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ORIGINAL ARTICLE

Morbidity associated with operative management of bladder stones in spinal cord-injured patients

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Study design: Retrospective cohort study of spinal cord-injured (SCI) patients undergoing bladder stone removal operations between 1999 and 2013.

Objectives: To determine the morbidity associated with different operative management of bladder stones in SCI patients.

Setting: National Spinal Injuries Unit, Stoke Mandeville Hospital, UK.

Methods: Data on age, sex, level and Frankel classification of spinal cord injury, method of bladder drainage, method of bladder stone removal, complications and length of stay were collected from patient records. Complication was defined as bladder perforation, sepsis or persistent haematuria. Predictors of complications and length of stay were determined using univariate and multivariate regression analyses.

Results: Overall, 112 consecutive bladder stone removal operations were performed, one open cystolithotomy and 111 transurethral procedures utilising simple washout, stone punch or electrohydraulic lithotripsy (EHL). Of these procedures, 17% (19/112) had complications; 0/11 (0%) following washout, 5/44 (11%) after stone punch, 3/12 (25%) following EHL and 10/26 (38%) after combined procedures using stone punch and EHL. In a multivariate model, patients with a cervical-level injury and those undergoing a combined procedure were significantly more likely to have a complication ($P=0.032$ and $P=0.046$). Length of stay was longer following a complication, the mean was 4.18 days compared with 1.37 days without a complication ($P<0.001$). Controlling complications and age, use of a combined procedure was associated with significantly longer stay than use of stone punch alone.

Conclusion: This study provides important outcome data that should guide operative procedure choice and inform patients about possible risks during consent. It sets a benchmark that other centres can evaluate their outcomes against.

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INTRODUCTION

Urinary tract complications are responsible for a substantial burden of morbidity in spinal cord-injured (SCI) patients.[1] A significant proportion of this is due to urolithiasis. Incidence of stone formation in the upper tract has not reduced over the past 30 years,[2] despite improvements in the urological care of SCI patients, and although some reports suggest that bladder stone formation has decreased, we and others still see a substantial number of bladder stones in those with SCI.[3,4] SCI patients still have a higher prevalence of bladder stone formation when compared with the general population, largely due to urinary stasis, but also as a result of infection secondary to long-term catheterisation and hypercalciuria due to immobilisation.

Bladder stones generally require treatment, as they will simply continue to enlarge if left untreated to the point where open surgery is required, and because they may act as a source of chronic urinary tract infection and bladder outflow obstruction. SCI patients pose a particular challenge because of their multiple comorbidities, skeletal deformities, previous surgeries, urinary diversions and chronic bacteruria.[5] Open cystolithotomy was historically the procedure of choice, offering excellent stone clearance but with high complication rates and associated morbidity. Particularly, large stones may still require an open procedure; however, the majority of bladder stones in SCI patients are now treated as in the general population: transurethrally with stone punch, electrohydraulic lithotripsy (EHL) or holmium YAG laser, percutaneously, or with extracorporeal shock wave lithotripsy (ESWL). The overall complication rate following bladder stone removal in SCI patients is thought to be higher than in the general population;[5] however, there is very limited documentation of the outcomes associated with any of these techniques either in the general population or in SCI patients.

In our centre, the largest spinal injuries unit in the United Kingdom, we have for many years used the stone punch alone or in combination with EHL to fragment stones transurethrally. Surprisingly, when one considers the frequency of bladder stones in people with SCI, the specific morbidity associated with these endoscopic methods in SCI patients has not previously been documented. We investigated immediate post-operative complications following endoscopic stone removal in a consecutive cohort of SCI patients.

MATERIALS AND METHODS

Patients and procedures

A retrospective cohort study was conducted of bladder stone removal operations in SCI patients between 1999 and 2013. Cystolitholapaxy was conducted using either EHL through a 22-Ch cystoscope and/or a 26-Ch

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Mauermeyer stone punch. Antibiotic prophylaxis was administered in all patients in the form of gentamicin at a dose of $3\,mg\,kg^{-1}$ unless urine culture suggested gentamicin resistance (which was rare), in which case an alternative antibiotic based on urine culture was used.

Data on age, sex, level of spinal injury, Frankel classification of SCI, bladder drainage (that is, intermittent self-catheterisation (ISC), long-term urethral or suprapubic catheter (SPC)), method of bladder stone removal, intra-operative or post-operative complications and length of stay were collected from patient records. Complication was defined as bladder perforation, sepsis with positive urine or blood cultures, or persistent haematuria requiring greater than 12-h bladder irrigation or operative washout.

Statistical methods

Univariate and multivariate logistic regression was used to determine predictors of post-operative complication, including age, sex, Frankel classification of SCI, level of SCI, bladder drainage and bladder stone removal method. Similarly, univariate and multivariate linear regression was used to determine predictors of length of stay. Univariate predictors with P-values $\leqslant 0.20$ were considered for inclusion in multivariate analyses. Multivariate models were fitted using stepwise backwards selection using the Akaike information criterion to determine the best fitting model.[6] Robust variance estimates were used to adjust for within patient correlation as some patients had more than one procedure.[7] All analyses were performed using Stata 13.1 (StataCorp, College Station, TX, USA).

RESULTS

A total of 112 consecutive bladder stone removal operations were performed by one surgeon between 1999 and 2013 on 91 patients. Seventy-eight patients had one procedure, nine patients two procedures and two patients had three and five procedures each. No procedures were excluded from the data set. One open cystolithotomy was performed and 111 transurethral procedures; 11 simple washouts, 49 used a Mauermeyer stone punch, 15 EHL and 36 a combination of stone punch and EHL. Across all the procedures, the median (interquartile range) patient age was 44 (30–52) years, 39/122 (35%) of procedures were performed on female patients. Fifteen (14%) procedures were performed on a patient with a cervical-level injury, 87 (78%) on patients with a thoracic-level injury and 9 (8%) on patients with a lumbar-level injury. The level of spinal injury was not recorded in one patient. Most patients' spinal injuries were classified as Frankel grade A (that is, complete neurological injury, no motor or sensory function below level of injury; 68/109, 62%), or B (preserved complete/partial sensation only below level of injury; 34/109, 31%). Data of Frankel grade were not available in three patients. The majority of patients were managed with a suprapubic catheter (102-/112, 91%). The year the operation was performed, age, sex and level of injury, Frankel classification, and bladder drainage did not vary significantly between the operative procedures performed, Table 1. Stone clearance was complete in all cases. Careful visual (cystoscopic) inspection at the end of the procedure was used to confirm the stone-free status of all patients.

Seventeen percent (19/112) of procedures had a post-operative complication (Figure 1). There were no complications associated with simple washout. There were five complications with use of a stone punch: one bladder perforation and four episodes of haematuria. There were three complications following EHL: two cases of sepsis and one of haematuria. Ten complications occurred following the combined use of a stone punch and EHL: five sepsis and five haematuria episodes. The single open cystolithotomy was complicated by post-operative sepsis, and is not considered further in the analysis below.

Age had no impact on the complication rate ($P=0.95$, Table 2). On univariate analysis, there was a nonsignificant trend towards increased complications in men, 19% versus 10% in women, odds ratio 2.11 (95% confidence interval, CI, 0.67–6.62, $P=0.20$). There was

Table 1 Procedures performed and associated demographics

Procedure	*Washout*	*Stone punch*	*EHL*	*Combined*	*Open*	*Total*
n	11	49	15	36	1	112
Year the operation was performed, median (IQR)	2008 (2007–2009)	2007 (2005–2011)	2009 (2004–2010)	2008 (2005–2010)	2007	2008 (2005–2010)
Age, median (IQR)	44 (37–47)	44.5 (27.5–51.5)	40 (36–55)	46 (32–54)	29	44 (30– 52)
Sex						
Females	5 (13%)	16 (41%)	8 (21%)	10 (26%)	0 (0%)	39
Males	6 (8%)	33 (45%)	7 (10%)	26 (36%)	1 (1%)	73
Frankel classification						
A	6 (9%)	31 (46%)	7 (10%)	23 (34%)	1 (1%)	68
B	3 (9%)	13 (38%)	6 (18%)	12 (35%)	0 (0%)	34
C	2 (33%)	2 (33%)	1 (17%)	1 (17%)	0 (0%)	6
D	0 (0%)	1 (100%)	0 (0%)	0 (0%)	0 (0%)	1
Level of injury						
Cervical	2 (13%)	8 (52%)	1 (7%)	4 (27%)	0 (0%)	15
Thoracic	9 (10%)	35 (40%)	13 (15%)	29 (33%)	1 (1%)	87
Lumbar	0 (0%)	5 (56%)	1 (11%)	3 (33%)	0 (0%)	9
Bladder drainage						
Intermittent self-catherisation	0 (0%)	2 (50%)	1 (25%)	1 (25%)	0 (0%)	4
Long-term urethral catheter	0 (0%)	5 (83%)	0 (0%)	1 (17%)	0 (0%)	6
Suprapubic catheter	11 (11%)	42 (41%)	14 (14%)	34 (33%)	1 (1%)	102

Abbreviations: IQR, interquartile range; EHL, electrohydraulic lithotripsy.
Percentages are for row totals. Level of injury was not recorded for one patient and Frankel classification was not recorded for three patients. The was no significant difference in the year the operation was performed, age, sex, Frankel classification, level of injury, or bladder management across the different procedures performed ($P=0.78$, 0.71, 0.37, 0.69, 0.93, 0.70 respectively).

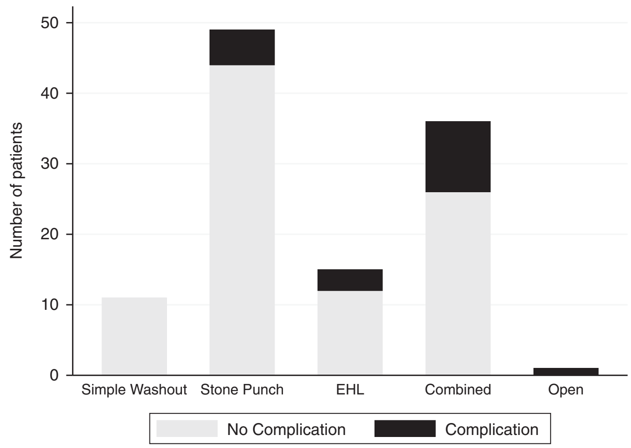

Figure 1 Procedures performed and complication rates. EHL, electrohydraulic lithotripsy. Complications include bladder perforation, sepsis or haematuria requiring further operative washout or >12 h of continuous bladder irrigation and therefore delaying discharge.

Table 2 Univariate predictors of complication

Risk factor	n	*Complications*	%	*Odds ratio (95% confidence interval)*	P
Age, per year of age	—	—	—	1.00 (0.97–1.03)	0.95
Sex					
Female	39	4	10%	1.00 (Reference)	—
Male	72	14	19%	2.11 (0.67–6.62)	0.20
Frankel classification					
A	67	13	19%	1.00 (Reference)	—
B	34	5	15%	0.72 (0.24–2.14)	0.55
C/D	7	0	0%	—	—
Level of injury					
Cervical	15	5	33%	3.08 (0.95–10.0)	0.061
Thoracic	86	12	14%	1.00 (Reference)	—
Lumbar	9	1	11%	0.77 (0.09–6.82)	0.82
Bladder drainage					
Intermittent self-catherisation	4	0	0%	—	—
Long-term urethral catheter	5	1	20%	0.99 (0.11–9.27)	0.99
Suprapubic catheter	84	17	20%	1.00 (Reference)	—
Procedure					
Simple washout	11	0	0%	—	—
Stone punch	44	5	11%	1.00 (Reference)	—
Electrohydraulic lithotripsy	12	3	25%	2.20 (0.48–10.1)	0.31
Combined	26	10	38%	3.38 (1.01–11.4)	0.049

The single open procedure in the data set is excluded. The level of injury was not recorded for a single patient. The Frankel classification was not available for three patients, only a single patient had a Frankel grade D injury. As there were no complications for Frankel grade C and grade D patients, or patients performing intermittent self-catheterisation, it is not possible to calculate an odds ratio for these categories.

moderate statistical evidence that patients with a cervical spine injury were more likely to experience a complication compared with patients with a thoracic injury, 33% versus 14%, odds ratio 3.08 (95% CI 0.95–10.0, $P=0.061$). Patients with lumbar-level injuries had similar complication rates to patients with a thoracic injury, 11% ($P=0.82$). Complication rates did not differ significantly in patients with Frankel grade A injuries, compared with those with grade B injuries ($P=0.55$). There were no complications in the four patients managed with ISC, and no difference in complications between those with a urethral catheter versus an SPC ($P=0.99$). Compared with the use of a stone punch there was no significance difference in the complication rate following EHL, rates of 11% and 25%, respectively ($P=0.31$). However, combined procedures were associated with increased risk of complications, rate 38%, compared with the use of a stone punch alone, 11%, odds ratio 3.38 (1.01–11.4, $P=0.049$). Only the level of injury and the procedure performed remained as predictors of complication in a multivariate model (Table 3). Cervical injury was associated with an odds ratio for complication of 4.52 (95% CI 1.13–18.0, $P=0.033$), and a combined procedure had an odds ratio of 4.02 (95% CI 1.02–15.8, $P=0.046$).

Length of stay data were available for 106 patients. On univariate analysis there was no evidence that age, sex, Frankel classification or level of injury affected the length of stay (Table 4). Patients with an urethral catheter had shorter length of stay ($P=0.06$ in the univariate analysis compared with patients with an SPC); however, this was not significant in a multivariate analysis. Length of stay was longer following a complication, mean (s.d.) was 4.18 (2.63) days compared with 1.37 (0.91) days without a complication ($P<0.001$). Total length of stay was shortest following a simple washout, 1.18 (0.87) days. There was no significant difference in the length of stay following a stone punch only procedure, 1.40 (1.17) days, compared with a simple washout ($P=0.51$). Use of EHL was associated with an increase in the length of stay to 2.08 (0.86) days ($P=0.029$ compared with stone punch), as was a combined procedure, length of stay 2.49 (2.34) days ($P=0.018$, compared with stone punch alone). In the multivariate analysis, the presence of a complication extended the length of stay by 2.63 days (95% CI 1.43–3.83, $P<0.001$) (Table 5). After controlling for the presence of complications and age, use of a combined procedure was associated with significantly longer stay than the use of stone punch alone, 0.78 (95% CI 0.09–1.48, $P=0.028$) extra days. There was a nonsignificant trend towards increased length of stay with EHL compared with stone punch, 0.31 (95% CI −0.15–0.76, $P=0.19$) extra days. As this multivariate analysis controls for the presence of

Table 3 Multivariate predictors of complication

Risk factor	*Odds ratio (95% CI)*	P
Level of injury		
Cervical	4.53 (1.13–18.0)	0.032
Thoracic	1.00 (Reference)	—
Lumbar	0.74 (0.09–6.24)	0.78
Procedure		
Simple washout	—	—
Stone punch	1.00 (Reference)	—
EHL	2.77 (0.57–13.5)	0.21
Combined	4.02 (1.02–15.8)	0.046

Abbreviations: CI, confidence interval; EHL, electrohydraulic lithotripsy.
The single open procedure in the data set is excluded. The level of injury was not recorded for a single patient. Age and sex were excluded from the final model by backwards selection.

Table 4 Univariate predictors of length of stay

Risk factor	n	*Length of stay, mean (s.d.)*	*Regression coefficient (95% confidence interval)*	P
Age, per year of age	—	—	0.013 (−0.007–0.033)	0.20
Sex				
Female	36	1.64 (1.15)	0.00 (Reference)	—
Male	70	1.91 (1.89)	0.27 (−0.36–0.91)	0.39
Frankel classification				
A	66	1.71 (1.40)	0.00 (Reference)	—
B	30	2.03 (2.37)	0.32 (−0.62–1.26)	0.50
C/D	7	2.00 (0.58)	0.29 (−0.26–0.84)	0.30
Level of injury				
Cervical	15	1.67 (1.68)	−0.16 (−1.00–0.68)	0.71
Thoracic	81	1.83 (1.72)	0.00 (Reference)	—
Lumbar	9	2.11 (1.54)	0.28 (−0.77–1.34)	0.60
Bladder drainage				
Intermittent self-catherisation	4	1.50 (0.58)	−0.38 (−1.00–0.25)	0.24
Long-term urethral catheter	5	1.00 (1.00)	−0.88 (−1.78–0.03)	0.06
Suprapubic catheter	97	1.88 (1.73)	0.00 (Reference)	—
Complication				
Present	17	1.37 (0.91)	2.81 (1.54–4.07)	<0.001
Not present	89	4.18 (2.63)	0.00 (Reference)	—
Procedure				
Simple washout	11	1.18 (0.87)	−0.22 (−0.90–0.45)	0.51
Stone punch	47	1.40 (1.17)	0.00 (Reference)	—
Electrohydraulic lithotripsy	13	2.08 (0.86)	0.67 (0.07–1.27)	0.029
Combined	35	2.49 (2.34)	1.08 (0.19–1.97)	0.018

The single open procedure in the data set is excluded and length of stay data were available for 106 patients. The level of injury was not recorded for a single patient. Frankel classification was not available for three patients, only a single patient had a Frankel grade D injury.

complications, the reported additional length of stay for each procedure is the additional length of stay mediated by effects other than complications. To assess the total contribution of procedure choice to length of a stay (including any effect mediated by complications), a further analysis was undertaken without including the presence of a complication as a variable in the multivariate model. In this analysis, use of a stone punch was not associated with significantly longer length of stay than a simple washout ($P=0.47$); however, EHL was associated with an additional length of stay of 0.63 (95% CI 0.02–1.24, $P=0.045$) days compared with the use of the a stone punch, and a combined procedure with 1.03 (95% CI 0.11–1.95, $P=0.029$) additional days.

DISCUSSION

Our study is the first of its kind to describe the immediate post-operative complication rates associated with different endoscopic techniques for bladder stone removal in SCI patients and we hope it will form a benchmark against which other surgeons and centres may

Table 5 Multivariate predictors of length of stay

Risk factor	*Regression coefficient (95% confidence interval)*	P
Age, per year of age	0.008 (−0.006–0.23)	0.26
Complication		
Present	2.63 (1.43–3.83)	<0.001
Not present	0.00 (Reference)	—
Procedure		
Simple washout	0.05 (−0.57–0.67)	0.87
Stone punch	0.00 (Reference)	—
Electrohydraulic lithotripsy	0.31 (−0.15–0.76)	0.19
Combined	0.78 (0.09–1.48)	0.028

The single open procedure in the data set is excluded and length of stay data were available for 106 patients. The level of injury was not recorded for a single patient. Patient sex and level of injury were excluded from the final model.

assess their outcome data. We demonstrate that the overall complication rate following endoscopic transurethral bladder stone fragmentation in SCI patients is substantial (17%; 19/112). Despite the routine use of peri-operative antibiotic prophylaxis, the main complications were sepsis and also persistent haematuria.

We show a clear increase in the risk of complications following combined use of stone punch and EHL versus a single method. This difference remains significant after accounting for year in which the operation was performed, age, sex, bladder drainage, Frankel classification and the level of spinal injury. Patients with cervical-level injury are also at increased risk of complication, regardless of the operative method used. This may be due in part to the increased comorbidities present in this group. Only the level of injury and procedure performed remained as predictors of complication in a multivariate model.

Combined procedures may carry more risk of complications as the requirement for a combined procedure may be a marker of more severe stone disease. However, some of the increased risks of complications may be determined by the use of EHL as part of a combined procedure. It is well recognised that EHL has the narrowest margin of safety of the various lithotripsy options because the shock wave generated by the EHL device may cause some degree of collateral bladder mucosal damage, increasing the risk of complications.[8] There is some support for this in the comparisons between use of stone punch or EHL alone. Although not statistically significant, the point estimates for the odds ratios for complications with EHL alone, compared with a stone punch alone were 2.2 in the univariate model, and 2.8 in the multivariate model ($P=0.31$ and 0.21, respectively). Given the wide CIs associated with these results, larger studies with greater statistical power are required to confirm this hypothesis.

Alternative forms of lithotripsy are available to SCI patients. ESWL poses difficulties with the drainage of stone fragments that are generated. One study reported ESWL to be effective in SCI patients, with no major complications when combined with urethral drainage with a sheath.[9] The lower reported complication rates associated with ESWL, when compared with the complication rates in our study, may be a result of selection bias as patients with a lower burden of smaller stones are more likely to be offered ESWL.

The advent of the Holmium laser for treating ureteric and renal stones has provided a method of fragmentation that has lower risk of mucosal injury and bladder perforation than EHL and traditional mechanical lithotripsy[10] and, most likely, the stone punch. Holmium laser was not available in our centre at the time of this study; however, in 2014 we are using this technique increasingly for stones too large to engage in the jaws of the Mauermeyer punch. Further studies comparing the complications associated with various lithotripsy methods and holmium laser in an SCI cohort are required to draw firm conclusions.

In addition to the clear morbidity associated with post-operative complications, such as sepsis, the length of stay associated with different procedures is also of importance to patients, health-care professionals and hospitals. As might be expected, presence of complication was the main predictor of increased length of stay; however, there is also some evidence that using a combined procedure increased length of stay, even after controlling for age and the presence of complication. Use of a combination of procedures to fragment bladder stones therefore increases the morbidity associated with bladder stone removal through both greater risk of complication and increased length of stay.

Limitations of our study include its retrospective nature and the inclusion of data from only one surgeon and centre. However, it incorporates patients with a range of Frankel grades of injury, all levels of SCI and a range of ages therefore representing a cohort typical of a major national spinal injuries centre. The data we present describe the immediate post-operative complications associated with bladder stone removal but we do not have data regarding long-term complications, particularly urethral stricture. Our data on the need for repeat procedures are limited to those conducted at our centre; 14 patients in our cohort of 91 patients, recorded over a 14-year-time period, required more than one procedure.

We were unable to determine whether individuals with low compliance bladders were at greater risk of complications, where conceivably lack of 'space' within the bladder for manipulating the stone during endoscopic treatment could feasibly increase the risk of bladder perforation or of mucosal damage leading to post-operative haematuria. This is because the majority of patients in our study were managed with an SPC, and therefore there was no indication for urodynamics to be performed. The single patient with a bladder perforation had an SPC and underwent a stone punch procedure.

We did not routinely analyse the composition of the removed stones on the assumption that the majority were infection-related in aetiology (given that the majority of patients were managed with a long-term catheter and hence were very likely to have some degree of chronic bacterial colonisation of the bladder). Thus, we cannot determine whether there is an association between stone composition and complication rate.

We, in Ord *et al.*,[11] along with others[4] have shown that efficient bladder drainage with ISC reduces the risk of bladder stone formation. ISC is not possible for every patient and many still require bladder management with an indwelling urethral or SPC, which carries greater risk of stone formation.[3,4,11] Patients who opt for long-term catheterisation must be made aware that their risk of bladder stone formation is substantial when compared with ISC or condom sheath drainage combined with sphincterotomy and that they will therefore potentially be exposed in future years to a degree of morbidity from bladder stone removal.

In conclusion, this study provides important outcome data that should help decide on operative procedure choice and inform patients about possible risk during the consent process. It sets a benchmark that other centres can evaluate their outcomes against.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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