Scientific Review

Towards a catheter free status in neurogenic bladder dysfunction: a review of bladder management options in spinal cord injury (SCI)

F Jamil*,¹

¹Duke of Cornwall Spinal Treatment Centre, Salisbury, Wiltshire

Study design: Review.

Objectives: To assess current available options for bladder management in SCI patients the post-acute phase.

Methods: Relevant articles were extracted from medline and Cinahl between 1966–1999. In addition, references earlier than 1966 that were listed in these articles were identified and extracted.

Results: Catheterisation (indwelling or self intermittent) is still carried out by the majority of SCI patients with more morbidity for indwelling catheterisation. Other methods include condom drainage, suprapubic tapping and suprapubic pressure are used and are associated with less complications. Complicated procedures like sacral anterior root stimulator and entero-cystoplasty are carried out with the onset of or impending complications.

Conclusion: Several methods of bladder management are available in the post-acute phase of SCI. The method used has to be based on urodynamic characteristics with the aim of producing a continent bladder with adequate low pressure storage capacity. Modern management of the bladder in SCI has successfully reduced renal related mortality in SCI from 95% in the first half of the 20th century to the present 3%.

Spinal Cord (2001) **39**, 355–361

Keywords: spinal cord injury (SCI); bladder management; indwelling catheter; FES

Introduction

While bladder management in acute spinal cord injury always involves catheterisation, one third of patients still use indwelling catheterisation for long-term bladder management. Ideally, bladder management is guided by the urodynamic characteristics. However, a less than ideal bladder management is often pursued depending on anatomical factors and patients preferences.

The end of the Second World War and the Korean War saw the onset of a steady decline in renal related mortality of the spinal cord injured patient. Amongst the factors suggested to have contributed to such improvement were: (a) intermittent catheterisation; (b) maintenance of catheter free status; (c) improved control of urinary tract infection; (d) specialised centres of care; (e) long term renal surveillance; (f) modern urodynamic testing; (g) improved treatment of calculi.¹

The reduction in renal disease related mortality in spinal cord injury (SCI) patients was clearly demonstrated in several publications about the subject. In 1958, Russi² reported the result of autopsy studies of

55 paraplegics who did not die immediately after injury. They had an average life expectancy of 53 months. Genito-urinary diseases were present in 90.2%. Renal disease, as the primary pathological diagnosis was present in 20.3%.² In 1963, Tribe³ reported the results of post-mortem studies of 122 cases of chronic paraplegics from Stoke Mandeville hospital. Fifty-three of the deaths were primarily of renal failure, all but three had chronic pyelonephritis.

Follow-up studies of World War II and the Korean War paraplegic veterans at 25 years showed a drop in renal related mortality from 63% to 26%. Renal amyloidosis accounted for 40% of causes of renal failure.⁴ Further study of Vietnam War paraplegic veterans showed that mortality at 15 years follow-up was 20% and renal related mortality was half of those of the World War II and Korean War paraplegic veterans. The authors attribute this reduction to the achievement of catheter free status with the use of external sphincterotomy.⁵

Large European spinal treatment centres were also reporting this steady reduction in renal related mortality in SCI patients. A 15-year follow-up study from Ireland of 406 SCI patients up to 1982 found

*Correspondence: F Jamil, Duke of Cornwall Spinal Treatment Centre, Salisbury District Hospital, Salisbury, Wiltshire SP2 8BJ

renal related mortality to be around 0.5%.⁶ A 17-year follow-up study from Sheffield of 885 patients up to 1978 found only 13 urological related mortality (0.015%) and no urological related female mortality out of the remaining 86 females with chronic spinal cord injuries.⁷ De Vivo *et al*⁸ reported renal disease related mortality to be around 3%.

Although more progress has been made in reducing the incidence of renal failure than any other serious complications of SCI, urinary tract complications continue to be a prominent cause of concern and morbidity.⁹ Factors such as change in bladder physiology over time, the often insidious nature of renal damage in SCI patients and the adoption by patients of bladder management most convenient for their physical and social needs all contribute to such morbidity.¹

In the acute phase of SCI, bladder management varies between indwelling and intermittent catheterisation depending on the practice of the unit and the financial resources of the health services. At 6–12 weeks, when spinal shock phase would have resolved in almost all patients, full video-urodynamics testing is usually carried out. The urodynamic findings help guide the clinician in advising the patient on the available choices of bladder management.

Bladder management options in the post-acute phase of SCI

Clean intermittent catheterisation (CIC)

Widely accepted as method of choice. Patients who meet certain criteria of adequate low pressure bladder capacity with a minimum volume of 350–400 mls, unobstructed urethra and a compliant, understanding, continent co-operative patient with adequate hand function¹⁰ are suitable for CIC. The main advantage of CIC is that it is the safest method of bladder management with regard to renal protection according to the studies published about the subject to date. There are, however, a few disadvantages; some patients may find it incompatible with social and/or work situations and male patients with incomplete SCI who retain urethral sensation may find it painful. In addition, forceful catheterisation against a closed external sphincter may result in the formation of false tracks with consequent stricture formation resulting in increasing pain and length of time required for catheterisation. Female patients with adductor spasms or with poor hand co-ordination are unsuitable for CIC.

Sekar *et al*¹¹ studied 1114 SCI patients who used different types of bladder management. Eighty per cent of the study population were followed-up for 10 years or less. Their finding was that while nearly a third of the male patients were discharged on CIC, only 8% continued to use it at 5 years and nearly 5% continued to use it at 10 years. The majority switched to condom drainage. Another study by Gallien *et al*¹² of 123 patients with SCI, CIC was used in 65% of patients.

Urinary complications occurred in 75% of patients, mostly urinary tract infection (UTI). Trauma of CIC resulted in a high rate of epididymo-orchitis. Other studies confirmed similar rates of infection.¹³ Stover¹⁴ reported that the majority of patients abandon this method of bladder management by 10 years.

Reflex voiding

Involuntary emptying, induced or spontaneous¹⁵ is another method of bladder management which is used in a wide range of SCI patients from complete upper motor neurone to complete lower motor neurone and also patients with incomplete or partial injuries. Patients with supra-sacral injuries often have detrusor hyper-reflexia and detrusor sphincter dyssynergia (DESD) resulting in elevated voiding pressures.¹⁶ Patients may use Credé manoeuvre, Valsalva manoeuvre or both to empty their bladders. In addition, bladder contraction may be triggered by supra-pubic tapping in bladders that exhibit weak uninhibited contractions. Catheter free status may be achieved through a program of fluid restriction and intermittent catheterisation. Regular voiding every 3 h with post void residual of less than 100 mls is an indication to discontinue intermittent catheterisation.¹⁷ Prolonged periods of supra-pubic tapping may be required to trigger detrusor contraction and can therefore interfere with work or leisure activities. Credé manoeuvre and Valsalva manoeuvres may exacerbate haemorrhoids, hernias and vesico-ureteric reflux and are therefore, usually only suitable for patients who are unable to do CIC and who have weak urethral sphincter such as SCI male patients with lower motor neurone lesions. Valsalva manoeuvre, may worsen the dyssynergia (DESD).¹⁸

Indwelling catheter

Urethral or suprapubic is used by about a third of SCI patients. The majority of female SCI patients rely on indwelling catheterisation because they are unable, unwilling or unsuitable for CIC. There are several drawbacks to the use of indwelling catheter almost all of which are due to the inevitable bacteriuria which is polymicrobial and dynamic.

From the moment the urethral catheter is introduced, the incidence of bacteriuria is 5% to 10% per day.¹⁹ Almost all complications of urinary catheterisation are the result of the consequent bacteriuria.¹⁹

An indwelling catheter allows access, maintenance and complications of bacteriuria through the following mechanisms:¹⁹

- (1) Acts as a conduit for the entry of micro-organisms into the bladder.
- (2) Allows for maintenance of bacteriuria through providing a niche on its luminal and external surfaces. It may also facilitate a transient increase in the adhesiveness between bacteria and uroepithelial cells.

- (3) As a foreign body, it may blunt the function of PMN leukocytes leading to urethritis and/or cystitis.
- (4) The bacteria may include urease-producing organisms causing stone formation and calcification leading to obstruction.

Most of the knowledge about catheter complications come from clinical practice where catheter use come under one of two categories:

- (1) Short term use of less than 4 weeks. Bacteriuria occur in about 15% in patients with short term catheterisation, but due to the large number of catheterisation for these purposes they are responsible for about 900 000 episodes of catheter associated bacteriuria in the United States making them the most common of all hospital acquired infections.²⁰ Insertion of urethral catheter results in transient bacteremia in about 8% of patients²¹ but only 2% to 4% of catheter associated bacteriuric patients develop clinical gram-negative bacteremia.^{22,23} A study by Platt and co-workers found a threefold increase in mortality in catheterised patients with bacteriuria and nearly 50% of those who died had features of serious infection.²⁴
- (2) Long term or chronic catheterisation. The two indications are chronic retention and chronic incontinence. By far the largest group are found in chronic care facilities where the prevalence of chronic catheterisation is about 9%.¹⁹

Complications of chronic indwelling catheterisation

Fever

In one study²⁵ of a group of chronically catheterised women, two thirds of the total fevers were attributed to possible urinary origin. Despite the febrile episodes comprising only 2% of the total patients-days of the study, six of the 12 deaths occurred during febrile episodes of urinary origin. The incidence of death during these febrile episodes was 60 times the incidence of death during the afebrile episodes. Maximum temperature $\geq 102^{\circ}\text{F}$ and a presence of bacteremia were significantly associated with the deaths.

Acute pyelonephritis

In one study of 75 patients who died in chronic care hospitals, 55 died with catheters in place, 40% of them had pyelonephritis at the time of death, compared to 5% of non-catheterised patients. ($P=0.004$).¹⁹

Urinary stones

In one study of catheterised spinal injuries patients who died of renal failure, 39% of those who died had

renal stones compared to 10% of those who died of non-renal causes.²⁶

Chronic renal inflammation

Autopsy studies of long term catheterised spinal injuries patients revealed chronic inflammation in 65% to 95% of patients.^{26,27} In addition, in SCI patients with end-stage renal disease (ESRD) renal amyloidosis, papillary necrosis, pyonephrosis and perinephric abscess are common.²⁷ Histologically, there is evidence of hypertensive arteriolo-nephrosclerosis (uncontrolled hypertension), and progressive loss of the remaining nephrons due to glomerular hyperfiltration and hypertension.²⁸

*Urinary malignancies*²⁹

In a study of 73 SCI patients followed-up for 20 years or more there was a statistically significant difference in the incidence of renal caliectasis/scarring between the catheterised (41%) and non-catheterised (17%) patients. There were nine lower urinary tract complications in the former compared to three for the latter.³⁰

In another study of 57 SCI tetraplegics followed-up for a mean period of 12 years, the overall incidence of upper and lower urinary tract complications between the 32 catheterised and the 25 non-catheterised patients were found not to be significantly different. The authors concluded that the decision to avoid an indwelling catheter should reflect patient's comfort, convenience and quality of life.³¹ It is noteworthy however, that death rate in the catheterised group was more than double that of the non-catheterised group (14/32 vs 5/25).

Kim *et al*³² studied 109 male spinal injured patients who used indwelling catheters for a mean period of 11.9 years. They found that of the 64 patients with moderately or severely impaired compliance with a leak point pressure >35 cm. H_2O and on no oxybutynin had 23% incidence of hydronephrosis, 27% incidence of febrile UTI, 22% incidence of reflux, 12% incidence of renal scars and 20% incidence of stones.

Pharmacotherapy

Any of the above methods of bladder management in SCI patients can be combined, when appropriate, with drugs that can influence the function of the bladder and/or the urethra. (a) For incontinence, anticholinergic drugs Oxybutynin and Probantheline. Oxybutynin competitively blocks post-ganglionic acetylcholine receptors and has local anaesthetic effects on the bladder wall. Propantheline has a primarily anticholinergic effect. The tricyclic antidepressant Imipramine increases bladder capacity, suppresses uninhibited bladder contractions and increases urethral resistance.³³ Alpha-adrenergic agonists may increase outlet resistance. Some success may be achieved in women with

leakage around Foley catheter with incomplete SCI and patulous urethra. It is essential to rule out detrusor hyper-reflexia and poor compliance with urodynamics before using alpha-adrenergic agonists.³⁵ (b) For retention, the most commonly used medications are those that decrease outlet resistance. Alpha-adrenergic blocking agents may aid bladder emptying in patients with detrusor-sphincter dyssynergia. They may also relieve symptoms of autonomic dysreflexia.^{34,35}

Other medications used in the management of neurogenic bladder dysfunction in SCI patients, either in isolation or in combination with other drugs or methods of bladder management include; drugs that can relax the striated external sphincter, Baclofen (GABA agonist), diazepam (increases GABA inhibitory transmission in the spinal cord) and Dantrolene (which acts peripherally by decreasing calcium release from the sarcoplasmic reticulum). Intravesical capsaicin³⁶ and anticholinergics³⁷ may improve storage capacity of the bladder. Occasionally, when conventional anticholinergic medication fail to control uninhibited detrusor contractions, desmopressin (DDAVP) may be helpful in keeping patients dry at night.³⁸

Operative interventions

Operations on the sphincter mechanism (i) Sling operation and peri-urethral injection of collagen in female patients with intrinsic urethral sphincter weakness. Male patients with similar problems can be treated with artificial urinary sphincter (AUS). There is a high risk of infection or erosion due to frequent episodes of bacteriuria. In one study of SCI patients with AUS, infection requiring the removal of the device occurred in 24% of patients.³⁹ Operations to increase the sphincter resistance should not be done in the presence of forceful uninhibited detrusor contractions as it may cause back pressure on the kidneys. Patients should also be warned of the high probability of the need for self intermittent catheterisation post-operatively. (ii) Patients with retention due to high outlet resistance: Pudendal nerve block or neurectomy⁴⁰ is rarely used today due to the risk of faecal and urinary incontinence. (iii) Insertion of stainless steel mesh stent endoscopically can keep the membranous urethra open in SCI patients with DESD. They become covered with epithelium in 3–6 months thus avoiding encrustation. Other advantages include reversibility and its utility in the treatment of urethral stricture.⁴¹ More recent stents like Memokath (thermosensitive temporary stent) in particular those that stent the external sphincter and the bladder neck were found, in one study, to be very effective in reducing the volume of residual urine. They were also found to be effective in reducing pre-operative hydronephrosis and autonomic dysreflexia.⁴² Another study, however, failed to demonstrate a substantial benefit; 19 out of 24 Memokath inserted

had to be removed.⁴³ The authors of the study recommended caution when using the stents in DESD and not to use them in the presence of chronic urinary tract infection. (iv) Botulinum toxin injection into the external sphincter mechanism has had some success in patients with DESD.^{44,45} (v) External sphincterotomy has been in clinical practice for the last three decades.⁴⁶ There are many reports supportive of sphincterotomy in the literature.^{46–48} They reported improvement in dysreflexic symptoms, reduction in residual urine volume, and reduction in the frequency of urinary tract infection.

Disadvantages of external sphincterotomy include; its non-utility for female patients, practical problems with the fitting of an external collecting device particularly in obese patients with relatively small genitalia, and skin reaction to the condom material. Follow-up studies showed up to 50% failure rate including stricture formation at the site of sphincterotomy, incomplete external sphincterotomy, failure to include the bladder neck in the incision, and post-operative bladder hypo-contractility.⁴⁹

Operations on the bladder They are aimed at increasing bladder capacity and/or rendering detrusor contraction inefficient. (i) Bladder auto-augmentation: The procedure involves a complete myomectomy of the dome of the bladder creating wide mouth diverticulum. Stohrer *et al*⁵⁰ reported good results in 50 patients who were given the operation over a period of 7 years. They recommended its applicability to patients with neurogenic voiding dysfunction with small capacity, low compliance bladders that are unresponsive to a less invasive method of bladder management. (ii) Entero-cystoplasty like the Clam entero-cystoplasty or other modifications of it. It is suitable for patients with hyper-reflexic bladder contractions with relatively undamaged bladder wall with competent sphincter mechanism and who are unresponsive to less invasive methods of controlling detrusor hyper-reflexia. Patients with damaged or incompetent sphincter mechanism should have, in addition, either an artificial urinary sphincter, or, bladder neck closure and a Mitrofanoff stoma constructed on the anterior abdominal wall. Patients should be assessed for their ability to perform self intermittent catheterisation (SIC) before they are considered for the procedure. Complications include excessive mucus production and its reported association with high morbidity and a negative effect on the patient's quality of life.⁵¹ Patients with damage or advanced abnormality of the bladder wall and competent sphincter mechanism, can benefit from lower urinary tract reconstruction where most of the supra-trigonal bladder wall is removed and replaced with detubularised, reconstructed bowel. In one study of 28 patients who received such procedures, there was a 70% stopping of incontinence, however, complications like recurrent UTI occurred in 59% of patients. There was also 22% incidence of stone formation.

Complications leading to further surgery occurred in 44% of patients.⁵² Detubularised reconstructed bowel with continent catheterisable abdominal stoma can be used as a complete urinary diversion eg Indiana pouch (ileo-caecal bowel segment).⁵³ Urinary diversion (continent or otherwise) are most useful for female patients with bladders that are too diseased to be used as a reservoir. It is also recommended before surgery on patients with complex urethro-cutaneous fistulae.

Functional electrical stimulation (FES) Electrical stimulation of the anterior roots of S2, 3 and 4 is very successful in completely emptying the paralysed bladder in people with spinal cord injury.^{54,55} The device in use is the Finetech-Brindley Bladder Controller. Over 2000 devices have been implanted worldwide. The primary purpose is to improve bladder emptying thus eliminating urinary infection, to assist in defecation and to enable male patients to have sustained full erection.⁵⁶ The anterior roots of S2, 3 and 4 are stimulated via a receiver block implanted under the skin which is in turn stimulated by electromagnetic induction at the radio frequencies 7 and 9 Mhz. Until recently, all implants were of the intra-dural type, however, most centres are switching to extra-dural implants in conjunction with posterior root rhizotomy at the level of the conus medullaris. The posterior root rhizotomy (deafferentiation) cures reflex incontinence, improves bladder compliance, diminishes detrusor sphincter dyssynergia and ensures that neither use of the implant nor overfilling of the bladder will trigger autonomic dysreflexia,^{56–58} however, its effect on autonomic dysreflexia was challenged in one study.⁵⁹

The device (Finetech-Brindley Bladder Controller) is suitable for any patient with complete, non-progressive spinal cord lesion and a reflex bladder. It can be recommended to female patients after 3 months and to male patients after 9 months of complete supra-sacral SCI. The presence of three of the four non-vesical sacral segment reflexes (ankle jerks, bulbo-cavernosus reflex, anal skin reflex and reflex erection) and a phasic detrusor pressure rise of 35 cm H₂O in the female and 50 cm H₂O in the male on cystometry indicates intact efferent nerve supply to the bladder and consequently the possibility of success of the implant.

Patients with incomplete lesions, majority of patients with multiple sclerosis, majority of patients with spinal bifida and all children, are unsuitable for implantation of the device.⁵⁶

Reflex erection and ejaculation will be lost with posterior rhizotomy.⁵⁶

Brindley⁵⁴ reviewed the first 500 cases up to 1994 with a mean follow-up period of 4 years. Infection rate was 1%. Operations to remedy implant failures were carried out in 20% of patients.

Wielink *et al*⁶⁰ studied cost effectiveness and quality of life analysis of 52 patients with sacral anterior root stimulators and dorsal rhizotomy over a 3 year period.

They concluded that the device costs were recouped within 8 years. Even though the general indicators of the quality of life showed no significant changes, factors related to the psychological wellbeing, satisfaction with bladder emptying and reduction of incontinence were significantly improved.

Long term studies from developed countries indicate fairly good survival following SCI. Yeo *et al*⁶¹ studied the mortality of 1453 SCI patients over a 40 year period. After excluding patients who died within 18 months of their injury, they found that survival of the complete tetraplegics was 70% of normal population, 84% for the complete paraplegics and at least 92% of normal for patients with incomplete lesions. Figures from the model regional SCI care systems in the US showed that while 12 years survival of those with a mean age of 19 years for the incomplete paraplegics was 95% and for the complete tetraplegics was 87%, survival for the same period of those with a mean age of 59 years with incomplete paraplegia was 72% and complete tetraplegia of 18%.⁶² These publications show that even though renal related mortality dropped to around 3%, death from sepsis was around 9% and death from undetermined cause was around 8%. It could be argued that a good proportion of these sepsis related deaths may be of urinary origin. Urinary tract infection remains the most common complication within 6 weeks of SCI (46%),⁶³ and 1 year (59%) where catheter use for bladder management is at its peak. Urinary tract infection becomes the third most common complication at 30 years after injury (14%)⁶⁴ possibly because only about one third of SCI patients use catheterisation as a method of long term bladder management. Even studies that showed no significant difference in complication rates between the catheterised and non-catheterised SCI patients at 10 years found that the complication rate and upper tract damage become significant after 10–12 years.^{30,31}

Conclusion

Complications as a result of problems with bladder drainage remain a source of mortality and significant morbidity for patients with spinal paralysis. The most serious of these complications are related to the long term use of indwelling catheterisation. Clean intermittent catheterisation and non-catheterising methods of bladder drainage such as reflex voiding and external sphincterotomy with an external collecting device, with or without appropriate pharmacotherapy, are associated with low incidence of upper urinary tract damage. Major surgery aimed at increasing bladder capacity, increasing compliance and providing continence have high complications and patients dissatisfaction rates. FES offers a physiological method of bladder drainage, however, division of the posterior roots has limited its acceptance by the patients. In addition, the expense of the implant,

20% revision rate at 5 years and the technically demanding nature of the procedure are restricting its widespread use. Research aimed at avoiding division of the posterior roots is underway.

References

- 1 Lloyd LK. Long-term follow-up of neurogenic bladder. *Phys Med Rehab Clin N Am* 1993; **4**: 391–409.
- 2 Dietrick RB, Russi S. Tabulation and Review of autopsy findings in fifty-five paraplegics. *JAMA* 1958; **166**: 41–44.
- 3 Tribe CR. Causes of death in early and late stages of paraplegia. *Paraplegia* 1963; **1**: 19–45.
- 4 Hackler RH. A 25-year prospective mortality study in the spinal cord injured patients: comparison with the long-term living paraplegics. *J Urol* 1977; **117**: 486–488.
- 5 Borges PM, Hackler RH. The urologic status of the Vietnam war paraplegic: A 15-year prospective follow-up. *J Urol* 1982; **127**: 710–711.
- 6 Webb DR, Fitzpatrick JM, O'Flynn JD. A 15-year follow-up of 406 consecutive spinal cord injuries. *BJU* 1984; **56**: 614–617.
- 7 Thomas DG, Clarke SJ. The urological status of 86 females following spinal cord injury. *BJU* 1979; **51**: 515–517.
- 8 De Vivo MJ *et al.* Causes of death for patients with spinal cord injuries. *Arch Intern Med* 1989; **149**: 1761–1766.
- 9 Stover SL, Lloyd KL, Waites KB, Jackson AB. Urinary tract infection in spinal cord injury. *Arch Phys Med Rehabil* 1989; **70**: 47–54.
- 10 Binard JE *et al.* Intermittent catheterisation the right way: (Volume vs. Time directed). *J Spinal Cord Medicine* 1996; **19**: 194–196.
- 11 Sekar P *et al.* Comparison of long-term renal function after spinal cord injury using different urinary management. *Arch Phys Med Rehabil* 1997; **78**: 992–997.
- 12 Gallien P *et al.* Influence of urinary management on urologic complications in a cohort of spinal cord injury patients. *Arch Phys Med Rehabil* 1998; **79**: 1206–1209.
- 13 Barnes DG, Shaw TR, Timoney AG, Tsokos N. Management of neuropathic bladder by suprapubic catheterisation. *Br J Urol* 1993; **72**: 169–172.
- 14 Stover S. *Spinal cord injury. The facts and figures.* Birmingham: University of Alabama.
- 15 Diokno A. Urological management of tetraplegic patients. *Spinal Cord* 1999; **37**: 1–5.
- 16 Kaplan SA, Chancellor MB, Blavias JG. Bladder and sphincter behaviour in patients with spinal cord lesions. *J Urol* 1991; **146**: 113–117.
- 17 Opitz JL. Treatment of voiding dysfunction in spinal cord injured patient: Bladder retraining. In: Barrett DM, Wein AJ (eds). *Controversies in neuro-urology*. New York: Churchill-Livingston, 1984, pp 437–451.
- 18 Barbaiaas GA, Klaubert GT, Blavias JG. Critical evaluation of the Credé manoeuvre: a urodynamic study of 207 patients. *J Urol* 1983; **130**: 720–723.
- 19 Warren JW. Catheter-Associated Urinary Tract Infections. *Inf Dis Clin N Am* 1987; **1**: No 24.
- 20 Haley R *et al.* The nationwide nosocomial infection rate: a new need for vital statistics. *Am J Epidemiol* 1985; **121**: 159–167.
- 21 Sullivan NM *et al.* Clinical aspects of bacteremia after manipulation of the genitourinary tract. *J Infect Dis* 1973; **127**: 49–55.
- 22 Gordon D *et al.* Diagnostic criteria and natural history of catheter-associated urinary tract infections after prostatectomy. *Lancet* 1983; **1**: 1269–1271.
- 23 Bryan C, Reynolds K. Hospital-acquired bacteremic urinary tract infection: Epidemiology and outcome. *J Urol* 1984; **132**: 494–498.
- 24 Platt R, Polk BF, Murdock B, Rosner B. Mortality associated with nosocomial urinary tract infection. *N Engl J Med* 1982; **307**: 637.
- 25 Warren JW *et al.* Fever, bacteremia and death as complications of bacteriuria in women with long term urethral catheters. *J Infect Dis* 1987; **155**: 1151–1158.
- 26 Tribe CR, Silver JR. *Renal failure in Paraplegia*. London: Pitman Medical Publishing Co. 1969.
- 27 Barton CH, Vaziri ND, Gordon S, Tiles S. Renal pathology in end stage renal disease associated with paraplegia. *Paraplegia* 1984; **22**: 31–41.
- 28 Vaziri ND. Pathophysiology of end-stage renal disease in spinal cord injury. *The Mount Sinai J Med* 1993; **60**: No. 4.
- 29 West DA *et al.* The role of chronic catheterisation in the development of bladder cancer in patients with spinal cord injury. *Urology* 1999; **53**: 292–297.
- 30 Chao R, Clowers D, Mayo ME. Fate of upper urinary tract in patients with indwelling catheters after spinal cord injury. *Urology* 1993; **42**: 259–262.
- 31 Dewire DM *et al.* A comparison of the urological complications associated with long-term management of quadriplegics with and without chronic indwelling catheters. *J Urol* 1992; **147**: 1069–1071.
- 32 Kim YH, Bird ET, Priebe M, Boone TB. The role of Oxybutynin in spinal cord injured patients with indwelling catheters. *J Urol* 1997; **158**: 2083–2086.
- 33 Wyndaele JJ. Pharmacotherapy for urinary bladder dysfunction in spinal cord injury patients. *Paraplegia* 1990; **28**: 146–150.
- 34 Scott MB, Morrow JW. Phenoxybenzamine in neurogenic bladder dysfunction after spinal cord injury: II. Autonomic dysreflexia. *J Urol* 1978; **119**: 483–484.
- 35 Perkash I. Efficacy and safety of terazocin to improve voiding in spinal cord injury patients. *J Spinal Cord Med* 1995; **18**: 236–239.
- 36 Das A *et al.* Intravesical capsacin in neurologic impaired patients with detrusor hyperreflexia. *J Sci Med* 1996; **19**: 190–193.
- 37 Brendler CB, Radebaugh LC, Mohler JL. Topical Oxybutynin chloride for relaxation of dysfunctional bladder. *J Urol* 1989; **141**: 1350–1352.
- 38 Chancellor MB, Rivas DA, Staas Jr WE. DDAVP in the urological management of the difficult neurogenic bladder in spinal cord injury. Preliminary report. *Soc J Am Para* 1994; **17**: 165–167.
- 39 Light JK, Scott FB. Use of the artificial urinary sphincter in spinal cord injury patients. *J Urol* 1983; **130**: 1127–1129.
- 40 Engel RME, Schrimmer HKA. Pudendal neurectomy in neurogenic bladder. *J Urol* 1974; **112**: 57–59.
- 41 Chancellor MB *et al.* Multicenter trial in North America of Urolume urinary sphincter prosthesis. *J Urol* 1994; **152**: 924–930.

- 42 Shah NC, Foley SJ, Edhem I, Shah PJ. Use of Memokath temporary urethral stent in the treatment of detrusor-sphincter dyssynergia. *J Endourol* 1997; **11**: 485–488.
- 43 Low AI, McRae PJ. Use of the Memokath for detrusor-sphincter dyssynergia after spinal cord injury—a cautionary tale. *Spinal Cord* 1998; **36**: 39–44.
- 44 Wheeler Jr JS, Walter JS, Chintam RS, Rao S. Botulinum toxin in voiding dysfunction following SCI. *J Spinal Cord Med* 1998; **21**: 227–229.
- 45 Dykstra DD *et al.* Effects of Botulinum A toxin on detrusor-sphincter dyssynergia in spinal cord injury patients. *J Urol* 1988; **139**: 919–922.
- 46 Catz A *et al.* The role of external sphincterotomy in spinal cord lesion. *Spinal Cord* 1997; **35**: 48–52.
- 47 Fontaine E *et al.* Reappraisal of endoscopic sphincterotomy for post-traumatic neurogenic bladder: a prospective study. *J Urol* 1996; **155**: 277–280.
- 48 Perikash I. Modified approach to sphincterotomy in spinal cord injury patients. *Paraplegia* 1976; **13**: 247–260.
- 49 Yang CC, Mayo ME. External sphincterotomy; long term follow-up. *Neurourol Urodynam* 1995; **14**: 24–31.
- 50 Stohrer M *et al.* Bladder autoaugmentation in adult patients with neurogenic voiding dysfunction. *Spinal Cord* 1997; **35**: 456–462.
- 51 Flood HD *et al.* Long-term results and complications using augmentation cystoplasty in reconstructive urology. *Neurourol Urodynam* 1995; **14**: 297–309.
- 52 Mast P *et al.* Experience with augmentation cystoplasty. A review. *Paraplegia* 1995; **33**: 560–564.
- 53 Plancke HR, Delaere KP, Pons C. Indiana pouch in female patients with spinal cord injury. *Spinal Cord* 1999; **37**: 208–210.
- 54 Brindley GS. Long term follow-up of patients with sacral anterior root stimulator implants. *Paraplegia* 1994; **32**: 795–805.
- 55 Van Kerrebroeck PE. The role of electrical stimulation in voiding dysfunction. *European Urology* 1998; **34** (Suppl 1): 27–30.
- 56 FTM063/001-Finotech-Brindley Bladder Controller: Notes for Surgeons and Physicians, 1998.
- 57 Van Kerrebroeck PE *et al.* Results of the treatment of neurogenic bladder dysfunction in spinal cord injury by sacral posterior root rhizotomy and anterior sacral root stimulation. *J Urol* 1996; **155**: 1378–1381.
- 58 Van der Aa HE, Hermens H, Alleman E, Vorsteveld H. Sacral anterior root stimulation for bladder control in patients with a complete lesion of the spinal cord. *Acta Neurochirurgica* 1995; **134**: 88–92.
- 59 Schurch B *et al.* Does sacral posterior rhizotomy suppress autonomic hyper-reflexia? *BJU* 1998; **81**: 73–82.
- 60 Wielink G, Essnik-Bot ML, van Kerrebroeck PE, Rutten FF. Sacral rhizotomies and electrical bladder stimulation in spinal cord injury. Cost effectiveness and the quality of life analysis. Dutch study group on sacral anterior root stimulation. *European Urology* 1997; **31**: 441–446.
- 61 Yeo JD *et al.* Mortality following spinal cord injury. *Spinal Cord* 1998; **36**: 329–336.
- 62 DeVivo M, Stover S, Black K. Prognostic factors for 12-year survival after SCI. *Arch Phys Med Rehabil* 1992; **73**: 156–162.
- 63 Bracken M *et al.* A randomized, controlled trial of methylprednisolone or naloxone in the treatment of acute spinal cord injury. *N Engl J Med* 1990; **322**: 1405–1411.
- 64 Ditunno J, Formal C. Chronic spinal cord injury. *N Engl J Med* 1994; **330**: 550–556.