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Urological outcome after myelomeningocele: 20 years of follow-up

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Study Type – Therapy (case series)
Level of Evidence 4

What's known on the subject? and What does the study add?
Although treatment modalities have improved over the years, long-term follow-up studies on the myelomeningocele population still include a high proportion of patients with urological complications such as impairment of kidney function and urinary incontinence. In selected consecutive material, our study could relate the urological outcome of adults to urodynamic variables performed in childhood 20 years before.

OBJECTIVE

- To evaluate the urological outcome in a long-term follow-up of individuals with myelomeningocele and relate the findings obtained to urodynamic variables in childhood.

PATIENTS AND METHODS

- Individuals with myelomeningocele born from 1964–1988 were included at time of urodynamic investigation.
- Age at inclusion was in the range from 1 month to 19.5 years (median, 6 years).
- Detrusor function was classified as overactive, underactive or non-contractile.
- Urethral function was classified according to the leak point pressure.
- In childhood and at follow-up, kidney function was estimated with renography and isotope-glomerular filtration rate examinations.

RESULTS

- In total, 52 individuals (28 boys and 24 girls) aged 19–41 years (median, 29 years) had follow-up.
- Of these, 37 (71%) individuals had bilateral normal kidney function at follow-up; seven (14%) had normal total renal function but unilateral deteriorated kidney, and eight individuals (15%) had deteriorated kidney function.
- Adult individuals with bilateral kidney deterioration had a significant higher frequency of diagnosed detrusor overactivity at childhood urodynamics (63%) compared to those with normal function of both kidneys (24%). In total, 48% of the 52 myelomeningocele individuals were continent at follow-up.
- Continence surgery was performed in eight patients, nine used anticholinergica, three had regular botulinum toxin detrusor injections, and 27 used clean intermittent catheterization.

CONCLUSIONS

- Overall, 15% of patients had impairment of kidney function and 48% were urinary continent.
- Considering the present age distribution of the present study population, this figure appears to be comparable to the data in the literature.
- Urodynamic findings in childhood were predictive for later kidney deterioration.

KEYWORDS

myelomeningocele, neurogenic bladder, follow-up, renal function deterioration, urinary continence

INTRODUCTION

Almost all individuals with myelomeningocele (MMC) develop neurogenic bladder dysfunction (NBD) [1–3]. This process is related to the embryological abnormalities of the autonomous nervous system and has onset antenatally. Although most children are born with a normal upper urinary tract, the NBD may result in a high risk of developing vesico-ureteric reflux, progression of reflux and formation of renal scars in early childhood [3–5]. Renal failure is still one of the most common causes of death in adults born with MMC [6].

It is obvious that the renal status of the adults with MMC at present partly reflect the modalities of treatment regimes available many years ago. The most widely used methods in surveillance of the upper urinary tract and bladder dysfunction are ultrasonography, renography and urodynamics in the imaging of the urinary tract and kidneys, and a description of the bladder function, respectively. The latter investigation has been used for early identification of children at high risk of kidney function deterioration caused by the NBD and, later in childhood, to obtain the necessary knowledge regarding the appropriate strategy for treatment of incontinence [2,3,7,8]. In the NBD, four main combinations of overactive/underactive detrusor and sphincter function exist [9]. The overactive detrusor and overactive sphincter combination often leads to urine leakage at high bladder pressure and is known to be a risk factor for renal deterioration. McGuire

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et al. [10] found that a high leak point pressure was associated with vesico-ureteric reflux and renal deterioration in individuals with MMC. Concurrent with high intravesical pressures, smooth muscle cells become fibrotic and the bladder wall may loose its elastic properties, becoming more rigid, which has been described as low bladder compliance [11]. Untreated patients with an underactive sphincter function will most often be incontinent. The present study aimed to evaluate the urological outcome in a long-term follow-up of individuals with MMC in adulthood and relate the findings obtained to urodynamic variables in childhood.

PATIENTS AND METHODS

The initial sample comprised 94 consecutive patients (54 boys and 40 girls) with congenital MMC, born during the 25-year period from 1964–1988 who were included at time of urodynamic investigation at the Department of Paediatric Surgery, Rigshospitalet, Copenhagen [3]. Age at inclusion was in the range 1 month to 19.5 years (median, 6 years and 2 months). Duration of observation under the regime of the department previously described varied in the range 3 months and 18 years (median, 8 years) [3]. The detailed principles of the urodynamic method have been described previously [3]. Cystometry was performed in the supine position. Combined cystometry and a pressure-flow study were not performed when handicaps or the small size of the child made this too difficult. A filling rate of 30 mL/min was used in children aged >5 years, and a rate of 10 mL/min was used in children aged <5 years. The accommodation test [12] was used for calculating compliance. This implies that the infusion was discontinued and a possible fall in pressure subsequently recorded. The intravesical pressures, which were stable ≈15–25 s after the end of infusion, were used for calculation of compliance in the case of a fall in pressure. Change in intravesical pressure was typically calculated at a Δ volume of 80% of the maximum cystometric bladder capacity minus the initial volume, 0–10 mL. Leakage pressure was recorded (i.e. the intravesical pressure at which discharge of urine occurs; leak point pressure).

As previously described [3], the detrusor function was classified as overactive, underactive or non-contractile (i.e. no detrusor contractions and normal compliance). The urethral function was classified according to the leak point pressure [10]. A leak point pressure <40 cmH_2O defined the urethral function as incompetent. Otherwise, urethral function was classified as overactive.

According to data from the neurosurgical department, the levels of the MMC were classified as thoracolumbar, lumbar, lumbosacral or sacral. The proportion of children generally using a wheelchair was noted.

The presence or absence of vesico-ureteric reflux was investigated with voiding-cysto-urethrography.

In childhood and at follow-up, adulthood kidney function was estimated with renography and isotope-GFR examinations.

During a 5-year follow-up period, individuals with MMC were informed about current updated treatment regimes, including possibilities of botoliniumtoxin detrusor injections if relevant. Episodes of UTIs noted in the paediatric files and in the files at follow-up visits were registered as the presence of UTI; otherwise, it was assumed that the MMC individuals had no significant episodes of UTI.

Bladder emptying methods and treatments were noted including clean intermittent catheterization (CIC), anticholinergic drugs, botolinium-toxin detrusor injections and performed operative procedures.

MMC individuals were considered urinary incontinent according to the definition by the ICS if they had a complaint of any involuntary leakage of urine.

For statistic analysis, the chi-squared test was used and $P < 0.05$ was considered statistically significant.

RESULTS

In total, four children died during childhood or adolescence before follow-up (3). Of these, one boy died, aged 3 months, from congenital heart disorder and two girls died, aged 9 and 11 years, respectively, from a combination of hydrocephalus–shunt device malfunction, meningitis and pneumonia. Both were multi-handicapped and severely retarded. These three patients had normal kidney function. The fourth patient, a girl, was first referred at the age of 10.5 years. She suffered from bilateral chronic pyelonephritic changes, right-sided reflux, moderately reduced renal function and nephrogenic arterial hypertension. At the age of 16 years, she had a urinary diversion a.m. Bricker performed, and died, aged 23 years, with renal failure as a contributing cause. Of the remaining 90 individuals, 38 (42%) were lost to follow- up. There was no significant difference between the individuals included in the follow-up and those lost for follow-up with respect to age at inclusion at childhood, levels of MMC, use of a wheelchair, NBD according to the initial urodynamic evaluation, and a diagnosis of vesico-ureteric reflux at any time in childhood (Table 1).

Fifty-two individuals with MMC (28 boys and 24 girls) aged 19–41 years (median, 29 years) at latest contact were available for follow-up.

Some 37 (71%) individuals with MMC had bilateral normal kidney function at follow-up. Information on urodynamic variables and UTIs in childhood, as well as the treatments performed and continence at follow-up, is provided in Tables 2 and 3. At follow-up, 18 individuals used transurethral CIC to the genuine bladder (four with supplementary anticholinegica and two with botolinium-toxin detrusor injections); 11 of these were fully continent and 10 (two with supplementary anticholinegica) used a non-invasive voiding regime, including the use of regular intervals for bladder emptying. This group includes those individuals using abdominal pressure micturition a.m. Valsalva or Credé, percussion reflex bladder emptying or a combination thereof. Of these 10 individuals, three were fully continent. Most of the individuals in this group had previously tried a CIC regimen and/or anticholinergica but, finding no advantage, had given it up.

There were two individuals who had artificial urinary sphincter and were continent; one individual had each one of the following surgeries performed combined with CIC and were all continent: a Mitrofanoff canal; an ileocystoplasty augmentation; an ileocystoplasty augmentation and a Mitrofanoff canal; and an Indiana pouch.

There were two individuals with a suprapubic catheter. In total, 54% of these 37 MMC individuals with normal kidney function were

continent and 17 (46%) had no registered episodes of UTI at follow-up.

At follow-up, seven (14%) individuals with MMC had normal total renal function but an unilateral deteriorated kidney (taking a functional share of 1–38%, median 14%, of total renal function, i.e. normal GFR). However, only three of these individuals had a normal upper urinary tract at first investigation in childhood and one of these seven individuals died during follow-up because of UTI and septicaemia. Two were continent on CIC, one with supplementary anticholinergica and one also had an ileocystoplasty augmentation performed; one individual was continent on a non-invasive voiding regime; and two individuals had a suprapubic and a transurethral catheter, respectively. In this group of seven individuals, all but one had recurrent UTI in childhood and, in three, this continued in adulthood.

At follow-up, eight (15%) MMC individuals had deteriorated kidney function; one of these individuals had a renal transplantation. She had originally a Bricker urinary diversion performed in early childhood because of functional infravesical obstruction and renal deterioration. At age 19 years, she had an urinary undiversion with ileocystoplasty augmentation and CIC regimen. However, because of progressive renal insufficiency as a result of the early damage, renal transplantation was required 15 years later.

The other seven individuals had a creatinine-EDTA clearance at follow-up of 15–80 (median, 65) mL/min; one of them had a Bricker urinary diversion performed at 3 years of age because of renal deterioration, bilateral reflux and UTIs. Of the remaining six individuals, five had detrusor overactivity and one a leak point pressure <40 cmH_2O at childhood urodynamic investigation. At follow-up, two of these six individuals were continent. Both used CIC (one with supplementary anticholinergica). The remaining four individuals included one using CIC with supplementary botolinium-toxin detrusor injections, one using CIC with supplementary anticholinergica, one with suprapubic and one with transurethral catheter.

All eight individuals in this group had recurrent UTIs in childhood as well as in adulthood.

Of the eight individuals, six did not have bilateral normal renal function at inclusion in childhood but kidney function deteriorated further in varying degree. Two had initially bilateral normal renal function when included at 6 and 9 months, respectively. They had both detrusor-overactivity and leak point pressure >60 cmH_2O at urodynamics in childhood and diagnosed detrusor-sphincter dyssynergia on

TABLE 1 Age at inclusion in childhood, level of myelomeningocele, use of a wheelchair, neurogenic bladder dysfunction according to the initial urodynamic evaluation, and a diagnosis of reflux for the group available for follow-up as well as the individuals lost to follow-up

Characteristic	Follow-up (*n* = 52)	No follow-up (*n* = 38)
Age at inclusion		
Median	6 years	5.5 years
Range	1 month to 19.5 years	1 month to 19 years
Level of myelomeningocele, *n*		
Thoracolumbal	5	2
Lumbar	11	11
Lumbosacral	33	17
Sacral	3	8
Children in a wheelchair, *n* (%)	9 (15)	6 (16)
Urodynamic classification at inclusion, *n*		
Detrusoroveractivity/overactive urehral function	17	14
Underactive detrusor/overactive urehral function	12	4
Non-contractile detrusor/overactive urehral function	7	8
Detrusoroveractivity/incompetent urethral function	0	3
Underactive detrusor/incompetent urethral function	8	3
Non-contractile detrusor/incompetent urethral function	8	6
Children with diagnosed reflux, *n* (%)	16 (31)	9 (24)

TABLE 2 Urodynamic variables and data on urinary tract infection in childhood in 52 individuals with myelomeningocele divided into three groups according to status on renal function in adulthood

Characteristic	Bilateral normal kidney function	Unilateral kidney impairment	Bilateral kidney function impairment	Total
Number of individuals, *n* (male/female)	37 (22/15)	7 (1/6)	8 (5/3)	52
Childhood data, *n* (%)				
Detrusor overactivity	9 (24)	3 (43)	5 (63)	
Leak point pressure <40 cmH_2O	13 (35)	1 (14)	2 (25)	
Recurrent UTI in childhood	20 (54)	6 (86)	8 (100)	34 (65)
Reflux	7 (19)	4 (58)	5 (63)	16 (31)
CIC when included in childhood	13 (35)	2 (29)	5 (63)	20 (39)

CIC, clean intermittent catheterization.

TABLE 3 Urological status of treatment at follow-up in 52 individuals with myelomeningocele divided into three groups according to status on renal function in adulthood

Characteristic	Bilateral normal kidney function	Unilateral kidney impairment	Bilateral kidney function impairment	Total
Number of individuals, *n* (male/female)	37 (22/15)	7 (1/6)	8 (5/3)	52
Data at follow-up				
Age (years)				
Median	29.5	30	26	
Range	19–41	20–36	19–40	
Anticholinergic drugs, *n* (%)	6 (16)	1 (14)	2 (25)	9 (17)
Botulinum toxin detrusor injections, *n* (%)	2 (5)	–	1 (13)	3 (6)
Major continence surgery, *n* (%)	6 (16)	1 (14)	1 (13)	8 (15)
CIC at follow-up, *n* (%)	22 (60)	2 (29)	5 (63)	27 (52)
Continent, *n* (%)	20 (54)	3 (43)	2 (25)	25 (48)
Urinary diversion a.m. Bricker, *n* (%)	1 (3)	1 (14)	1 (13)	3 (6)
Indwelling catheter (suprapubic/transurethral), *n* (%)	2 (5)	2 (29)	2 (25)	6 (12)

CIC, clean intermittent catheterization.

urodynamics at follow-up. Both had used CIC since childhood (one with supplementary anticholinergica). Despite this, they both ended up with a creatinine-EDTA clearance at 76 mL/min.

The proportion of individuals ending up with bilateral kidney deterioration had a significant higher frequency of diagnosed detrusor overactivity at childhood urodynamics (63%) compared to those with normal function of both kidneys at follow-up (24%) ($P = 0.04$).

In total, 48% of the 52 MMC individuals were continent at follow-up.

DISCUSSION

To our knowledge, the present study is unique because patient status at 20 years follow-up is presented after the systematic classification of consecutive individuals with MMC at inclusion in childhood.

For some decades, detrusor-overactivity, decreased bladder-compliance and high leakage pressure were known to be associated with an increased risk of upper urinary tract deterioration in individuals with MMC [2,10,13]. Although this trend was also seen in the present study (Table 2), only the higher frequency of childhood detrusor overactivity in the group of MMC individuals ending up with bilateral renal function impairment compared to the group with bilateral normal kidney function was found to be significant. There may be several explanations for this finding. The original studies were based on a population of MMC individuals' with less treatment before urodynamic evaluation. Thus, although the initial investigations in the present study were made in childhood, the main part of severe renal deterioration may be seen already within the first 7 years of life in mainly urologically untreated MMC individuals [14]. The median age at inclusion at childhood of the present study population was 6 years and significant kidney damage was noted already in some individuals at the time of inclusion. Many studies now support an evaluation in the first year of life because more permanent and high-risk urodynamic changes will often occur in the first year of life.

Studies showing a significant relationship between high-risk urodynamic variables and renal function impairment are often based on larger samples than the present one [2,3,7]. At follow-up with modest size samples, as in the present study, it has been previously shown how difficult it is to relate urodynamic variables to upper urinary tract pathology [11]. However, the main reason is probably related to MMC individuals being treated much more actively during the last 20 years compared to previously. The aim of treatment programmes is to obtain continence and prevent renal deterioration in high-risk groups. However, the findings of the present study support the results of previous studies showing that a combination of overactive detrusor function and overactive urethral function at early urodynamic evaluation strongly implies a risk of later renal function impairment. Of the MMC individuals in the present study with these urodynamic findings within the first year of life, two had normal upper urinary tract in early childhood but deteriorated despite CIC treatment. The risk of an increasing prevalence of renal damage in post-pubertal MMC individuals treated conservatively through puberty has been noted previously [15]. It is not clear whether this increased risk of renal damage is related to the deterioration of bladder function with increased outlet resistance stemming from a pubertal enlargement of the prostate gland in boys and oestrogenization of the urethra in girls, or whether it represents a rebellion of teenagers against the discipline of CIC. In either case, additional studies may help to clarify these observations [15]. However, in some MMC children with NBD, CIC and anticholinergic drugs are not sufficient to prevent kidney deterioration over time and surgical bladder augmentation was needed to improve bladder compliance [3,16,17]. Currently, the possibility of using botulinum toxin detrusor injections for neurogenic detrusor overactivity appears to be promising for individuals with MMC, as it has shown to be for individuals with spinal cord lesions in general [18].

Recurrent UTIs are well documented as a significant factor in the development of reduced renal function in individuals with

MMC and this in accordance with the results of the present study [19]. UTIs occur at a variable frequency in a substantial part of children with MMC, although they are less frequent in individuals without functional obstruction at the bladder/urethral level, as also shown in the present study. Because damage to the upper urinary tract and UTIs often is coexistent, there has been a tendency towards considering the former as a consequence of the latter. However, a common cause is more probable, namely functional obstruction at the bladder/urethral level, resulting in residual urine. If this obstruction is present together with vesico-ureteric reflux, UTI is definitely a threat towards the upper urinary tract and CIC treatment and antibiotics is mandatory [3]. Because of the retrospective design of the present study, data collection did not allow us to discriminate between febrile and non-febrile UTI.

TABLE 4 The percentage of urological operations and impaired renal function reported in studies reviewed by Jorgensen [11]

Study	Subjects	Age (years), mean (±SD) (range)	Urological surgery (%)	Impaired kidney function (%)
Torre *et al.* (2008)	244	13.5 (1–37)		5.3
Aurora *et al.* (2007)	30	4.5 (0.5–18)		10
Dik *et al.* (2006)	144	6.8 (0.5–13.5)	29	0
Olsson *et al.* (2006)	175	16.5 (15-8)	24	2
Lemelle *et al.* (2006)	421	21.7 (±7.9)	55	2
Glott *et al.* (2001)	51	30 (16–46)	53	34
Lin-Dyken *et al.* (1992)	39	14.5 (10.5–23)	13	32

In the present study, 15% of the individuals with MMC had impairment of renal function. Considering the age distribution of the present study population, this figure is comparable to data of 1104 patients presented in a review by Jorgensen [11,16,20–25] (Table 4). Although, as reported, a comparison of the results obtained was difficult because definitions, the age of the included individuals, types of urological interventions, a definition of decreased kidney function and thresholds were all different in the various studies [11]. However, besides showing that preservation of renal function may have improved over time, the review shows that increasing the follow-up period may result in further kidney deterioration [11]. In the present study, 15% of individuals had major continence surgery performed. Because any strategy employed with respect of surgical treatment varies in different studies, the figures are difficult to compare. Some studies favour a more conservative approach to surgery, awaiting for continence spontaneously during puberty in selected patients [15]. However, this strategy also induces a substantial delay in obtaining continence because a precise assessment predicting those individuals who will develop continence spontaneously is lacking. Whether this delay is acceptable or not should be settled between the individual with MMC, the parents and the various medical specialists and the urotherapists. In the present study, 48% of the total MMC population was continent at follow-up. This is in accordance with the 39% of continent young adults (16–25 years old) among 142 individuals with spina bifida reported recently by Verhoef *et al.* [26]. However, compared to centres advocating early prophylactic treatment programmes, where up to 89% of the children achieve continence, the figure from the present study is low [16,17]. A prophylactic treatment programme includes the start of treatment within the first months of life with CIC, anticholinergic drugs, antibiotic prophylaxis and urodynamic surveillance. In the case of a suspected upper urinary tract threat despite this treatment, or later in the case of incontinence, bladder augmentation has been performed in 25–30% of the MMC individuals. Considering that only half of the participants in the present study are continent and, furthermore, that CIC and anticholinergics were not found to be sufficient for preventing upper urinary tract damage in some individuals with overactive detrusor and overactive urethral function, a higher rate of intervention with botulinum toxin detrusor injection or other procedures is probably required in future MMC children. In the group with bilateral normal renal function, 35% had a leak point pressure <40 cmH_2O at urodynamics in childhood. A low leak point pressure protects the kidney function but also predicts a small chance of achieving continence spontaneously or as a result of a CIC regimen. Therefore, botulinum toxin detrusor injection or, in selected cases, continence surgery must be considered.

Three patients (aged 27, 36 and 39 years) had a Bricker urinary diversion made in childhood. However, this procedure is no longer used in MMC individuals and those mentioned were the last individuals to have this operation performed in our department. There are better alternatives and the Bricker urinary diversion in itself may produce progressive damages to the renal parenchyma [3]. Some individuals with MMC have impaired motor and/or intellectual function and, to maintain some independency for social reasons, they may choose indwelling catheters, as observed for 12% of the present study population [3].

In the only individual who died during follow-up, the cause of death was related to the urological problem, supporting the knowledge that renal failure is still one of the most common causes of death in adults born with MMC [6].

In conclusion, in this 20-year follow-up study of 52 individuals with MMC, overall, 15% of patients had impairment of kidney function and 48% were urinary continent. Considering the present age distribution of the MMC population in the present study (19–41 years; median 29 years), this figure appears comparable to the data in the literature. However, with an early prophylactic treatment strategy based on urodynamic classification of individuals at risk and the increased use of botulinum toxin detrusor injections, as well as surgical treatment in selected individuals, including bladder augmentation, an increased rate of continence and normal kidney function should be expected in future series. In the present series, the overall management was relatively conservative, with clean intermittent catheterization being the mainstay of treatment. Only eight patients (15%) underwent lower tract surgery (e.g. augmentation, Mitrofanoff, artificial sphincter). It is presumably for this reason that the overall continence rate was lower than that reported in other centres with a higher reconstruction rate.

The present study clearly shows that CIC alone is not sufficient to protect against the long-term risks of upper tract damage in all cases of MMC. This is not an original observation, although the detailed and carefully conducted study reported here adds weight to this important message.

CONFLICT OF INTEREST

None declared.

REFERENCES

1 **Stark G.** Prediction of urinary continence in myelomeningocele. *Dev Med Child Neurol* 1971; **13**: 388

2 **Van Gool JD.** *Spina Bifida and Neurogenic Bladder Dysfunction – A Urodynamic Study*. Utrecht: Impress, 1986: 9–238

3 **Thorup J.** Urodynamic examination of the lower urinary tract in children with normal and congenital neurogenic bladder. *Scand J Urol Nephrol Suppl* 1994; **158**: 1–59

4 **Wilcock AR, Emery JL.** Deformities of the renal tract in children with myelomeningocele and hydrocephalus compared with those of children showing no such central nervous deformities. *Br J Urol* 1970; **42**: 152–7

5 **Woods C, Atwell J.** Vesicoureteric reflux in the neuropathic bladder with particular reference to the development of renal scarring. *Eur Urol* 1982; **8**: 23–8

6 **McDonnell GV, McCann JP.** Why do adults with spina bifida and hydrocephalus die? A clinic-based study. *Eur J Pediatr Surg* 2000; **10** (Suppl. 1): 31–2

7 **Rickwood AMK, Thomas DG, Philp NH, Spicer RD.** Assessment of congenital neurovesical dysfunction by combined urodynamic and radiological studies. *Br J Urol* 1982; **54**: 512–8

8 **Kaye K, Blerk JPV.** Urinary continence in children with neurogenic bladders. *Br J Urol* 1981; **53**: 241–5

9 **Bauer SB.** Neurogenic dysfunction of the lower urinary tract in children. In Walsh PC, Retik AB, Vaughn ED eds. *Cambells Urology Study Guide*, 2nd edn, Chapt 65. Philadelphia: WB Saunders Company, 1998: 285–8

10 **McGuire EJ, Woodside JR, Borden TA, Weiss RM.** Prognostic value of urodynamic testing in myelodysplastic patients. *J Urol* 1981; **126**: 205–9

11 **Jorgensen B.** Aspects of the neurogenic bladder in children. Thesis. Faculty of Health Sciences. University of Aarhus 2008: pp 1–57.

12 **Coolsaet B.** Bladder compliance and detrusor activity during the collection phase. *Neurourol Urodyn* 1985; **4**: 263–73

13 **Stott MA, Abrams PH.** Bladder compliance in patients with spina bifida. *Neurourol Urodyn* 1988; **7**: 181–2

14 **Lorber J.** Results of treatment of myelomeningocele. *Dev Med Child Neurol* 1971; **13**: 279–303

15 **Almodhen F, Capolicchio JP, Jednak R, El Sherbiny M.** Postpubertal urodynamic and upper urinary tract changes in children with concervatively treated myelomeningocele. *J Urol* 2007; **178**: 1479–82

16 **Dik P, Klijn AJ, Van Gool JD, De Jong-de Vos van Steenwijk CCE, De Jong TPVM.** Early start to therapy preserves kidney function in spina bifida patients. *Eur Urol* 2006; **49**: 908–13

17 **Kaefer M, Pabby A, Kelly M, Darbey M, Bauer SB.** Improved bladder function after prophylactic treatment of high risk neurogenic bladder in newborns with myelomeningocele. *J Urol* 1999; **162**: 1068–71

18 **Akbar M, Abel R, Seyler TM *et al*.** Repeated botulinum-A toxin injections in the treatment of myelodysplastic children and patients with spinal cord injuries with neurogenic bladder dysfunction. *BJU Int* 2007; **100**: 639–45

19 **Moser C, Kriegbaum NJ, Larsen SO, Hoiby N, Biering-Sorensen F.** Antibodies to urinary tract pathogens in patients with spinal cord lesions. *Spinal Cord* 1998; **36**: 613–6

20 **Torre M, Buffa P, Jasonni V, Cama A.** Long-term urologic outcome in patients with caudal regression syndrome, compared with myelomeningocele and spinal cord liporna. *J Ped Surg* 2008; **43**: 530–3

21 **Arora G, Narasimhan KL, Saxena AK, Kaur B, Mittal BR.** Risk factors for renal injury in patients with meningomyelocele. *Indian Pediatr* 2007; **44**: 417–20

22 **Olsson I, Dahl M, Mattsson S, Wendelius M, Aström E, Westbom L.** Medical problems in adolescents with myelomeningocele (MMC): an inventory of the Swedish MMC population born during 1986–1989. *Acta Paediatr* 2007; **96**: 446–9

23 **Lemelle JL, Guillemin F, Aubert D, Guys JM, Lottmann H, Lortat-Jacob S.** A multicenter evaluation of urinary incontinence management and outcome in spina bifida. *J Urol* 2006; **175**: 208–12

24 **Glott T, Stanghelle JK, Rand-Hendriksen S, Johnsen V, Thyberg M, Melhus M, Brabrand K, Fjeld JG, Bakke A.** Voiding problems and urinary tract complications in adolescents and adults with myelomeningocele. *Tidsskr Nor Laegeforen* 2001; **121**: 1211–5

25 **Lin-Dyken DC, Wolraich ML, Hawtrey CE, Doja MS.** Follow-up of clean intermittent cathterization for children with neurogenic bladders. *Urology* 1992; **40**: 525–9

26 **Verhoef M, Lurvink M, HA B *et al*.** High prevalence of incontinence among young adults with spina bifida: description, prediction and problem perception. *Spinal Cord* 2005; **43**: 331–40

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Abbreviations: **CIC**, clean intermittent catheterization; **MMC**, myelomeningocele; **NBD**, neurogenic bladder dysfunction.