Pediatr Nephrol (1988) 2: 43–47

Pediatric Nephrology

Practical pediatric nephrology

Investigation of the dilated urinary tract

Helen Fitzmaurice Parkhouse and T. Martin Barratt

Department of Paediatric Nephrology, Institute of Child Health, 30 Guilford Street, London WC1N 1EH, UK

Abstract. Dilatation of the urinary tract does not necessarily imply obstruction, and other factors may be operative: maldevelopment, infection, reflux, and polyuria. Obstruction of the urinary tract in intra-uterine life is associated with renal dysplasia: the original obstructive lesion may be transient but the consequent dysplasia and dilatation may be permanent. Routine antenatal ultrasound identifies a new population of infants with urinary tract dilatation, many of whom remain asymptomatic and would not otherwise have come to medical attention: the natural history and appropriate schedules of investigation and management of this group are still being evaluated. Anatomical imaging by ultrasound establishes the presence and extent of dilatation. Micturating cystourethrography, intravenous urography and antegrade pyelography establish the site but not the functional significance of an obstructive lesion. Isotope renal scaning with ^{99m}Tc-DTPA may identify an acutely obstructed kidney with a decreased renal uptake, prolonged parenchymal transit time, and delayed clearance of the isotope from the renal pelvis after furosemide. However, such analyses often give equivocal results in infants with poor renal function and markedly dilated urinary tracts. Obstructive uropathy should be seen as a disturbance of the normal pressure-flow relationships in the urinary tract, and be defined and investigated as such. Antegrade perfusion with renal pelvic pressure measurements has technical pitfalls, but is the definitive method of establishing upper tract obstruction. Videocystourethrography is the established method of investigating the lower urinary tract in older children but needs further development to be applicable to infants.

Key words: Urinary tract dilatation – Obstructive uropathy

Introduction

Obstructive lesions of the urinary tract are a most important group of disorders, for they constitute a major preventable cause of chronic renal failure. At first sight they may seem straightforward mechanical problems, but such simplicity is illusory, for the range of anatomical variants is wide, the nature of the obstructive process is poorly defined in urodynamic terms, and the consequences for renal function are ill- understood [1]. It comes as something of a surprise to realise that partial urinary tract obstruction, a concept long enshrined in the clinical practice of paediatric urology, does not have a formal physiological definition.

Dilatation of the urinary tract

Dilatation of the urinary tract is the most characteristic result of obstruction, but it cannot be concluded that it necessarily implies obstruction as other factors may be operative: maldevelopment, infection, reflux, or polyuria. For example, the ureteric dilatation of the prune belly syndrome is as much a manifestation of disordered development of the whole urinary tract as a consequence of a specific obstructive lesion [2]. Urinary tract infection (UTI), especially in young infants, may result in considerable dilatation that is reversible

Offprint requests to: T. M. Barratt

with medical treatment alone [3], and ureteric dilatation is a regular feature of children with infective renal calculi: experimentally it has been shown that bacterial toxins may paralyse ureteric musculature [4]. The ureteric dilatation associated with vesicoureteric reflux (VUR) is variable, being determined by detrusor pressure. Continued polyuria may also cause ureteric dilatation as seen, for example, in children with nephrogenic diabetes insipidus [4]. These factors may interact: an infant with a posterior urethral valve (PUV), in addition to simple lower urinary tract obstruction, may have maldevelopment of the urinary tract, UTI, VUR, and polyuria as a consequence of the obstructive nephropathy, all contributing to the dilatation.

Diagnostic problems arise when upper tract dilatation persists in spite of an apparently adequate surgical correction of an obstructive lesion: does ureteric dilatation after PUV resection indicate inadequate urethral surgery, detrusor instability, or secondary ureterovesical junction obstruction, or is there a limit to the extent to which a chronically distended urinary tract can revert to normal? Does hydronephrosis following pyeloplasty indicate continuing pelvi-ureteric junction (PUJ) obstruction or a redundant renal pelvis? Ultimately, obstructive uropathy must be seen as a disturbance of the normal pressure-flow relationships in the urinary tract, to be evaluated by the techniques of urodynamic physiology. Even so, in the absence of other rigorous criteria of obstruction, the critical pressure in the urinary tract taken to indicate a significant impediment to the outflow of urine is not established.

Antenatal dilatation

It is now apparent that urinary tract obstruction in utero is responsible for a wide range of renal and urological pathology [5]. Transient urethral obstruction, possibly a consequence of prostatic hypoplasia, appears to be the cause of the prune belly sequence, with the abdominal wall muscle deficiency being a consequence of the fetal abdominal distension due to the enlarged bladder and resulting in testicular maldescent [6, 7]. Thus urinary tract dilatation may persist even though the original obstructive cause has disappeared spontaneously.

It has also been shown experimentally that urinary tract obstruction in early pregnancy may result in renal dysplasia [8, 9], and the association is well established clinically. Thus impairment of renal function accompanying urinary tract obstruction may have several causes in addition to the back-pressure effect itself, some reversible, others not: UTI, sodium and water depletion, and renal dysplasia. These associated phenomena complicate the assessment and outcome of the child with a dilated urinary tract. Improvement in function after surgical relief of obstruction therefore does not of itself prove that significant obstruction was present, for these other factors may have been corrected at the same time. Significant obstruction may be defined as a circumstance which, if uncorrected, leads to deterioration of renal function, but the converse is not true: deterioration in the conservatively treated case may have causes other than obstruction, particularly the hyperfiltration associated with remnant kidney nephropathy [10].

The widespread use of routine antenatal ultrasound in pregnancy has led to the antenatal diagnosis of urological abnormality in a substantial number of babies [5]. They comprise a wide variety of anatomical lesions with a spectrum of renal function ranging from normality to complete anuria. In those presenting to paediatric urological units the commonest anatomical abnormality is simple hydronephrosis with normal lower ureter, bladder, and outflow tract [11]. It may be unilateral or bilateral; the renal pelvis may be hugely dilated or only transiently distended; renal function may be normal or severely impaired. Amongst these infants are a number who remain asymptomatic and would not otherwise have come to medical attention. It cannot be assumed that the natural history of these cases is the same as that of symptomatic infants, nor that the traditional protocols of investigation and management are appropriate for them.

Anatomical imaging

Ultrasound is the first investigation and establishes the presence and site of dilatation, and sometimes reveals the level of the obstruction itself, such as a dilated posterior urethra proximal to a valve, or a ureterocele in the bladder distal to a dilated ureter. A micturating cystourethrogram is usually the next logical investigation, especially in young children, and may demonstrate bladder abnormality, urethral obstruction, or VUR; if reflux is present, information on the upper urinary tract is also available. The intravenous urogram (IVU) has a less important role than previously, but is essential in complex cases, as with duplex systems, and is the best modality for demonstrating detailed ureteric pathology; delayed films several hours after contrast injection are often the most informative. Percutaneous antegrade pyelography is the definitive investigation for determining the level of upper urinary tract obstruction if not evident from other studies, and has largely replaced retrograde pyelography in children.

Functional studies

The acutely obstructed kidney is characterised by a reduced glomerular filtration rate (GFR), an increased renal transit time of non-reabsorable solutes, and a delayed clearance from the renal pelvis. These functions can be assessed by renal scanning with 99m-technetium diaminotetraethyl-pentacetic acid (^{99m}Tc-DTPA) and are coarsely reflected in the IVU [12].

The rate of uptake of ^{99m}Tc-DTPA or contrast medium by each kidney is determined by the product of its GFR and the prevailing plasma conentration. The ratio of GFR in the two kidneys can therefore be calculated from the relative slopes of the background-corrected ^{99m}Tc-DTPA uptake curves in the early phase after injection. Similar information is available from the relative uptakes of 99m-technetium dimercaptosuccinic acid (^{99m}Tc-DMSA), although the physiology of renal handling of the two radiolabelled chelates is different. Absolute values for individual kidney GFR can be calculated from the amount of isotope injected, the absolute rate of uptake of radioactivity by the kidney, and the blood curve calibrated by a single timed plasma sample [13].

The transit time of ^{99m}Tc-DTPA through the kidney can be derived by deconvolutional analysis. The whole kidney transit time is composed of parenchymal and pelvic moieties, which reflect different functions of the system. These can be analysed separately in the adult, but the resolution of parenchymal areas of interest distinct from the renal pelvis presents technical problems in infants [14]. With acute urinary tract obstruction there is a prolonged renal parenchymal transit time of ^{99m}Tc-DTPA due to increased fractional renal tubular reabsorption of sodium and water: the prominent nephrogram in the IVU reflects the same phenemenon. With long-standing obstruction and nephron loss, however, the renal handling of ^{99m}Tc-DTPA is indistinguishable from other forms of chronic renal damage. The rate of clearance of ^{99m}Tc-DTPA from the renal pelvis is determined by the relationship between the volume of the renal pelvis and the rate of urine flow. Adequacy of drainage of the urinary tract may be investigated by studying the clearance of isotope from the renal pelvis during a furosemide-induced diuresis, which is a hybrid test of the ability of the kidney to mount a diuretic response and of the renal pelvis to accommodate it.

For all its physiological interest, the ^{99m}Tc-DTPA scan has in practice proved rather disappointing as a tool to diagnose significant urinary tract obstruction, particularly in infants with congenital obstructive lesions. The method gives good estimates of individual kidney function, especially if the contralateral kidney is normal, and provides limited anatomical information as well, albeit of rather poor resolution compared with the IVU, but without the hazards of contrast medium. However, in kidneys with poor function and a dilated renal pelvis it has proved difficult to analyse renal transit time and pelvic clearance, and the problem is compounded by low kidney-background ratios, insufficient anatomical resolution, dependence of the scan on states of hydration and sodium balance [15], and lack of an independent criterion of significant obstruction by which to validate the analysis.

Urodynamic assessment

Complete ureteric obstruction is rare in childhood, and the significance of partially obstructive lesions can only be appreciated by reference to the prevailing rate of urine flow, which may vary considerably from time to time in the same patient. This is most dramatically seen in PUJ obstruction, where antidiuresis may be associated with normal intrapelvic pressure, whereas diuresis may result in high pressures manifested by pain and hydronephrosis.

Upper urinary tract

Whitaker [16] introduced the technique of assessing possible upper tract obstruction by antegrade perfusion. Obstruction was deemed to exist if the intrapelvic pressure rose above 22 cm H_2O relative to bladder pressure. Pressure below 15 cm H_2O were taken to be normal and those in the 15–22 cm H_2O were considered to be equivocal.

A number of factors affect the results. Sidearm pressure measurements via the infusion line are prone to artefact, and a double lumen catheter enabling separate pressure measurements is preferable. The state of bladder filling is critical: if PUJ obstruction is suspected, an empty bladder should be maintained throughout the investigation by catheter drainage so that intrapelvic pressure can be measured with reference to a bladder pressure of zero; when vesicoureteric junction obstruction is suspected, the intrapelvic pressure should be measured during perfusion at varying degrees of bladder filling, which may critically affect the relevant anatomy [17]. The position of the patient may affect the outcome of the study by virtue of the hydrostatic effect of a column of urine in a dilated ureter lacking effective occlusive peristalsis. The time taken to achieve an equilibrium state in a dilated urinary system is an important variable: during the early stages of filling the intrapelvic pressure is a function of the compliance of the urinary tract, but once the system has been filled beyond its critical capacity there may be a steep rise in pressure [18]. The appropriate rate of perfusion in children has not been defined [19]. Whitaker [16] used 10 ml/min (which approximates to the rate of urine flow in a single healthy adult kidney during maximum water diuresis), but it seems more logical to correct this rate to the surface area of the child.

Lower urinary tract

Anatomical studies by micturating cystourethrography or endoscopy may show the site of an obstructive lesion, but their physiological significance and bladder function as a whole can only be studied by urodynamic techniques. The simplest investigation is the rate of urine flow, and free flow rate nomograms are available for age, sex, and initial bladder volume in adults [20] and children [21]. However, there is a considerable overlap of urine flow rates in normal children and those with bladder outflow obstruction [21]: a child has the capacity for considerable detrusor hypertrophy, which may maintain a normal urine flow rate in spite of severe intravesical obstruction.

Full investigation therefore requires the combination of cystometry with pressure-flow voiding studies [22]. The technique of videocystourethrography is well established for the investigation of adults and older children with suspected urinary tract obstruction but has not yet been developed for infants. In order for the study to reflect the patient's usual vesico-urethral behaviour, informed relaxed cooperation is required: the study must be undertaken in the fully conscious state as general anaesthesia and sedatives have a profound effect on detrusor function. The use of double lumen suprapubic catheters, inserted the day prior to the study, enables the investigation to be carried out with the minimum of stress and without a urethral catheter, which may itself modify function.

Some developments may be anticipated: the most significant factor as far as the kidney is concerned may not be the peak pressure transient achieved during maximum diuresis, but may be the integrated pressure burden experienced over a period of time, so some form of monitoring of renal pelvic or bladder pressures during a 24-h period should be developed. Methods are required for the simple measurement of urine flow rate in babies. Advances in the surgical management of the dilated urinary tract in childhood are now dependent on the evolution of more accurate methods of urodynamic assessment.

References

1. Barratt TM, Manzoni GA (1987) The dilated urinary tract. In: Holliday MA, Barratt TM, Vernier RL (eds) Pediatric nephrology, 2nd edn, chapter 38. Williams and Wilkins, Baltimore, pp 667–680
2. Woodard JR (1981) Prune belly syndrome. In: Kelalis PP, King LR, Belman AB (eds) Clinical pediatric urology, 2nd edn, chapter 20. Saunders, Philadelphia, pp 805–824
3. Teague N, Boyarsky S (1968) Further effects of coliform bacteria on ureteral peristalsis. J Urol 99: 720–724
4. Ten Bensel RW, Peters ER (1970) Progressive hydronephrosis, hydroureter and dilatation of the bladder in siblings with congenital nephrogenic diabetes insipidus. J Pediatr 77: 439–443
5. Woodard JR, Parrott TS (1987) Neonatal urology. In: Holliday MA, Barratt TM, Vernier RL (eds) Pediatric nephrology, 2nd edn, chapter 57. Williams and Wilkins, Baltimore, pp 945–961
6. Pagon RA, Smith DW, Sheperd TM (1979) Urethral obstruction malformation complex: a cause of abdominal muscle deficiency and the "prune-belly". J Pediatr 94: 900–906
7. Moerman P, Fryns JP, Goddeeris P, Lauweryns JM (1984) Pathogenesis of prune-belly syndrome: a functional urethral obstruction caused by prostatic hypoplasia. Pediatrics 73: 470–475
8. Beck AD (1971) The effect of intrauterine obstruction upon the development of the fetal kidney. J Urol 105: 784–789
9. Glick PL, Harrison MR, Noall RA, Villa RL (1983) Correction of congenital hydronephrosis in utero. III. Early mid-trimester ureteral obstruction produces renal dysplasia. J Pediatr Surg 18: 681–687
10. Hostetter TH, Olson JL, Rennke HG, Venkatachalam MA, Brenner BM (1981) Hyperfiltration in remnant nephrons: a potentially adverse response to renal ablation. Am J Physiol 241: F83–F95
11. Ransley PG, Manzoni GA (1985) 'Extended' role of DTPA scan in assessing function and UPJ obstruction in neonate. Dialog Pediatr Urol 8: 6–8
12. Gordon I, Barratt TM (1987) Imaging the kidneys and urinary tract in the neonate with acute renal failure. Pediatr Nephrol 1: 321–329
13. Piepsz A, Denis R, Ham HR, Dobbleair A, Schulman C, Erbemann F (1978) A simple method for measuring separate glomerular filtration rate using a single injection of ^{99m}Tc-DMSA and the scintillation camera. J Pediatr 93: 769–774
14. Vivian GC, Barratt TM, Todd-Pokropek A, Gordon I (1984) Renal parenchymal determination and analysis during dynamic ^{99m}Tc-DTPA scans in children. Nucl Med Commun 5: 35–40

15. Vivian G, Barratt TM, Todd-Poyropek A, Gordon I (1895) Physiological variations of the normal transit time in children. Eur J Nucl Med 11: 173–181
16. Whitaker RH (1973) Methods of assessing obstruction in dilated ureters. Br J Urol 45: 15–22
17. Glassberg KI (1985) Current issues regarding posterior urethral valves. Urol Clin North Am 12: 175–185
18. Bullock KN (1983) The biochemical principles of upper urinary tract pressure-flow studies. Br J Urol 55: 136–139
19. Lupton EW, Holden D, George NJ, Barnard RJ, Rickards D (1985) Pressure changes in the dilated upper urinary tract on perfusion at varying flow rates. Br J Urol 57: 622–624
20. Siroky MB, Olsson CA, Krane RJ (1979) The flow rate nomogram. 1. Development. J Urol 122: 665–668
21. Toguri AG, Uchida T, Bee DE (1982) Pediatric uroflow rate nomograms. J Urol 127: 727–731
22. Bates CP, Whiteside CG, Turner-Warwick R (1970) Synchronous cine/pressure/flow/cysto-urethrography with special reference to stress and urge incontinence. Br J Urol 42: 714–723

Received September 10, 1987