37 |
| Total | 86 kidneys | 4 | 14 | 68 |

Because not in all patients an IVU was performed soon after the operation and at 3 months, there were 86 patients available for this comparison.
The final results of the various types of pyeloplasties, as judged from the postoperative IVU, was as follows:

| Final result | Poor | | Fair | | Good | | No follow-up | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Anderson-Hynes | 1 | 1% | 8 | 10% | 63 | 82% | 5 | 7% | 77 |
| Culp | 1 | 5% | 3 | 22% | 13 | 72% | 1 | 1% | 18 |
| Foley | 2 | 15% | 4 | 31% | 6 | 46% | 1 | 8% | 13 |
| Fenger | 2 | 18% | 5 | 46% | 4 | 27% | 1 | 9% | 12 |
| Davis | 0 | 0 | 1 | 100% | 0 | 0 | 0 | 0 | 1 |
| Total | 6 | | 21 | | 86 | | 8 | | 121 kidneys |

The postoperative IVU performed before the patient left the hospital usually revealed persistent dilatation due to oedema at the site of the anastomosis. As has been discussed in chapter 7, the final result may be expected 3-6 months after the operation. This is reflected in the difference between the results of the 2 groups. A considerable improvement can be seen.

9.2.10. Postoperative renography.

Postoperative renography was performed in 60 patients. The results were:

- unchanged (obstructed) excretion in 22 patients
- improved excretion in 37 patients
- improved excretion in bilateral PUJO in 2 patients.

In the group of 37 patients with improved excretion there were 4 patients with an initially obstructive curve but rapid excretion followed after administration of a diuretic.

The correlation between the postoperative IVU and the postoperative renography was as follows:

| Renography | Good IVU | | Fair IVU | |
|---|---|---|---|---|
| improved excretion 37 kidneys | 34 | 91% | 3 | 9% |
| obstructed excretion 21 kidneys | 15 | 71% | 6 | 29% |

Included in the group of 34 patients with improved excretion and a good IVU are 2 patients with bilateral PUJO. In some patients there was no postoperative IVU available so that a comparison could not be made.

In 37 patients the postoperative renography showed an improved excretion which can be considered as evidence that the aim of the operation was achieved. As is discussed in chapter 7, the diuresis renography gave an extra dimension to the follow-up. Four patients in this series had an obstructive curve, but after administration of a diuretic, the curve showed rapid excretion, which is supposed to exclude a real obstruction. The obstructive type of curve in patients after a pyeloplasty is sometimes caused by a rather capacious collecting system. It is therefore likely that the majority of the 22 patients with the unchanged (obstructed) excretion on standard renography, would have shown a rapid excretion on diuresis renography. This procedure was not performed in those years.

The data of the correlation between the postoperative renography and IV-urography show, that improved excretion on renography gives a good IVU in 91%. So the relation between these two investigations is very strong, although one should keep in mind that the IVU-picture depends on the technique that has been used.

9.2.11. <u>Postoperative clinical picture</u>.

The clinical picture of the 152 patients after the operation was as follows:

| | | |
|---|---|---|
| - all nephrectomised patients had no complaints | 25 patients | 17% |
| - no complaints<br>good or fair IVU<br>sterile urine | 102 patients | 67% |
| - no complaints<br>fair or poor IVU<br>sterile urine | 8 patients | 5% |
| - no complaints<br>no IVU performed | 9 patients | 6% |
| - complaints improved<br>fair or poor IVU<br>sterile urine | 6 patients | 4% |
| - unknown | 2 patients | 1% |
| Total | 152 patients | 100% |

Ten of the 11 patients in whom the operation for correction of PUJO consisted of adhesiolysis were all free of symptoms. In one patient a secondary operation (pyeloplasty) was necessary. The final result of the IVU was fair in 8 patients and good in 3.
The patient in whom we performed a ligation of an accessory vessel was later free of symptoms with a fair IVU.
The postoperative clinical picture shows that there were only 6 patients (4%) in this series, with occasionally vague sensations in the flank and it is doubtful if this had anything to do with the kidney.
Ninety-six % of the patients was completely free of any complaints.

9.2.12. Hypertension.

In this series there were 6 patients (4 male, 2 female) with hypertension. After a pyeloplasty was performed, 3 patients became normotensive and 2 needed anti-hypertensive drugs, although the operation in itself was successful.

As is discussed in chapter 4, PUJO may be accompanied by hypertension, probably caused by increased plasma renin activity (PRA). After nephrectomy or pyeloplasty, hypertension can be observed to disappear, especially when the contralateral kidney was not damaged.

9.2.13. Renal function.

It is important to realize that a rise in serum creatinine concentration will only be observed when the renal function falls roughly below 50% of normal. The serum creatinine concentration is dependent on sex, age and body weight. As no creatinine clearances were performed, the pre- and postoperative renal function was evaluated from the serum creatinine concentration.

In 126 patients the serum creatinine concentration remained the same, because there was a normal contralateral kidney. In 16 patients no postoperative serum creatinine concentration values were available.

In cases of bilateral PUJO and PUJO in a solitary kidney a change in renal function could be expected because the influence of the normal functioning controlateral kidney is absent. There were 10 patients that belonged to this category:

A. Bilateral PUJO

B. Bilateral PUJO with nephrectomy of one side

C. PUJO with aplasia of the contralateral kidney.

These data show a clear improvement in renal function in most patients after the PUJO was relieved. In general a similar improvement can be expected when a normal contralateral kidney is present.

| | Sex | Age | Preoperative serum creatinine conc. µmol/L | Postoperative serum creatinine conc. µmol/L | Improvement µmol/L |
|---|---|---|---|---|---|
| A 1 | ♀ | 2 | 48 | 47 | 1 |
| 2 | ♂ | 2 | 88 | 64 | 24 |
| 3 | ♀ | 37 | 103 | 61 | 42 |
| 4 | ♀ | 66 | 404 | 193 | 211 |
| 5 | ♀ | 77 | 352 | 101 | 251 |
| B 1 | ♀ | 3 | 147 | 65 | 82 |
| 2 | ♂ | 13 | 690 | 77 | 613 |
| 3 | ♂ | 63 | 264 | 132 | 132 |
| 4 | ♀ | 71 | 265 | 75 | 190 |
| C 1 | ♂ | 51 | 255 | 193 | 63 |

In 3 children in this group of 10 patients a pre- and postoperative creatinine clearance was performed:

| Creatinine clearance (ml/min/1,73m$^2$) | | | |
|---|---|---|---|
| | Preoperative | Postoperative | Improvement |
| A.1 | 64 | 125 | 61 |
| A.2 | 64 | 118 | 54 |
| B.1 | 25 | 76 | 51 |

A considerable increase in creatinine clearance can be noticed in all patients, which again proves the ability of recovery of kidneys after a PUJO is relieved.

9.2.14. Histology.

The general opinion is that the cause of PUJO could be found by examination of the function of the obstructing segment. Histological examination may give important information that could lead to the solution of the problem.

In cooperation with the Department of Pathology and the Anatomy Laboratory, histological investigation of the pelvi-ureteric junction and renal pelvis was performed. All specimens were fixed in formalin and stained with H-E. The histology of the pelvi-

ureteric junction and renal pelvis as described in chapter 3 was considered as "normal".
Light microscopy of the pelvi-ureteric junction was performed in a group of 15 patients, randomly chosen, who had undergone an Anderson-Hynes pyeloplasty or a nephrectomy because of hydronephrosis due to PUJO.
In 78 cases light microscopy was routinely performed by the Department of Pathology (Head: Prof. Dr. Ph.J.Hoedemaeker).
Ten pelvi-ureteric junctions obtained at autopsy from patients without any urological antecedents, who died from non-kidney related diseases, served as a control group.
A variety of abnormalities was observed. A variable degree of inflammatory cell infiltration (also observed in 5 specimens in the control group), fibrosis in the submucosa and a marked diversity in muscle fibre organisation were noticed.
The results of the examination of the pelvi-ureteric junction of both groups together (15 + 78 = 93) was as follows:

| | |
|---|---|
| - fibrosis in the submucosa | 18 patients |
| - fibrosis in the submucosa and inflammatory cell infiltration | 5 patients |
| - fibrosis in the submucosa and muscle fibre hypertrophy | 6 patients |
| - narrow lumen | 14 patients |
| - narrow lumen and fibrosis in the submucosa | 7 patients |
| - narrow lumen and inflammatory cell infiltration | 11 patients |
| - narrow lumen and inflammatory cell infiltration and reduced muscle bulk | 1 patient |
| - inflammatory cell infiltration | 7 patients |
| - normal PUJ | 24 patients |
| | 93 patients |

In the group of 24 patients with a normal PUJ, the renal pelvic wall showed fibrosis in the submucosa in 2 patients and muscle fibre hypertrophy in 10 patients.
It is obvious that stones in the renal pelvis could cause inflammatory cell infiltration and fibrosis in the submucosa of the renal pelvic wall. Histological examination of the pelvi-

ureteric junction and the renal pelvic wall of 13 of the 25 patients with nephrolithiasis in this study were as follows:

| | |
|---|---|
| - fibrosis in the submucosa | 5 patients |
| - fibrosis in the submucosa and inflammatory cell infiltration | 3 patients |
| - inflammatory cell infiltration | 2 patients |
| - inflammatory cell infiltration of the renal pelvic wall | 2 patients |
| - narrow lumen | 1 patient |

A narrow lumen, observed at microscopy, could be an artefact after fixation of the tissue. During operation, however, a narrow lumen, which can not be passed by a probe, is often encountered.
The results show a wide variation in the specimens. However, in 36 patients (38%), fibrosis in the submucosa was observed. This is collagenrich acellular fibrous tissue, which is regarded as scar tissue. As is discussed in chapter 3, electronmicroscopy revealed excessive collagen between the muscle cells of the obstructed PUJ and the adjacent muscle cells in the area just proximal to the junction. The presence of this collagen tissue and the collagen tissue found by us, could provide an explanation for the functional obstruction theory, because the peristaltic waves of the renal pelvis are interrupted by these local pathological changes. Fibrosis in the submucosa, inflammatory cell infiltration and muscle fibre hypertrophy, however, could be secondary to obstruction and dilatation. Similar observations have been made in the colon in Hirschsprung's disease.
Despite numerous reports of varying pathological findings at the PUJ and our own investigations, the real cause of PUJO remains obscure. There is a widespread conviction, however, that the actual process is a functional obstruction.

# 10. Summary and Conclusions

In chapter 1 the history of pelvi-ureteric junction obstruction (PUJO) is described. In the past (Hippocrates and Tulp) this condition was recognized but it was not until the 17th century that the first operations were performed in order to drain the kidney or to remove stones. The first nephrectomy was described by Simon (1862). Trendelenburg (1886) performed the first conservative operation for correction of a PUJO. Later Küster (1891), Fenger (1892), von Lichtenberg (1921), Foley (1923), Davis (1933), Anderson-Hynes (1949), Culp (1951) and many others described the pyeloplasty techniques named after them.

Chapter 2 deals with the embryology and anatomy of the kidneys, renal pelves and ureters. The ureteric bud arises as an outgrowth of the mesonephric duct. It forms the ureter and dilates at its upper end to form the renal pelvis. Embryological studies do not help in elucidating the aetiology of PUJO.

In chapter 3 the histology of the normal ureter and pelvi-ureteric junction and also the changes found in PUJO are described. By lightmicroscopy the wall of the ureter can be seen to consist of three layers: an external adventitia, a smooth muscle coat and an inner mucous membrane of transitional cell epithelium.
It seems advisable to abandon the historical concept of "layers" of muscular fibres disposed in a longitudinal or circular fashion, in favour of a concept of an intermingling mass of bundles laid down in a spiral fashion. The ultrastructure by electronmicroscopy is also described.
In the search for the aetiology of PUJO, many investigators performed lightmicroscopy of the resected PUJ segment. The results were rather disappointing because of the great variation found in the specimens. Apart from completely normal specimens, a variety of changes was observed. These included submucosal fibrosis

inflammatory cell infiltration, muscle fibre hypertrophy, reduced muscle bulk and a narrow lumen. This leads to the conclusion that lightmicroscopy is of limited use for determining the aetiology of PUJO. However electronmicroscopy revealed excessive collagen between the muscle cells of the obstructed PUJ and adjacent muscle cells in the area just proximal to the junction, which could provide an explanation for the functional obstruction.

Chapter 4 of this thesis deals with the physiology and pathophysiology of the PUJ, renal pelvis and kidney. The normal PUJ is inconspicious and ill-defined as there is a gradual tapering between the renal pelvis and the upper ureter. It is this gradual tapering which makes it so effective as an emptying system. In fact the most effective PUJ is the one that is not visible on intravenous urography (IVU). The funnel shaped PUJ enables the peristaltic activity, somewhere in the course of the funnel, to close the lumen, so converting the mixing activity into the propulsion of a preformed bolus.
The mechanism of progression of the peristaltic wave remains as controversial today as it has always been. This discussion involves those who favour the myogenic theory and those who support the neurogenic theory of ureteric peristalsis. We consider the process as a neuromuscular activity, taking into account that combined mechanical, electrical, chemical and visco-elastic activities and forces are present. The site of origin of the peristaltic wave is the calyx , infundibular area or the region of the PUJ. The frequency of the peristaltic wave depends on the urine volume produced by the kidney.
Obstruction occurring in the upper urinary tract implies that the usual flow is reduced or only maintained at the cost of a higher than normal pressure within the renal pelvis. This prolonged, increased pressure will result in dilatation of the calyces and parenchymal destruction ("backpressure atrophy"). In obstructive uropathy great importance has been attributed to the unique role of backflow (pyelo-tubular, pyelo-venous, pyelo-lymphatic, pyelo-interstitial ). Initially renal impairment is caused by tubular dysfunction which leads to polyuria.
The reduced flow in PUJO may lead to infection and stone formation.

The theory of renal counterbalance, proposed by Hinman in 1923 has proven to be false. Severely damaged kidneys, certainly in children, have a great ability to recover after a pyeloplasty, even in the presence of a healthy contralateral kidney. Remarkable post-obstructive polyuria has been recorded and this potential hazard should be recognized and adequately treated. Hypertension associated with hydronephrosis is probably renin-dependent in some cases.

Chapter 5 concerns the aetiology. The intrinsic and extrinsic causes of PUJO, found at operation, are considered.
Accessory vessels have been considered to be important for many decades. However all extrinsic factors like accessory vessels and fibrous bands are now thought to be of only secondary importance and may aggravate a developing hydronephrosis.
High insertion of the ureter into the renal pelvis is also regarded as secondary to dilatation and bulging of the inferior pelvic wall which leads to an upward displacement of the pelvi-ureteric junction.
In recent years it has become clear that a functional obstruction at the pelvi-ureteric junction is the most probable cause. The peristaltic waves of the renal pelvis are interrupted due to local pathological changes. Electronmicroscopy revealed excessive collagen between the muscle cells of the obstructed PUJ and adjacent muscle cells in the area just proximal to the junction. How and why these changes took place is still unknown.

In chapter 6 the symptomatology is described. Pain, urinary tract infections, haematuria, a palpable mass in the renal area, gastro-intestinal manifestations, hypertension, polycythemia and renal failure may present as symptoms. The pain can be either colicky and intermittent or a dull ache and can sometimes be provoked by increased fluid intake or administration of a diuretic. Haematuria may appear spontaneously or can be caused by a relatively minor trauma.
In children the presenting symptoms are urinary tract infections, abdominal pain, loin pain, gross haematuria, a palpable abdominal mass, nocturnal enuresis and failure to thrive.

Chapter 7 concerns the diagnostic procedures.
Because intravenous urography is the cornerstone in the diagnosis of PUJO, this procedure is discussed in detail. The IVU should be made during an attack of pain because in intermittent hydronephrosis the IVU could show a "normal" picture between attacks. Diuresis IVU is a more accurate screening test which can demonstrate a PUJO in 85% of cases.
The postoperative IVU, before the patient leaves the hospital, is in most cases disappointing because there is residual oedema and infiltration of tissues at the anastomosis associated with the repair process. The picture after 3 months will provide a good impression of the ultimate result, as after this period, little, if any improvement occurs.
Micturating cystourethrography is valuable, certainly in children, because vesicoureteric reflux may lead to dilatation of the renal pelvis and suggest a PUJO. A reimplantation of the ureter will usually stop the pelvic dilatation and can result in a dramatic reversion to a normal pelvi-ureteric function.
Retrograde pyeloureterography is only necessary if the proximal ureter is not visualized on IVU and should be performed just prior to exploration of the kidney. The period between retrograde pyeloureterography and exploration should be as short as possible because infection can be introduced and passing the ureteric catheter upward into the renal pelvis may cause oedema of the PUJ which makes drainage of the hydronephrosis even worse.
Since high dose (standard and diuresis) IVU, renography, renal scintigraphy, ultrasound and CT scan examination are available, there is seldom an indication for renal angiography. In cases of ectopic kidneys and in horseshoe kidneys with PUJO it would be useful to be informed about the vascular pattern if it became necessary to transect the isthmus.
Antegrade pyeloureterography and pelvi-ureteric pressure-flow studies can be very useful, but the technique is invasive. Pressure-flow studies can be performed by percutaneous puncture of the renal pelvis or during exploration of the kidney.
Standard renography gives information about the renal parenchymal function and excretion and is therefore an important pre- and postoperative diagnostic procedure.

In cases of equivocal PUJO e.g. if there is a dilated renal pelvis with an obstructive curve on renography, the injection of a diuretic (diuresis renography), may demonstrate obstruction or rapid excretion, which makes the obstruction less probable.
Renal scintigraphy (DMSA Technetium scan) gives good morphological information concerning the renal parenchyma and could be combined with renography.
Adequate information about the pre- and postoperative renal function, especially in cases of a solitary kidney, is necessary because for the urologist the indications for performing a pyeloplasty are to preserve kidney function and also to relieve the patient of his complaints.
The CT scan and ultrasound examination are both non-invasive supplementary diagnostic procedures. CT scan however, gives a relatively high radiation dose. Ultrasound is simple, harmless to the patient and could be combined with percutaneous puncture of the renal pelvis which permits antegrade pyeloureterography, pressure-flow studies and/or a temporary pyelostomy.

Chapter 8 describes the therapeutic possibilities. The aim of the treatment in PUJO is to relieve the patients of their complaints or symptoms and to preserve as much renal parenchyma as possible. The result should be a funnel-shaped, dependent, well draining pelvi-ureteric outlet. If necessary, part of the dilated renal pelvis should be resected to prevent stasis . Infection should be eliminated.
The therapy can be divided in several groups: nephrectomy, drainage of the kidney (like a nephrostomy or pyelostomy) and non-dismembered and dismembered pyeloplasties.
In the beginning of this century any operation had a high mortality rate and a nephrostomy or nephrectomy was all that could be performed. Even in 1952 nephrectomy was done in 56% of the patients with hydronephrosis due to PUJO. The nephrectomy rate is now reduced to 3-10%. Because even badly damaged kidneys can recover very well, one should aim at preserving as much renal parenchyma as possible.
Nowadays a nephrostomy or pyelostomy is only used in exceptional cases or as a temporary method of drainage.

Many operative techniques of the non-dismembered and dismembered group are described in detail in this chapter.
It is stressed that so called aberrant or accessory vessels should not necessarily be ligated. They are not supposed to be a primary cause of PUJO, but they can aggravate an already developing hydronephrosis.
In the light of the information provided by electron-microscopic studies it should be possible to examine the rationale of each pyeloplasty. In a Y-V pyeloplasty, advancement of a flap, containing many abnormal wall components with minimal reduction of dead space, is performed. In the Culp-spiral flap pyeloplasty a flap, containing relatively healthy muscle tissue, is used with some reduction of dead space. In the Anderson-Hynes pyeloplasty a complete excision of the obstructed segment is performed, often with reduction of the dead space by excision of a part of the affected pelvis. This may be the reason why this procedure gives good results. In general the Anderson-Hynes pyeloplasty is our first choice.
The effect of transection of the ureter is discussed. Several different ways of urinary drainage and splinting with their advantages and disadvantages are mentioned.
The ideal operation would be one requiring neither drainage nor splinting. However, there are still splinters and non-splinters. Although the general idea is, that tubes in the urinary tract lead to a higher percentage of infections, this has not been shown in all papers about this subject. In general one should decide during operation, to use a splint with or without renal drainage if one suspects problems in the postoperative period. In secondary operations, solitary kidneys and in children it seems advisable to use a splint as a safeguard. The ureteric splint should be soft, made of non reactive material such as Silastic®, and should fit easily into the ureter. A tube that splints the ureter and one draining the renal pelvis as a pyelostomy or nephrostomy is our first choice. The splints should be left in place for about 2 weeks, although the time depends on the local factors found at operation. A vacuum drain is always used.
The technique of the pyeloplasty in cases of a duplicated renal pelvis or ureter is described.

Many cases of massive hydronephrosis, filled with gallons of urine have been described and in some of these cases it was even possible to salvage the kidney.
In cases of PUJO in a horseshoe kidney, it has been found necessary for many decades to cut the isthmus because the obstruction appeared to be due to stretching of the ureter over it.
Nowadays a pyeloplasty is regarded as sufficient to correct the problem in many of these cases.
A lumbar approach is normally used, although in cases of horseshoe kidney a laparotomy is preferred. The anterolateral extra- and/or transperitoneal approaches are advocated by others. Some paediatric urologists are inclined to use a ventral incision and in cases of bilateral PUJO in children a long transverse incision.
The possibility of intestinal obstruction is a disadvantage of the transperitoneal approach.
The complications of a pyeloplasty, like leakage of urine, infection, stone and stricture formation are discussed.
A symptomless PUJO can lead to a slow deterioration and loss of parenchyma. It is therefore necessary to perform a pyeloplasty or keep these patients under careful control.
In cases of bilateral PUJO a pyeloplasty can be performed on both sides through a transverse incision.

In chapter 9 a review of our series of 152 patients is given. Preoperative, operative and postoperative data are discussed. The series consists of 90 male and 62 female patients of whom 11 had been operated before (14 operations totally) in an other hospital. In 4 of the 9 patients with bilateral PUJO nephrectomy of the contralateral kidney had already been performed elsewhere. Forty-four patients (29%) fell in the 0-15 years of age group. Pain, urinary tract infections and gross haematuria were important presenting symptoms.
The main presenting symptom in children (0-15 years) were urinary tract infections (39%), while in adults this was pain (81%).
The number of IV-urograms that had been performed, before the diagnosis was made, was surprisingly high in several patients.
Nephrolithiasis was observed in 25 patients (16%).
Renography has been of increasingly great value. In all patients

with a mild, moderate or severe hydronephrosis due to PUJO, an obstructive curve was found on renography. When an afunctional curve was observed, nephrectomy was performed. In 26 patients with unilateral PUJO, a closed type of renal pelvis was observed on the contralateral side. In 22 of these patients, the renogram showed a normal and in 4 patients a slightly obstructive curve.

Retrograde urography was performed in 102 patients. In 50 patients the IVU gave sufficient information.

Of the 146 patients with unilateral PUJO, 80 (55%) were operated on the right side and 66 (45%) on the left.

The following 158 operations were performed: 25 nephrectomies, 11 adhesiolysis, one ligation of an accessory vessel alone and 121 pyeloplasties. Of the pyeloplasty techniques, the Anderson-Hynes procedure was used most frequently (64%).

All 5 patients with bilateral PUJO were first operated on the most endangered kidney.

The incidence of primary nephrectomy in this series was 15% (23 patients). In 4 patients with bilateral PUJO, nephrectomy of the contralateral kidney had already been performed in another hospital .

Of the 39 accessory vessels that were found, 18 were ligated because they were at that time thought to be a causative factor of the PUJO or they interfered with the adequate performance of the pyeloplasty.

Some method of urinary drainage was used in 72 operations (60%). The data of this series show that the final results of the operations with and without urinary drainage were almost the same. The use of urinary drainage is advocated because it may prevent complications of urinary leakage and obstruction. It may therefore shorten the duration of hospitalization. Twenty three of the 28 patients with postoperative urinary tract infections had been operated with some method of urinary drainage.

There were 10 pyeloplasty-related postoperative complications. Introduction of an ureteric catheter solved the problem in one patient, a secondary pyeloplasty was necessary in 2 patients and a secondary nephrectomy in 7.

The postoperative IVU, performed before the patient left the hospital, usually revealed persistent dilatation due to oedema at

the site of the anastomosis. A considerable improvement could be noticed on the final IVU 3 months postoperatively. The results of the final IVU were: good in 72%, fair in 23% and poor in 5%. The best results were observed in the patients that had been operated following the Anderson-Hynes procedure (82% good), which is also our first choice of operation in cases of PUJO.
The postoperative renogram showed an improved excretion in 37 patients and in 2 patients with bilateral PUJO. In the group of 37 patients with improved excretion, there were 4 patients with an initially obstructive curve but rapid excretion after a diuretic was administed (diuresis renography).
Of the 152 patients, 144 became completely free of complaints (95%). Six patients had occasionally vague sensations in the loin but it was doubtful if this had anything to do with the kidney. Two patients were lost for follow up.
Three of the 6 patients with hypertension became normotensive after a pyeloplasty was performed.
As only in three children a creatinine clearance was performed, which showed an considerable improvement after the PUJO was relieved, the pre- and postoperative renal function was evaluated from the serum creatinine concentration. In 126 patients the serum creatinine concentration remained the same, because there was a normal contralateral kidney. The pre- and postoperative serum creatinine concentrations of patients with bilateral PUJO ( 5 patients), bilateral PUJO with nephrectomy at one side (4 patients) and PUJO with aplasia of the contralateral kidney are given. These data show a clear improvement in renal function in most patients after the PUJO was relieved. In general a similar improvement can be expected when a normal contralateral kidney is present.
Histological investigation of the PUJ segment was performed in 93 patients. The results showed a wide variation. However, fibrosis in the mucosa was observed in 46 patients (40%). This collagen rich acellular fibrous tissue could provide an explanation for the functional obstruction theory. Fibrosis in the submucosa, inflammatory cell infiltration and muscle fibre hypertrophy, however, could be secondary to obstruction and dilatation, due to a still unknown cause.

# 10. Samenvatting en Conclusies

In hoofdstuk 1 wordt een historische beschrijving gegeven van de pyelo-ureterale obstructie. In het verleden (Hippocrates en Tulp) waren er theorieën over deze aandoening, maar pas in de 17e eeuw werden de eerste operaties verricht met als doel de nier te draineren of om stenen te verwijderen.
De eerste nephrectomie werd beschreven door Simon (1862). Trendelenburg (1886) verrichtte de eerste conservatieve operatie ter correctie van een pyelo-ureterale obstructie. Later beschreven Küster (1891), Fenger (1892), Von Lichtenberg (1921), Foley (1923), Davis (1933), Anderson-Hynes (1949), Culp (1951) en vele anderen de operatieve technieken, die naar hen werden genoemd.

In Hoofdstuk 2 wordt de embryologie en anatomie van de nieren, nierbekkens en ureteren beschreven. De ureter-knop ontstaat als een uitstulping van de ductus mesonephricus.Deze vormt de ureter en wordt aan het uiteinde wijder en splitst zich om tenslotte het nierbekken en de calices te vormen. Op grond van de embryologie kan geen verklaring worden gevonden voor de aetiologie van de pyelo-ureterale obstructie.

In Hoofdstuk 3 wordt de histologie van de normale ureter en de pyelo-ureterale overgang beschreven evenals de veranderingen die ontstaan bij de pyelo-ureterale obstructie. Microscopisch onderzoek toont dat de wand van de ureter uit 3 lagen bestaat: een uitwendige adventitia, een laag glad spierweefsel en een binnenste slijmvlieslaag van overgangsepitheel. Het lijkt beter om het historische concept dat er "lagen" spiervezel op longitudinale en circulaire wijze zijn gerangschikt te verlaten en aan te nemen, dat de spiervezels volgens een spiraal zijn gerangschikt.
De ultrastructuur, die bij electronenmicroscopisch onderzoek gezien wordt, wordt ook beschreven.

Bij het zoeken naar de aetiologie van de pyelo-ureterale obstructie hebben vele onderzoekers de gereseceerde pyelo-ureterale overgang microscopisch bekeken. De resultaten waren nogal teleurstellend door de grote variatie die in de preparaten werd gevonden. Naast de volstrekt normale preparaten, werd een grote variatie van veranderingen waargenomen. Deze bestonden uit submuceuze fibrose, ontstekingsinfiltraat, spiervezelhypertrofie, een vermindering van de hoeveelheid spierweefsel en een nauw lumen. Hieruit kan men concluderen, dat lichtmicroscopie slechts van beperkte waarde is bij het vaststellen van de aetiologie van pyelo-ureterale obstructie. Electronenmicroscopie toonde echter veel collageen weefsel aan tussen de spiercellen in de geobstrueerde pyelo-ureterale overgang, wat een verklaring zou kunnen geven voor de functionele obstructie.

Hoofdstuk 4 van deze dissertatie behandelt de physiologie en de pathophysiologie van de nier, het nierbekken en de pyelo-ureterale overgang. De normale pyelo-ureterale overgang is niet duidelijk zichtbaar, omdat het nierbekken geleidelijk overgaat in de proximale ureter. Het is juist deze geleidelijke overgang, die de ontlediging zo effectief maakt. In feite is de pyelo-ureterale overgang, die op het intraveneuze urogram niet zichtbaar is het meest effectief. De trechtervormige pyelo-ureterale overgang stelt de peristaltische golven, ergens in het verloop van de trechter, in staat om het lumen te sluiten, waardoor een urinebolus gevormd wordt, die in de richting van de ureter wordt bewogen.
Het mechanisme waardoor de peristaltische golf zich voortbeweegt zal een punt van tegengestelde opinies blijven tussen hen, die geloven in de myogene en anderen die een voorkeur hebben voor de neurogene theorie van het ontstaan van de ureterperistaltiek. Wij beschouwen het proces als een neuromusculaire activiteit, waarbij mechanische, electrische, chemische en viscoelastische krachten en eigenschappen een rol spelen. De plaats waar de peristaltische golf ontstaat kan de calyx, het infundibulum, het pyelum of de regio van de pyelo-ureterale overgang zijn. De frequentie van de peristaltiek is afhankelijk van de hoeveelheid urine die de nier produceert.

Obstructie in de hogere urinewegen houdt in, dat de urine-flow afneemt, of hetzelfde blijft ten koste van een hogere druk dan normaal in het nierbekken. Deze voortdurende druk zal leiden tot dilatatie van de calices en verlies van parenchym (back pressure atrophy). Bij obstructieve uropathie is een grote rol toegeschreven aan backflow (pyelotubulair, pyeloveneus, pyelolymfatisch, pyelointerstitieel). In het begin is het vooral de tubulaire dysfunctie die de oorzaak is van de nierfunctiestoornis die leidt tot polyurie.
De verminderde flow bij pyelo-ureterale obstructie kan leiden tot infectie en steenvorming.
De theorie van de "renal counterbalance" zoals voorgesteld door Hinman Sr. in 1923, is gebleken niet op realiteit te berusten. Zelfs ernstig beschadigde nieren, zeker bij kinderen, hebben een sterk herstellingsvermogen nadat de obstructie is opgeheven, zelfs bij aanwezigheid van een goede nier aan de contralaterale zijde.
Sterke polyurie met alle gevaren van dien, is beschreven nadat de obstructie is opgeheven.
Hypertensie bij patienten met hydronephrose berust waarschijnlijk in sommige gevallen op een verhoogde renine productie.

In Hoofdstuk 5 wordt de aetiologie behandeld. Op grond van de bevindingen bij operatie van patienten met hydronephrose als gevolg van een pyelo-ureterale obstructie, werd gedacht aan extrinsieke en intrinsieke oorzaken. Accessoire vaten hebben gedurende vele decennia een belangrijke rol gespeeld. Alle extrinsieke factoren zoals accessoire vaten en fibreuze banden worden thans echter als secundair beschouwd en kunnen eventueel wel leiden tot een verergering van een zich reeds ontwikkelende hydronephrose.
Een hoge insertie van de ureter in het pyelum wordt ook beschouwd als een secundair gevolg van de dilatatie van het onderste deel van het nierbekken, dat leidt tot een verplaatsing van de pyelo-ureterale overgang naar craniaal.
De laatste jaren is het duidelijk geworden, dat een "functionele" obstructie van de pyelo-ureterale overgang de meest waarschijnlijke oorzaak is. De peristaltische golven van het nierbekken worden onderbroken als gevolg van locale pathologische verande-

ringen. Electronenmicroscopisch onderzoek toonde veel collageen aan tussen de spiercellen van de obstruerende pyelo-ureterale overgang en de spiercellen proximaal daarvan in het pyelum. Hoe en waarom deze veranderingen plaatsvonden is nog onbekend.

In Hoofdstuk 6 wordt de symptomatologie beschreven. Pijn, urineweginfecties, macroscopische haematurie, een palpabele tumor in de nierstreek, gastro-intestinale symptomen, hypertensie, polycythaemie en nierfunctiestoornissen kunnen als symptomen optreden. De pijn kan koliekachtig en intermitterend zijn, maar ook wel zeurend en kan soms worden geprovoceerd door een verhoogde diurese. Macroscopische haematurie kan spontaan optreden of worden veroorzaakt door een relatief gering trauma.
De symptomen bij kinderen bestaan uit urineweginfecties, buikpijn, pijn in de flank, macroscopische haematurie, een palpabele tumor in de buik, enuresis nocturna en achterblijven in groei.

In Hoofdstuk 7 wordt de diagnostiek beschreven. Omdat de intraveneuze urografie (IVU) de hoeksteen is bij het stellen van de diagnose van pyelo-ureteral obstructie, wordt deze procedure gedetailleerd beschreven. Intraveneuze urografie moet bij voorkeur worden verricht gedurende een pijnaanval, omdat bij intermitterende hydronephrose het intraveneuze urogram, tussen de aanvallen er "normaal" uit kan zien. Het diurese IVU kan als eerste onderzoek, in 85% van de gevallen, de diagnose pyelo-ureterale obstructie vaststellen.
Het postoperatieve IVU, voor de patient het ziekenhuis verlaat, is in de meeste gevallen nogal teleurstellend als gevolg van stuwing door oedeem van de anastomose. Het IVU-beeld, dat drie maanden na de operatie verkregen wordt, zal een goede indruk kunnen geven van het uiteindelijke resultaat, omdat er na deze periode weinig of geen verbetering verwacht kan worden.
Het doen van mictiecystourethrografie is waardevol, zeker bij kinderen, omdat vesico-ureterale reflux kan leiden tot dilatatie van het nierbekken, dat kan lijken op een pyelo-ureterale obstructie. Een ureter-neoimplantatie zal in het algemeen de dilatatie doen teruggaan.
Retrograde uretero-pyelografie is alleen noodzakelijk indien de

proximale ureter niet zichtbaar wordt op het IVU en dient te worden uitgevoerd vlak voor de operatie. De periode tussen dit retrograde onderzoek en de exploratie moet zo kort mogelijk zijn, omdat een infectie kan worden geintroduceerd. Het opvoeren van de uretercatheter tot in het pyelum kan oedeem ter plaatse van de pyelo-ureterale overgang veroorzaken en leiden tot een verslechtering van de drainage van de hydronephrose.
Omdat standaard- en diurese intraveneuze urografie, renografie, nierscintigrafie, echografie en de CT-scan tot onze beschikking staan, is er nauwelijks nog enige indicatie voor nierangiografie. Slechts bij patienten met ectopische nieren en bij hoefijzernieren met een pyelo-ureterale obstructie kan het nuttig zijn om tevoren geinformeerd te zijn over het vaatpatroon.
Antegrade pyelo-ureterografie en urodynamisch onderzoek kunnen zeer nuttig zijn, doch deze techniek is invasief. Urodynamisch onderzoek kan worden verricht door percutaan, of tijdens de operatie, het nierbekken te puncteren.
Standaard renografie geeft informatie over de functie van het nierparenchym en de excretie en is daarom van belang zowel als pre- als postoperatief onderzoek.
Wanneer er twijfel bestaat over het bestaan van een pyelo-ureterale obstructie, bijvoorbeeld wanneer er een gedilateerd nierbekken wordt gezien met bij renografie een obstructiebeeld, kan de injectie van een diureticum (diurese renografie) of een echte obstructie of een snelle excretie aantonen, die dan een obstructie minder waarschijnlijk maakt.
Nierscintigrafie (DMSA Technetiumscan) geeft goede morphologische informatie over het nierparenchym en kan worden gecombineerd met renografie.
Adequate informatie over de pre- en postoperatieve nierfunctie, met name bij patienten met een solitaire nier, is noodzakelijk. Het streven van de uroloog moet niet alleen zijn de patient van zijn klachten af te helpen, maar tevens d.m.v. een pyelumplastiek de nierfunctie te behouden.
De CT-scan en echografie zijn beide niet-invasieve aanvullende onderzoekingsmethoden. Bij de CT-scan worden echter relatief veel röntgenstralen gebruikt. Echografie is eenvoudig uit te voeren zonder enig gevaar voor de patient en kan worden gecombineerd met

percutane punctie van het nierbekken waarna antegrade pyelo-ureterografie kan worden verricht of een urodynamisch onderzoek. Tevens kan deze drain in het nierbekken functioneren als een tijdelijke pyelostomie.

In Hoofdstuk 8 worden de therapeutische mogelijkheden beschreven. Het doel van de therapie van pyelo-ureterale obstructie is de patient klachtenvrij te maken en zoveel mogelijk nierweefsel te behouden. Het resultaat moet een trechtervormige, goed drainerende pyelo-ureterale overgang zijn. Indien het nierbekken sterk gedilateerd is, dient een deel te worden gereseceerd om stasis te voorkomen. De urine dient steriel te worden en te blijven.
De therapie kan worden verdeeld in verschillende groepen: nephrectomie, drainage van de nier, zoals door een nephrostomie of pyelostomie en pyelumplastieken met en zonder onderbreking van de continuiteit.
In het begin van deze eeuw had elke operatie een hoge mortaliteit en was het aanleggen van een nephrostomie of het verrichten van een nephrectomie bijna het enige dat kon worden verricht. Zelfs in 1952 werd nog bij 56% van de patienten met een hydronephrose als gevolg van een pyelo-ureterale obstructie, nephrectomie verricht. Het percentage van de primaire nephrectomieën is nu gedaald tot 3-10%. Omdat zelfs ernstig beschadigde nieren zich goed kunnen herstellen moet niet te snel tot nephrectomie besloten worden.
Het aanleggen van een nephrostomie of pyelostomie wordt nu uitsluitend nog in uitzonderings situaties verricht of als een tijdelijke methode van drainage. Vele technieken met en zonder onderbreking van de continuiteit worden gedetailleerd in dit hoofdstuk beschreven.
Er wordt met nadruk op gewezen, dat de zogenaamde aberrante of accessoire vaten niet behoeven te worden geligeerd. Zij worden niet beschouwd als de primaire oorzaak van pyelo-ureterale obstructie. Zij kunnen wel een reeds zich ontwikkelende hydronephrose verergeren.
Naar aanleiding van de verkregen informatie bij electronenmicroscopie kunnen de voor- en nadelen van verschillende pyelumplastiek methoden worden vergeleken. Bij de Y-V pyelumplastiek wordt

een lap ingevoegd die mogelijk vele abnormale componenten bevat met een minimale reductie van dode ruimte. Bij de Culp pyelumplastiek wordt een lap pyelum gebruikt die van relatief gezonde kwaliteit is, met enige reductie van dode ruimte. Bij de Anderson-Hynes pyelumplastiek wordt een complete excisie verricht van het obstruerende segment, vaak met verkleining van dode ruimte door excisie van een deel van het nierbekken. Mogelijk is dit de reden waarom deze procedure zulke goede resultaten geeft. In het algemeen is de Anderson-Hynes pyelumplastiek onze eerste keus.
Het effect dat doorsnijding van de ureter heeft wordt besproken. Verschillende mogelijkheden van urinedrainage en splinting met hun voor- en nadelen worden genoemd.
De ideale operatie zou die zijn, die geen drainage of splinting nodig heeft. Er zijn echter nog steeds voor- en tegenstanders van het gebruiken van een splint. Hoewel algemeen wordt aangenomen, dat het gebruik van drains in de urinewegen tot een hoger percentage infecties leidt, wordt dit niet in alle publicaties over dit onderwerp bewezen. In het algemeen zal men tijdens de operatie moeten beslissen of men wel of geen splint of urinedrainage wil gebruiken, mede afhankelijk van eventueel in de postoperatieve periode te verwachten problemen. Bij secundaire operaties, solitaire nieren en bij kinderen lijkt het gebruik van een splint veiligheidshalve aan te raden. De uretersplint moet zacht zijn en van niet irriterend materiaal, zoals Silastic®, en moet gemakkelijk in de ureter passen. Wij geven de voorkeur aan een buis die als splint voor de ureter functioneert en een die het nierbekken draineert, als pyelostomie of nephrostomie. De splint zou 2 weken in situ moeten blijven, hoewel deze tijd afhankelijk is van de bevindingen tijdens de operatie. Een vacuum drain wordt altijd gebruikt.
De techniek van een pyelumplastiek bij verdubbeling van het nierbekken of de ureter wordt beschreven.
In de literatuur zijn vele gevallen van zeer grote hydroneprosen, gevuld met vele liters urine, beschreven. Bij sommige van deze patienten was het zelfs mogelijk om de nier te sparen.
Gedurende vele decennia heeft men het noodzakelijk geacht om, wanneer er sprake is van pyelo-ureterale obstructie bij een hoef-

ijzernier, de isthmus te klieven omdat de obstructie leek te worden veroorzaakt door het gestrekte verloop van de ureter over de isthmus. Nu wordt in vele gevallen een pyelumplastiek voldoende geacht om het probleem op te lossen.
De gebruikelijke chirurgische benadering is via een lumbotomie, hoewel bij een hoefijzernier een laparotomie wordt geprefereerd. Door anderen wordt de antero-laterale extra- of transperitoneale benadering gepropageerd. Sommige kinderurologen zijn geneigd om een ventrale incisie te gebruiken en bij kinderen met dubbelzijdige pyelo-ureterale obstructie een lange dwarse incisie. De mogelijkheid van het later ontstaan van een ileus door adhaesies is een nadeel van de transperitoneale benadering.
De complicaties van een pyelumplastiek, zoals lekkage van urine, infectie, steenvorming en strictuurvorming worden besproken.
De asymptomatische pyelo-ureterale obstructie kan leiden tot een langzame verslechtering en verlies van parenchym. Daarom is het noodzakelijk om een pyelumplastiek te verrichten of deze patienten onder nauwkeurige controle te houden.
Bij bilaterale pyelo-ureterale obstructie kunnen, via een dwarse incisie, beide kanten worden geopereerd.

Hoofdstuk 9 geeft een overzicht van onze serie van 152 patienten. Preoperatieve, operatieve en postoperatieve gegevens worden besproken. De serie bestaat uit 90 mannen en 62 vrouwen, van wie er 11 tevoren al waren geopereerd (14 operaties) in een ander ziekenhuis. Bij 4 van de 9 patienten met bilaterale pyelo-ureterale obstructie was elders reeds nephrectomie verricht aan de contralaterale zijde. Vier en veertig patienten (29%) vielen in de leeftijdsgroep van 0-15 jaar.
Pijn, urineweginfecties en macroscopische haematurie bleken de belangrijke symptomen te zijn. Het belangrijkste symptoom bij kinderen (0-15 jaar) was een urineweginfectie (39%), terwijl bij volwassenen pijn (81%) op de voorgrond stond.
Het aantal intraveneuze urogrammen, dat werd gemaakt voor de diagnose duidelijk werd, was bij verschillende patienten opvallend hoog. Nephrolithiasis werd bij 25 patienten gezien (16%).
Renografie bleek een zeer waardevol onderzoek te zijn. Bij alle patienten met een hydronephrose als gevolg van een pyelo-ureterale

obstructie, toonde het renogram een obstructieve curve. Wanneer er een afunctionele curve werd gezien, werd nephrectomie verricht. Bij 26 patienten met unilaterale pyelo-ureterale obstructie werd een gesloten type nierbekken aan de contralaterale kant gezien. Bij 22 van deze patienten toonde het renogram een normale en bij 4 patienten een licht obstructieve curve.
Retrograde urografie werd bij 102 patienten verricht. Bij 50 patienten gaf het IVU voldoende informatie, zodat retrograad onderzoek niet nodig was.
Van de 146 patienten met unilaterale pyelo-ureterale obstructie werden 80 (55%) aan de rechter kant geopereerd en 66 (45%) aan de linker kant. De volgende 158 operaties werden verricht: 25 nephrectomieën, 11 adhesiolyses, 1 ligering van een accessoir vat alleen en 121 pyelumplastieken. Van de pyelumplastieken werd de techniek van Anderson-Hynes het meest frequent (64%) toegepast.
De 5 patienten met bilaterale pyelo-ureterale obstructie werden allen eerst geopereerd aan die nier die het meest in gevaar was.
De frequentie van primaire nephrectomie in deze serie was 15% (23 patienten). Bij 4 patienten met bilaterale pyelo-ureterale obstructie was reeds nephrectomie van de contralaterale nier verricht, in een ander ziekenhuis.
Van de 39 accessoire vaten die werden gevonden, werden er 18 geligeerd omdat zij destijds werden beschouwd als een oorzakelijke factor van de pyelo-ureterale obstructie of omdat zij tijdens het verrichten van de pyelumplastiek de adequate uitvoering daarvan verhinderden.
Eén of andere vorm van urinedrainage werd toegepast bij 72 operaties. De resultaten van deze serie tonen aan dat het uiteindelijke resultaat van de operatie met of zonder urinedrainage bijna hetzelfde was. Het gebruik van urinedrainage wordt aangeraden, omdat complicaties, zoals urinelekkage en obstructie, kunnen worden voorkomen. Daardoor kan het de opnameduur verkorten. Tevens verschaft het de mogelijkheid het adequaat functioneren van de anastomose te controleren. Drieëntwintig van de 28 patienten met postoperatieve urineweginfecties waren geopereerd met een of andere vorm van urinedrainage.
Er waren 10 postoperatieve complicaties als gevolg van de pyelumplastiek zelf. Het opvoeren van een uretercatheter loste het pro-

bleem bij één patient op, een secundaire pyelumplastiek was noodzakelijk bij 2 patienten en een secundaire nephrectomie bij 7. Het postoperatieve IVU, gemaakt voordat de patient het ziekenhuis verlaat, liet over het algemeen nog duidelijke dilatatie zien als gevolg van oedeem t.h.v. de anastomose. Een duidelijke verbetering kon worden vastgesteld op het IVU dat 3 maanden postoperatief werd gemaakt. De resultaten van de intraveneuze urogrammen 3 maanden of langer na de operatie waren: goed 72%, redelijk 23% en slecht 5%. De beste resultaten werden gezien bij de patienten die waren geopereerd volgens de Anderson-Hynes techniek (82% goed). Deze techniek is ook onze eerste keus bij patienten met pyelo-ureterale obstructie.

Postoperatieve renografie werd verricht bij 60 patienten. Bij 37 patienten met unilaterale en bij 2 patienten met bilaterale pyelo-ureterale obstructie toonde de curve een verbeterde excretie. In de groep van 37 patienten met een verbeterde excretie, werden 4 patienten gezien, die eerst een obstructieve curve vertoonden, doch een vlotte excretie lieten zien nadat een diureticum was gegeven (diurese renogram).

Van de 152 patienten werden 144 volledig klachtenvrij (95%). Zes patienten hadden zo nu en dan vage sensaties in de zij, maar het was twijfelachtig of dit iets te maken had met de nier. Van 2 patienten was geen follow-up mogelijk.

Drie van de 6 patienten met hypertensie hadden weer een normale bloeddruk nadat een pyelumplastiek was verricht.

Omdat slechts bij 3 kinderen een creatinine clearance was verricht, die bij alle 3 een duidelijke verbetering toonde nadat de pyelo-ureterale obstructie was opgeheven, kon de pre- en postoperatieve nierfunctie alleen worden beoordeeld aan de hand van de serumcreatinine waarden. Bij 126 patienten bleef de waarde van het serumcreatinine onveranderd, omdat er een normaal functionerende contralaterale nier was. De pre- en postoperatieve serumcreatinine waarden worden vermeld van patienten met bilaterale pyelo-ureterale obstructie (5 patienten), met bilaterale pyelo-ureterale obstructie bij wie reeds de contralaterale nier was verwijderd (4 patienten) en van de patient met een pyelo-ureterale obstructie en een aplasie van de contralaterale nier. Deze waarden toonden een duidelijke verbetering van de nierfunctie bij 9 van

de 10 patienten, nadat de pyelo-ureterale obstructie was opgeheven. In het algemeen kan een zelfde verbetering van de geopereerde nier worden verwacht, wanneer er een normaal functionerende contralaterale nier aanwezig is.
Histologisch onderzoek van het pyelo-ureterale segment werd bij 93 patienten verricht. Er werd een enorme variatie gezien. Bij 46 patienten (40%) werd fibrose in de submucosa waargenomen. Dit collageenrijke, acellulaire fibreuze weefsel, zou een verklaring kunnen geven voor de theorie van de functionele obstructie. Fibrose in de submucosa, ontstekingsinfiltraat en spiervezelhypertrophie zouden echter secundair kunnen zijn ontstaan door obstructie en dilatatie als gevolg van een nog onbekende oorzaak.

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