Advances in paediatric urology

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Paediatric urological surgery is often required for managing congenital and acquired disorders of the genitourinary system. In this Series paper, we highlight advances in the surgical management of six paediatric urological disorders. The management of vesicoureteral reflux is evolving, with advocacy ranging from a less interventional assessment and antimicrobial prophylaxis to surgery including endoscopic injection of a bulking agent and minimally invasive ureteric reimplantation. Evidence supports early orchidopexy to improve fertility and reduce malignancy in boys with undescended testes. A variety of surgical techniques have been developed for hypospadias, with excellent outcomes for distal but not proximal hypospadias. Pelvi-ureteric junction obstruction is mostly detected prenatally; indications for surgery have been refined with evidence, and minimally invasive pyeloplasty is now standard. The outlook for patients with neurogenic bladder has been transformed by a combination of clean intermittent catheterisation, algorithms of diagnostic investigations, and innovative medical and surgical therapies. Posterior urethral valves are associated with considerable mortality; fetal diagnosis allows stratification of candidates for intervention, but ongoing bladder dysfunction in patients after valve ablation remains a cause of long-term morbidity.

Introduction

A substantial portion of paediatric urology entails surgical correction of congenital and acquired disorders of the genitourinary system. With rapid developments in clinical and basic research, from prenatal diagnosis and minimally invasive surgery to evidence-based clinical guidelines, paediatric urology has become a major subspecialty. In this Series paper, we describe the exciting advances and innovations in the surgical management of six important paediatric urological disorders. Although minimally invasive surgery and innovative surgical techniques have improved early outcomes of common, non-lethal disorders such as vesicoureteral reflux, undescended testes, and the mild forms of hypospadias and pelvi-ureteric junction obstruction, most paediatric urological disorders, especially the severe anomalies, are associated with longterm morbidity. Treatment of neurogenic bladder exemplifies the advantages of a multidisciplinary approach with medical and innovative surgical therapies. Although fetal and neonatal diagnosis and treatment have improved survival in children with rare, complex, and life-threatening diseases such as posterior urethral valve, the management of long-term sequelae remain challenging.

Vesicoureteral reflux

Vesicoureteral reflux is the retrograde flow of urine from the bladder to the ureter (or ureters), affecting 1-25% of children and predisposing them to urinary tract infection and renal scarring. A comprehensive review is available elsewhere;[1] here we focus on recent research findings. Although vesicoureteral reflux resolves in many cases, the ability to predict resolution in a given patient is limited. Vesicoureteral reflux grade is important. Multivariable models incorporating a range of factors, including vesicoureteral reflux index,[2] normograms, and ureteral diameter, might increase prognostic accuracy compared with vesicoureteral reflux grade alone, but the results for an individual patient can differ substantially between models, warranting caution in their clinical application.

Vesicoureteral reflux has a genetic basis, with concordance in identical twins approaching 100%, and a

27% prevalence in siblings.[3] Although numerous genetic loci have been associated with vesicoureteral reflux, progress in identifying specific genetic targets for diagnosis or therapy is limited because of the heterogeneous genetic pattern.[4] New genetic techniques are rapidly advancing discovery of human genetic contributors to congenital anomalies of the kidney and urinary tract, including vesicoureteral reflux.

The UK's National Institute for Health and Clinical Excellence and the American Academy of Pediatrics[5] recommend a less interventional approach to assessing children with febrile urinary tract infection, with deferral of micturating cystourethrography until urinary tract infection recurrence. The rationale is to avoid overdiagnosis and overtreatment of indolent disease. One principle is that ultrasound serves as an initial screen to identify children who should immediately proceed to further imaging by micturating cystourethrography, but there are limitations to using ultrasound to screen for vesicoureteral reflux, and a normal ultrasound does not exclude high-grade vesicoureteral reflux.[6] Many specialists contest the conservative approach and warn that leaving vesicoureteral reflux undiagnosed puts a subset of children at increased risk of additional morbidity and potential renal damage associated with recurrent urinary tract infection.

When cystography is indicated, contrast-enhanced voiding sonography is increasingly seen as an alternative to fluoroscopic or radionuclide cystography. Results from several centres show comparable rates of detection of vesicoureteral reflux using this technique,[7] but the quality and completeness of information provided in reports varies, and some variation also can be seen in the same patient. Awareness of variations and standardisation is much needed.[8]

The screening of asymptomatic siblings is controversial. According to guidelines[3] released in 2010, screening of siblings is an option, but an observational approach could also be taken. In view of the relatively indolent nature of most sibling vesicoureteral reflux and the number of patients needed to screen to prevent adverse outcomes, the potential for benefits of screening siblings is low.[9]

For the medical treatment of children with vesicoureteral reflux, data from the RIVUR[10] randomised controlled trial showed that antimicrobial prophylaxis with trimethoprim plus sulfamethoxazole reduced the incidence of recurrent urinary tract infection by about 50% in children with vesicoureteral reflux or a history of vesicoureteral reflux. Findings from a subsequent metaanalysis[11] confirmed a significant effect of antibiotic prophylaxis. Antibiotic prophylaxis has not been shown to reduce renal scarring, but no study has been adequately

powered to assess this outcome. However, strong evidence does suggest that a febrile urinary tract infection is associated with risk of scarring, and early treatment of febrile urinary tract infection can decrease the incidence. Although open ureteral reimplantation is the gold standard for surgery, many centres have pursued roboticassisted laparoscopic reimplantation (figure 1). Adoption has been limited because of concerns with higher complication rates and lower success rates than for open reimplantation,[12] although favourable results have been reported from a series of robot-assisted procedures.[13] Pneumovesicoscopic reimplantation (figure 2) has been used as a minimally invasive alternative in several centres,[14] and although the short-term results of open and pneumovesical approaches were comparable, patients undergoing pneurovesicoscopic ureteral reimplantation had shorter hospital stays but longer operating times than patients undergoing open ureteral reimplantation. Results of a follow-up study confirmed satisfactory intermediate outcomes of pneumovesical ureteric reimplantation.[15] Whether pneumovesicopic techniques will become more widely adopted remains to be seen since the increasing use of robotic-assisted transperitoneal approaches could limit their uptake in affluent communities. Endoscopic therapy (primarily with dextranomer hyaluronic acid copolymer; figure 3) is a widely used alternative to surgical reimplantation. In the Swedish reflux trial,[16] antibiotic prophylaxis and endoscopic treatment were superior to surveillance along in preventing recurrent urinary tract infection. Endoscopic treatment is less invasive than ureteric reimplantation but also has a lower success rate in correcting vesicoureteral reflux.[17] Boys younger than 6 months with vesicoureteral reflux might benefit from circumcision as this procedure is associated with a ten-times reduction in the risk of urinary tract infection.[18]

Undescended testes

Undescended testes is considered the most common genital anomaly in boys, with a reported incidence that varies between 0·5% and 9% (1-5% in most reports). This variation reflects the clinical nature of the diagnosis, the patient population studied, and the inclusion or otherwise of acquired undescended testes.[19] The apparent increase in incidence suggested in some reports probably reflects a combination of enhanced screening, improved survival of premature infants, and strengthened recognition of the ascending testis syndrome.[19] Ultrasound, although often used, has very little value in the diagnosis and management of undescended testes. Most cases appear congenital, but an important group of cases present later in childhood, either as a result of delayed diagnosis or development of ascending testis syndrome in a previously descended testis[19,20,21]—hence the importance of follow-up of boys with retractile testes.

Bilateral, non-palpable testes at birth are rare and should prompt endocrinological and genetic assessment to exclude congenital adrenal hyperplasia or bilateral vanishing testes. A cases of acquired undescended testes occur as a result of postsurgical adhesions complicating inguinal surgery or reascent after orchidopexy.

With increasing evidence that early surgery for undescended testes improves subsequent fertility (which is particularly impaired in men with bilateral undescended testes), reduces risk of torsion, has cosmetic advantages, and improves detection of any future malignancy,[22] the American Urological Association and the European Association of Urology advocate orchidopexy at 6-18 months of age.[23,24] Unfortunately, many boys are still not having early surgery,[25] and awareness of the need for early referral and timely surgical intervention should be improved (figure 4).

Fertility is typically assessed with surrogate markers such as testicular volume, testicular histology, and semen analysis.[26,27] In one study,[26] normal sperm counts were reported in 96% of patients who had surgical treatment before 1 year of age, compared with 75% of patients who had surgery when aged 1-2 years. Hormonal treatment is controversial but might have a role in selected cases with a high risk of infertility.[28]

The testes undergo a critical phase of development in the first 6 months of life, with selected gonocytes transforming into adult dark-spermatogonia for future spermatogenesis and non-transforming gonocytes undergoing apoptosis.[29] Adult dark-spermatogonia seem to be crucial determinants of future sperm counts and potential fertility.[27] Although the overall risk of malignancy in adult men who had early surgery for undescended testes is 1·6-7·5 times the baseline prevalence, this prevalence is known to increase 2·9-32 times in men who had surgery when they were older than 10 years.[22,30,31] Persistent non-transforming gonocytes might be the originating cells of testicular malignancies in men with undescended testes. To enhance fertility and reduce malignancy, there is an argument for even earlier surgery at 3 months of age, but this option must be assessed in long-term studies.

Most boys with palpable undescended testes will have an open, inguinal orchidopexy, with the testes placed in a scrotal, subdartos pouch. Minimally invasive surgery is appropriate for boys with impalpable undescended testes, and parascrotal incision is used for low undescended testes. Outcomes from these different approaches will depend on the initial position of the testis, the mobility and length of the testicular vessels,

surgery has transformed the ability to assess and manage impalpable or intra-abdominal undescended testes.The traditional Fowler-Stephens staged orchidopexy, with initial division of the testicular vessels to stimulate

collateral circulation through gubernacular vessels and the artery to the vas, followed by a delayed second-stage orchidopexy, could be readily performed laparoscopically as a day-case procedure, with reported atrophy of 2-33%.[32] With outcomes now equivalent to those of testicular autotransplantation, attention has moved to the possibility of a one-stage procedure.[33] Establishing equivalence of orchidopexy outcomes remains very difficult without consistent, objective assessment of initial testicular position and its mobility at the time of surgery.[19,22]

Hypospadias

The incidence of hypospadias (1/300 newborn boys) was once thought to be increasing, with a doubling of incidence in the USA in the 1970s and 1980s. However, European and Australian data have indicated a more stable incidence in the past 10 years.[34,35] The data reported worldwide remain conflicting, and reported incidence ranges from 0·6 to 34·2 per 10 000 live births.[36] Increasing awareness of the disease, putative effects from environmental endocrine disruptors, and differing study methodologies might all have contributed to the variations in reported incidence.

The aetiology of hypospadias seems to be multifactorial. Genetic anomalies are likely to be important, but most mutations have been identified comparatively infrequently and typically in the most severe or syndromal cases. Distal hypospadias, the most common type, is probably polygenic or multifactorial.[37] Limited epidemiological evidence[38] suggests a small increased risk with prenatal and postnatal exposure to environment-disrupting chemicals such as pesticides, cosmetics, industrial chemicals, and some medications. In a systematic review from 2012,[37] low birthweight, maternal hypertension, and pre-eclampsia were consistently implicated in hypospadias.

Surgical repair aims to reconstruct the urethra, correct chordee, and improve cosmesis with minimal morbidity. Many techniques have been described, but no clear single best method of urethroplasty has been identified. Choice of method largely depends on a comparatively subjective appraisal of the patient's anomalous anatomy (including location of the urethral meatus and severity of chordee) and the surgeon's experience and preference.[39,40] Repair might take a one-stage or two-stage approach, using the patient's own preputial skin for reconstruction in most cases. Other tissues used in reconstruction include buccal mucosa, tunica vaginalis flap, scrotal skin, and bladder or tongue mucosa.

The single-stage tubularised incised plate method, first described by Snodgrass[39] and with complication rates of 7% and 11% in distal and proximal hypospadias, respectively, is an effective and popular option, especially for distal hypospadias. In a 2012 systematic review,[41]

tubularised incised plate and Mathieu (meatal-based flap) methods (figure 5) for repair of distal hypospadias were compared; although the complication rates of both procedures were low, repair by the tubularised incised plate method was associated with the lowest incidence of urethra-cutaneous fistula, whereas Mathieu repair had the lowest rate of meatal stenosis.

Preference of repair method for proximal hypospadias varies, but staged urethroplasty is preferred by nearly half of surgeons, particularly in the presence of severe chordee. Other common techniques include the extended tubularised incised plate method, with or without a graft, or an onlay procedure. Irrespective of the method, surgical repair of proximal hypospadias remains challenging: in one referral centre with a large patient volume, reoperation was required in up to 50% of patients, with urethro-cutaneous fistulas occurring in up to 30% of cases.[42] Operative complications are reduced substantially with increasing surgical experience.[43]

Operations for hypospadias are usually done within the first 2 years of life. Parents commonly ask about long-term function and future fertility. Outcome remains difficult to measure objectively, with changing surgical techniques in the past 30-40 years and inadequate data on long-term follow-up. Patients with distal hypospadias generally have low complication rates, with acceptable long-term functional and cosmetic outcomes. In a systematic review of long-term outcomes,[44] lower urinary tract symptoms such as a weak stream, dribbling, or spraying were twice as common in adult men who had hypospadias repair than in the control group. In a 2009 study,[45] semen quality did not differ between men with isolated hypospadias and men in a control group, yet the paternity rate was lower (24%) in men who had surgery for hypospadias than the general age-matched population (29%). Paternity and sexual function might be related to psychosexual development, and this seems to particularly affect boys with proximal hypospadias. More patients with hypospadias (33%) than in a general population (13%) reported an inhibition in seeking sexual contact.[46] Patients with severe hypospadias remain much less satisfied with penile appearance than patients with hypospadias in general or controls.[44] For the subset of patients with severe hypospadias, objective, validated assessment and good understanding of long-term outcome and function in adult life.

Pelvi-ureteric junction obstruction

Antenatal hydronephrosis is found in up to 4·5% of all pregnancies, making it one of the most common urological abnormalities. Non-operative management will fail in about a third of patients with high-grade hydronephrosis (Society for Fetal Urology grade 3-4) due to pelvi-ureteric or ureteropelvic junction obstruction, and the anterior-posterior diameter of the renal pelvis

appears to be the strongest predictor of the need for intervention postnatally.[47] Various cutoffs have been proposed, ranging from 16 mm[48] to 24 mm,[47] with variable sensitivity and specificity. Conservative management for high-grade hydronephrosis even in the first 12 months of age can be associated with some loss of renal function.[49] New schematics in classifying antenatal hydronephrosis by ultrasound, such as the upper tract dilation system, have been proposed. In some studies, the upper tract dilation system could not discriminate operative from non-operative candidates,[50] whereas in other studies, the upper tract dilation system has been found to be more predictive.[51]

The costs associated with imaging in terms of discomfort, time spent by the patient and family, and radiation exposure in nuclear renography creates a tremendous opportunity for urinary biomarkers in a diagnostic algorithm to select the patients needing surgical correction. Urinary concentration of molecular markers for kidney injury or adhesion, growth factors, and cytokines have been used in studies, but issues with the heterogeneous timing of assessment and sample size limit their applicability as predictive markers.[52] An unbiased examination of the urinary proteome will yield even more information from a broad sample of patients; for example, a screen of 1100 urinary proteins yielded 76 candidate proteins with diverse functions in inflammation, kidney cell adhesion, leucocyte migration, vasculogenesis, and carbohydrate metabolism.[53] Further studies could earn such a panel of biomarkers a place in a diagnostic algorithm. Functional magnetic resonance urography is a radiation-free way of assessing renal function, and although this technology offers an excellent 5% intraobserver and interobserver variability, issues of variability seem to be magnified in the infant population.[54]

Beyond infancy, minimally invasive surgery for pelviureteric junction repair (figure 6) is becoming increasingly popular, especially in school-aged children.[55] A definitive benefit of laparoscopy compared with traditional open repairs in terms of cost, reduction in complication, or shortened hospital stay has been difficult to demonstrate, and results of a single-centre randomised trial[56] showed clinical equivalence between the two methods, with the disadvantage of a 17 min longer operative time in the minimally invasive group ($p<0·01$) offset by the advantage of a 2·3 h shorter hospital stay ($p=0·02$). Outcomes described in singlecentre reports remain heterogeneous, especially for laparoscopy procedures, without details such as whether the Anderson-Hynes dismemberment was accomplished or other forms of plastic operations on the pelvi-ureteric junction were employed. However, even for the failed pyeloplasty, minimally invasive revision is safe and potentially more efficacious than open repair.[57] The simple surgical displacement of a crossing vessel, which

avoids a sutured anastomosis, is an attractive laparoscopic option that has been successful in some cases[58] but carries the risk of leaving intrinsic obstruction unrelieved.[59]
In affluent communities, robotic assistance is more common than laparoscopy alone, perhaps because of ease of suturing. The standard transperitoneal robotic approach leaves a well hidden umbilical scar, an ipsilateral lower quadrant scar, and a epigastric scar that can be cosmetically troublesome. An alternative robotic approach leaves an umbilical scar and two lower quadrant incisions at the level of a Pfannenstiel incision, which patients have been shown to prefer.[60] Further efforts are being made by surgeons to decrease surgical scars with conventional and robotic single-incision pyeloplasty.[61,62]
Infants will qualify for a standard robotic procedure when they have a pubis-to-xyphoid distance of more than 15 cm, which is generally reached by 6 months of age if full term.[63]

Neurogenic bladder

Neurogenic bladder affects 1·5-2 babies per 10 000 livebirths. The challenge for the paediatric surgical specialist is to protect renal function and achieve urinary continence. The most common cause of paediatric neurogenic bladder is spina bifida. Other congenital

causes include caudal regression and anorectal malformations. Acquired causes include spinal cord injury (trauma, infection, or tumour), extensive pelvic surgery, or CNS insults.[64] Renal failure was once the most common cause of death in young adults with spina bifida, but modern management has transformed the long-term outlook, although many challenges remain.
No consensus guidelines exist for the management of paediatric neurogenic bladder. In 2012, the International Children's Continence Society provided recommendations[65] for the management of neurogenic bladder in children, and the US Centers for Disease Control and Prevention (CDC) convened an expert group to develop protocolised management.[66] Patient recruitment began in 2015, and results are expected by 2020. This effort is in direct response to the known and substantial variability in the management of these patients.[67] Although a more conservative policy exists, the following recommendations are illustrative of a proactive approach based on the belief that renal and bladder deterioration relies can be prevented with close and consistent follow-up.
Early urodynamic studies and, if indicated, clean intermittent catheterisation and anticholinergic therapy, are protective against renal deterioration. External urethral sphincter function determines whether a patient's bladder and sphincter are synergic or dyssynergic and therefore whether the patient is at risk of renal deterioration. Since this status is most likely to change in the first few years of life, patients should

undergo urodynamic studies every 6 months during the first 2 years of life, yearly when aged 2-5 years, and on an individualised basis thereafter. An ultrasound of the kidneys and bladder is obtained at least on a yearly basis, with emphasis on renal anatomy. Data from urodynamic studies suggest that bladder wall thickness has little association with bladder function, emphasising the absence of alternatives to invasive testing.[68] A micturating cystourethrogram should be obtained in infants with dyssynergy or upper urinary tract dilation if video urodynamic study facilities and capability are not available. Finally, the CDC protocol recommends a dimercaptosuccinic acid scan at 3 months and 5 years of age to assess for renal scarring.[65]

Prenatal closure of spina bifida has recently been described and is being done in a limited number of centres in the USA.[69] Initial findings suggest reduced rates of ventriculoperitoneal shunting and improved ambulation. Some data suggest that bladder function in patients who have prenatal closure might not be different from patients closed postnatally,[70] but further follow-up is needed.

The mainstay of medical management of neurogenic bladder is anticholinergic therapy.[71] Oxybutynin chloride is the most widely used anticholinergic and is effective in neurogenic bladder treatment by increasing capacity, lowering urinary storage pressures, and abolishing overactive contractions.[72] Alternative options for patients with overactive bladder contractions who are intolerant or refractory to anticholinergic therapy include mirabegron, a β3-adrenoceptor agonist, and gabapentin. If urodynamic studies reveal inadequate urethral resistance, α-sympathomimetic agents are added. There is often close association between bladder and bowel dysfunctions so an effective bowel-management programme for constipation and faecal incontinence should also be in place.

Surgical options must be considered when medical management has failed.[73] Classically, bladder augmentation by enterocystoplasty is definitive, but this method causes substantial short-term and long-term complications. In the rare case where a patient has a grossly dilated ureter associated with a non-functioning or minimally functioning kidney, a ureterocystoplasty can be considered, in either an open or laparoscopic manner.[74] This technique eliminates several risks associated with enterocystoplasty.[75] The use of botulinum toxin injected endoscopically into the bladder is an alternative option.[76] Patient selection for botulinum therapy seems to be crucial; although effective in improving overactive contractions, botulinum therapy is ineffective in the management of fibrotic, poorly compliant bladders.[76]

Tissue engineering has the potential to provide off-theshelf tissues for reconstructive surgery. To date, pioneering techniques that showed short-term efficacy

have failed to show long-term success,[77,78] but intensive efforts to develop reliable tissue engineering-based options continue and are promising.

In patients for whom intermittent catheterisation via urethra is difficult or impossible, a continent catheterisable channel using appendix, reconfigured bowel, or ureter is an important tool in the paediatric surgeon's armamentarium.[79]

Treating sphincter weakness incontinence continues to be challenging; the effectiveness of bladder outlet procedures is highly variable, and when done without augmentation, cystoplasty might expose the upper tracts to increased pressures and lead to adverse outcome.[80]

Overall, the way children with neurogenic bladder are managed has improved dramatically in the past 40 years. An astounding number of patients now live into adulthood. This advance has been made possible by close follow-up, the advent of clean intermittent catheterisation, reliable urodynamic studies, drugs that modulate bladder function, and surgical techniques that have been promoted and refined in the past few decades.

Posterior urethral valves

With an incidence of about 1/5000 newborn boys, posterior urethral valves are the most common cause of congenital lower urinary tract obstruction (LUTO). Posterior urethral valves are associated with high fetal and neonatal mortality (30%) and considerable lifelong morbidity. In severe cases, the disorder can lead to anhydramnios and pulmonary dysplasia during the canalicular phase of lung development. Abnormal renal development persists into childhood and adolescence: 30-42% of patients develop end-stage renal failure, making posterior urethral valves the most common cause for paediatric renal transplantation. Some patients will develop bladder dysfunction.

Recent advances in treatment concern fetal diagnosis and management. LUTO is increasingly recognised as a spectrum of diseases, and candidacy for fetal intervention varies accordingly.[81] Patients with stage I disease (mild) present with normal amniotic fluid volume and fetal kidneys that are normal in echogenicity; no intervention is necessary at this stage. At the other end of the spectrum, patients with stage III disease (severe) present with oligohydramnios or anhydramnios and signs of abnormal fetal renal function (ie, renal dysplasia, cortical cysts, unfavourable fetal urinary biochemistry); intervention at this stage is controversial. Patients with stage II disease (severe) present with oligohydramnios or anhydramnios and severe bilateral hydronephrosis, but fetal renal function might be preserved (ie, no renal cysts or dysplasia, and favourable fetal urine biochemistry); experts suggest intervention and shunting at this stage could double the odds of survival.[82]

Intervention has traditionally taken the form of

vesicoamniotic shunting, percutaneously placing a double-coiled plastic tube with one coil in the fetal bladder and the other in the amniotic space. Little has changed in shunt design since the 1980s, and clogging or shunt dislodgement cause problems leading to the need for recurrent intervention, with risks of rupture of membranes assumed each time.[83] Outcomes of a large trial[82] suggest a 30% device-related complication rate. There was initial enthusiasm for fetoscopic ablation of posterior urethral valves because it addressed the problem definitively without issues of dislodgment. Although fetal cystoscopy is accurate for diagnosis, its therapeutic effectiveness compared with shunting has not been proven.[84] Therapeutic fetoscopy is not applicable for all causes of LUTO (ie, urethral atresia), and fetal valve ablation risks urethral and adjacent organ injury[85] because laser energy can travel posteriorly. Bypassing the fetus entirely, serial amnioinfusion to restore amniotic fluid volume, either percutaneously or with an infusion port, has been proposed. This procedure has been successful technically but is still at an early stage of study.[86]

Postnatally, it is crucial to determine precisely the cause of bladder-outlet obstruction. Ultrasound and fluoroscopic micturating cystourethrography are standard diagnostic investigations, although their performance characteristics are currently unassessable.[87] Just as in vesicoureteral reflux, ultrasound-based contrast agents have the potential to supplant fluoroscopic studies. Findings in early reports suggested that an ultrasound probe placed on the perineum and traditional micturating cystourethrography had similar sensitivity and specificity in detecting urethral anomalies.[88] Some infants might have dysplastic kidneys, and nuclear studies could prove useful, but rarely before 2 months of age. Notably, while the pop-off mechanism of unilateral vesicoureteral reflux has traditionally been thought to protect the contralateral renal unit from high pressure, more recent findings call this into question.[89]

In a full-term baby, the standard of care for posterior urethral valves is circumcision to reduce the risk of infection and cystoscopic valve ablation. Hook cautery, cold knife, and laser energy[90] are all effective. Adequacy of valve ablation might be difficult to assess initially as dilation often persists; a ratio of 2·5:1 or less between the width of the mid-posterior urethra on oblique fluoroscopic film and the maximum diameter of the bulbar urethra often indicates successful ablation.[91] A high level of suspicion should remain for stricture or residual posterior urethral valves if bladder emptying is poor. Even withstanding a normal micturating cystourethrograph, cystosopy might reveal remnants of valves in up to 50% of patients.[92]

In infants with extremely low birthweight, the urethra

might be too small to admit cystoscopic equipment safely. Long-term catheter drainage is inadvisable because of the risk of candidaemia. Rather than risking stricture with cystoscopic instrumentation, these babies should either undergo open vesicostomy or the rarely used but effective Fogarty balloon valve ablation under fluoroscopic guidance.[93]

Notwithstanding surgical relief of urethral obstruction, ongoing bladder dysfunction is both a cause of morbidity and potential threat to upper tract function. Up to 80% of vesicoureteral reflux will resolve after valve ablation.[94] A small, contracted bladder in infancy that progresses to a large-capacity, poorly compliant bladder, often found in the presence of persistent upper tract dilation and nephrogenic diabetes insipidus, has been termed valve bladder.[95,96] This can create a self-injurious cycle, with persistent dilation leading to a worsening renal concentrating defect and creating more work for a bladder at risk of muscular failure. Regular urodynamic monitoring is crucial in the management of these patients.

Discussion

Advances in paediatric urology have been remarkable, especially because innovations and randomised controlled trials are difficult to implement in the paediatric population and because diseases are heterogeneous. In the coming years, refinements in fetal diagnosis and interventions and the introduction of regenerative medicine and tissue engineering for bladder reconstruction can be anticipated. The benefits of minimally invasive surgery and robot-assisted surgery compared with conventional surgery and non-operative treatments needs to be defined through large, multicentre, randomised controlled trials. The importance of a smooth transition of care from paediatric urology to adult urology cannot be overemphasised. Many challenges remain, but research and innovations will be rewarding as the benefits for patients will be lifelong.

Contributors

PKHT wrote the summary, introduction, and conclusion. AJAH and IHYC wrote the sections about undescended testes and hypospadias. MPK and DAD wrote the sections about pelvi-ureteric junction obstruction and posterior urethral valves. CRE, SB, and DAD wrote the section about neurogenic bladder. CN, IHYC, and DAD wrote the section about vesicoureteral reflux. PKHT critically reviewed and redrafted the whole report. All authors approved the final version of the report for publication.

Declaration of interests

We declare no competing interests.

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