



Changes in the Trend in Bladder Emptying Methods in Patients With Spinal Cord Injury: A 20-Year Single-Center Retrospective Study

Sang-Wook Oh, MD, Joo Hwan Jung, MD, In Kyoung Cho, MD, Hye Jin Lee, MD,
Seung Hyun Kwon, MD, Bum Suk Lee, MD, MPH

Department of Rehabilitation Medicine, National Rehabilitation Center, Seoul, Korea

Objective To review trends in bladder emptying methods over a 20-year period in patients with spinal cord injury (SCI) by severity according to the American Spinal Injury Association impairment scale (AIS).

Methods Medical records of patients with SCI from 1994 to 1998 (group 1) and from 2012 to 2016 (group 2) were retrospectively reviewed. We classified bladder emptying methods according to the International Spinal Cord dataset. We grouped patients with normal voiding, bladder reflex triggering, and bladder expression as those using voiding without catheter.

Results A total of 667 patients were included in the analysis. The proportion of patients using voiding without catheter and intermittent catheterization decreased from 67.0% to 30.0% and increased from 26.8% to 54.8%, respectively. In patients with AIS-A and AIS-B, the proportion of patients with intermittent catheterization increased from 32.8% to 73.3%. In patients with AIS-D, the proportion of patients using voiding without catheter and intermittent catheterization decreased from 88.5% to 68.9% and increased from 11.5% to 26.8%, respectively. In group 2, among 111 patients with AIS-D using voiding without catheter at admission, 8 (7.2%) switched to intermittent catheterization at discharge due to decreased bladder volume, increased post-voiding residual urine, or incontinence.

Conclusion Over the past 20 years, trends in bladder emptying methods in patients with SCI changed from voiding without catheter to intermittent catheterization in Korea. This was especially prominent in patients with AIS-A, AIS-B, and AIS-C. Even in patients with AIS-D, the use of intermittent catheterization at hospital discharge increased.

Keywords Spinal cord injuries, Urinary catheterization, Neurogenic bladder

Received August 2, 2019; Revised September 2, 2019; Accepted October 23, 2019; Published online June 30, 2020

Corresponding author: Bum Suk Lee

Department of Rehabilitation Medicine, National Rehabilitation Center, 58-Samgaksan-ro, Gangbuk-gu, Seoul 01022, Korea. Tel: +82-2-901-1886, Fax: +82-2-902-3835, E-mail: iambs@korea.kr

ORCID: Sang-Wook Oh (<https://orcid.org/0000-0001-9493-5277>); Joo Hwan Jung (<https://orcid.org/0000-0003-2329-6812>); In Kyoung Cho (<https://orcid.org/0000-0002-8413-7498>); Hye Jin Lee (<https://orcid.org/0000-0001-9400-6283>); Seung Hyun Kwon (<https://orcid.org/0000-0001-8700-6306>); Bum Suk Lee (<https://orcid.org/0000-0002-0506-0403>).

© This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted noncommercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
Copyright © 2020 by Korean Academy of Rehabilitation Medicine

INTRODUCTION

Most patients with spinal cord injury (SCI) have neurogenic lower urinary tract dysfunction (NLUTD), which may continuously pose medical, physical, and social challenges. For this reason, proper bladder management to prevent secondary complications is very important in patients with SCI [1-3].

NLUTD due to SCI can cause urinary tract infection (UTI), urinary stones, and renal impairment. To prevent such complications, it is important to perform periodic urodynamic studies (UDS) and maintain appropriate bladder pressure and capacity by choosing an appropriate bladder emptying method [4-8].

The management of neurogenic bladder has evolved in recent decades. After World War II, an indwelling catheter was commonly used because of its easy application [9], where as normal voiding, reflex voiding, and expression voiding were commonly used in patients not using an indwelling catheter. According to two Korean studies, between the 1980s and 1990s, the proportion of patients using voiding without catheter was 82.8% to 86.6%, the proportion of patients with indwelling catheter was 2.5% to 8.6% and the proportion of patients with intermittent catheterization was about 8% [10,11]. However, since the 1990s, indwelling catheter and voiding without catheter have been replaced by intermittent catheterization, as this technique leads to fewer upper urinary tract complications and higher patient satisfaction [4,5,12,13]. Since the mid-1990s, many rehabilitation hospitals in Korea, including our own center, have started to recommend intermittent catheterization as the first approach for bladder management. Thus, active patient education has enabled more patients to select intermittent catheterization. However, there has been a lack of studies on the changes in bladder emptying methods used in patients with SCI in Korea.

In addition, previous studies reported differences in bladder emptying methods according to the American Spinal Injury Association impairment scale (AIS), which are also associated with the somatic nerve recovery of bladder function [3,14,15]. However, to our knowledge, no study has addressed bladder emptying methods according to the AIS classification in Korea.

Additionally, because hand function in tetraplegia patients is frequently impaired, a different study reported

differences in bladder emptying methods according to the level of injury (tetraplegia vs. paraplegia) [2].

Thus, in this study, we aimed to retrospectively analyze changes in the trend in bladder emptying methods according to the severity of injury in patients with SCI over the last 20 years in Korea.

MATERIALS AND METHODS

Patients and study design

This retrospective study was approved by the Institutional Review Board at the National Rehabilitation Center (No. NRC-2018-03-017) and included patients with SCI at a single center in Korea. Due to the retrospective nature of the study, the requirement for informed consent was waived. We retrospectively reviewed the medical records of patients with SCI admitted to the center between 1994 and 1998 (group 1) and between 2012 and 2016 (group 2). Among these patients, those aged 15 years or more and admitted within 2 years of the onset of injury were considered eligible to participate in the study. Patients with no or unclear information about AIS and bladder emptying methods were excluded from the final data. All patients were examined according to the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) guidelines. Collected data included sex, level of injury (tetraplegia/paraplegia), severity of the injury (AIS grade A, B, C, or D), length of hospital stay, duration of injury at admission, and bladder emptying method at admission and at discharge.

Bladder emptying methods

From medical records, we collected information on bladder emptying methods at admission and discharge from our center. Bladder emptying methods were categorized according to the International Spinal Cord dataset recommended by the International Spinal Cord Society (ISCoS) in 2018. In this study, we grouped patients according to normal voiding, bladder reflex triggering (voluntary/involuntary), and bladder expression (straining/external compression) as those who used voiding without catheter. Twenty years ago, the International Spinal Cord datasets regarding bladder emptying methods were not available, and patients with SCI often used a combination of bladder emptying methods. Thus, it was difficult to accurately classify bladder emptying methods according to

the International Spinal Cord dataset recommended by ISCoS. For this reason, we used voiding without catheter to classify patients in this study. Consequently, we categorized bladder emptying methods into four groups—voiding without catheter, intermittent catheterization, urethral indwelling catheter, and suprapubic indwelling catheter.

Statistical analysis

All statistical analyses were performed with SPSS version 20.0 (IBM SPSS Inc., Armonk, NY, USA). The level of statistical significance was set at $p < 0.05$. Data are presented as means \pm standard deviations for continuous variables and as percentages for categorical parameters. We used the paired t-test to test for differences in length of hospital stay and the chi-square test for other demographic factors. Chi-square tests were also used for comparing changes in bladder emptying methods over time between the two groups.

RESULTS

Demographics

From 1994 to 1998 (group 1) and from 2012 to 2016 (group 2), 944 patients with SCI were admitted to our center. A total of 667 patients, 194 in group 1 and 473 in group 2, met the study criteria and were thus included in the study (Table 1).

The mean age was 32.8 ± 11.9 years (range, 15–69 years) in group 1 and 49.1 ± 15.9 years (range, 15–84 years) in group 2. Men comprised 77.4% of group 1 and 71.2% of group 2. Patients with tetraplegia comprised 49.7% of group 1 and 47.8% of group 2. The severity of injury was evaluated using AIS. AIS grade A was found in 51.0% of group 1 and 31.5% of group 2.

Compared to group 1, patients in group 2 had a significantly higher severity of injury, a higher non-traumatic rate, were older, had longer length of hospital stay, and had a shorter duration of injury at admission.

Changes in the trend in bladder emptying methods at discharge

Changes in the trend in bladder emptying methods at

Table 1. Characteristics of the patients (n=667)

Demographic factors	Group 1 (n=194)	Group 2 (n=473)	p-value
Sex			0.109
Male	150 (77)	337 (71)	
Female	44 (23)	136 (29)	
Level of injury			0.602
Tetraplegia	97 (50)	226 (48)	
Paraplegia	97 (50)	247 (52)	
AIS			0.001
A	99 (51)	149 (32)	
B	36 (19)	68 (14)	
C	33 (17)	92 (19)	
D	26 (13)	164 (35)	
Etiology			0.001
Trauma	182 (94)	340 (72)	
Others	12 (6)	133 (28)	
Age (yr)	32.8 ± 11.9	49.1 ± 15.9	0.001
Length of hospital stay (day)	70.6 ± 20.6	93.3 ± 30.1	0.001
Duration of injury at admission (day)	376.5 ± 188.3	173.0 ± 151.3	0.001

Values are presented as number (%) or mean \pm standard deviation.

Group 1, patients admitted from 1994 to 1998; Group 2, patients admitted from 2012 to 2016; AIS, American Spinal Injury Association impairment scale.

discharge were analyzed by comparing group 1 (1994–1998) and group 2 (2012–2016). There was a significant change in the proportion of patients using different bladder emptying methods between group 1 and group 2 ($p=0.001$) (Table 2, Fig. 1).

The proportion of patients using voiding without catheter decreased over time from 67.0% in group 1 to 30.0% in group 2. The proportion of patients with intermittent catheterization increased over time from 26.8% in group 1 to 54.8% in group 2 (Fig. 1A).

We also analyzed data according to injury severity. Among patients with AIS-A and AIS-B, the proportion of those using voiding without catheter decreased from 61.9% to 3.7%. The proportion of patients with intermittent catheterization increased from 32.8% to 73.3% (Fig. 1B). In patients with AIS-C, the proportion of those using voiding without catheter decreased from 70.6% to 22.8%, and the proportion of those with intermittent catheterization increased from 14.7% to 60.9% (Fig. 1C). Similar trends were observed in AIS-A and AIS-B. However, in patients with AIS-D, the proportion of those using voiding without catheter decreased from 88.5% to 68.9%, and the proportion of those with intermittent catheteriza-

tion increased from 11.5% to 26.8%. In patients with AIS-D in group 1, only 11.5% of patients used intermittent catheterization, and no patients used indwelling catheter at discharge. In contrast, in patients with AIS-D in group 2, 31.1% of patients used intermittent catheterization (26.8%) or indwelling catheter (4.3%) at discharge. Voiding without catheter was still the most frequently used method in AIS-D (Fig. 1D). There were significant changes in bladder emptying methods in all AIS grades between group 1 and group 2 (Fig. 1).

Changes in the trend in bladder emptying methods from admission to discharge according to severity of injury

Changes in the trend in bladder emptying methods were analyzed by comparing patient status at admission and at discharge (Table 2).

In patients with AIS-A and AIS-B in group 1, the proportion of those using voiding without catheter decreased from 67.9% at admission to 61.9% at discharge, while the proportion of those with intermittent catheterization increased from 20.9% to 32.8% at discharge. In contrast, the proportion of patients with indwelling catheter decreased

Table 2. Bladder emptying method at admission and discharge by AIS grade

		AIS	VWC	IC	UC	SPC
Group 1 (n=194)	At admission	Total	139 (71.6)	35 (18.0)	10 (5.2)	10 (5.2)
		A,B	91 (67.9)	28 (20.9)	10 (7.5)	5 (3.7)
		C	26 (76.5)	3 (8.8)	0 (0)	5 (14.7)
		D	22 (84.6)	4 (15.4)	0 (0)	0 (0)
	At discharge	Total	130 (67.0)	52 (26.8)	5 (2.6)	7 (3.6)
		A,B	83 (61.9)	44 (32.8)	4 (3.0)	3 (2.3)
		C	24 (70.6)	5 (14.7)	1 (2.9)	4 (11.8)
		D	23 (88.5)	3 (11.5)	0 (0)	0 (0)
Group 2 (n=473)	At admission	Total	155 (32.8)	168 (35.5)	122 (25.8)	28 (5.9)
		A,B	17 (7.8)	106 (48.9)	72 (33.2)	22 (10.1)
		C	27 (29.3)	36 (39.1)	26 (28.3)	3 (3.3)
		D	111 (67.7)	26 (15.9)	24 (14.6)	3 (1.8)
	At discharge	Total	142 (30.0)	259 (54.8)	40 (8.4)	32 (6.8)
		A,B	8 (3.7)	159 (73.3)	25 (11.5)	25 (11.5)
		C	21 (22.8)	56 (60.9)	12 (13.0)	3 (3.3)
		D	113 (68.9)	44 (26.8)	3 (1.8)	4 (2.5)

Values are presented as number (%).

Group 1, patients admitted from 1994 to 1998; Group 2, patients admitted from 2012 to 2016; AIS, American Spinal Injury Association impairment scale; VWC, voiding without catheter; IC, intermittent catheterization; UC, urethral indwelling catheter; SPC, suprapubic indwelling catheter.

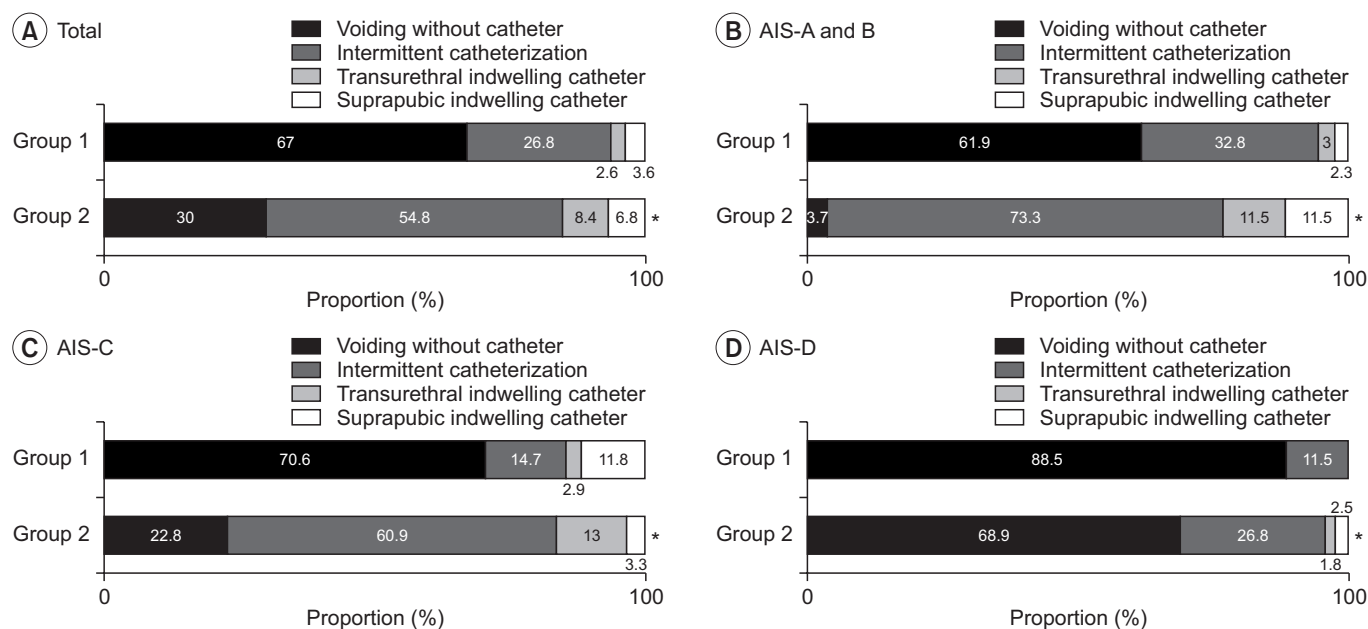


Fig. 1. Bladder emptying method at discharge. (A) Bladder emptying method at discharge in total patients. (B) Bladder emptying method at discharge in patients with AIS-A and AIS-B. (C) Bladder emptying method at discharge in patients with AIS-C. (D) Bladder emptying method at discharge in patients with AIS-D. Group 1, patients admitted from 1994 to 1998; Group 2, patients admitted from 2012 to 2016; American Spinal Injury Association impairment scale. * $p < 0.05$.

from 11.2% to 5.3% at discharge.

In patients with AIS-A and AIS-B in group 2, the proportion of those using voiding without catheter decreased from 7.8% at admission to 3.7% at discharge. The proportion of those with intermittent catheterization increased from 48.9% to 73.3% at discharge, whereas the proportion of those with indwelling catheter decreased from 43.3% to 23% at discharge.

In patients with AIS-C in group 1, the proportion of those using voiding without catheter decreased from 76.5% at admission to 70.6% at discharge, while the proportion of patients with intermittent catheterization increased from 8.8% to 14.7% at discharge. Finally, the proportion of patients with indwelling catheter was 14.7% at both admission and discharge.

In patients with AIS-C in group 2, the proportion of those using voiding without catheter decreased from 29.3% at admission to 22.8% at discharge. The proportion of those with intermittent catheterization increased from 39.1% to 60.9% at discharge, whereas the proportion of those with indwelling catheter decreased from 31.6% to 16.3% at discharge.

In patients with AIS-D, from admission to discharge, the proportion of those using intermittent catheterization

decreased in group 1 but increased in group 2.

In patients with AIS-D in group 1, the proportion of those using voiding without catheter slightly increased from 84.6% at admission to 88.5% at discharge and the proportion of those using intermittent catheterization decreased from 15.4% to 11.5%. In patients with AIS-D in group 2, the proportion of those using voiding without catheter slightly increased from 67.7% at admission to 68.9% at discharge. From admission to discharge, the proportion of those with intermittent catheterization increased from 15.9% to 26.8%, whereas the proportion of patients with indwelling catheter decreased from 16.4% to 4.3%.

Switch in bladder emptying methods during hospitalization in patients with AIS-D

Switches in bladder emptying methods in patients with AIS-D were analyzed by following up patient status at admission and discharge (Table 3).

There were no patients with AIS-D in group 1 who switched from voiding without catheter to intermittent catheterization during hospitalization. However, in patients with AIS-D in group 2, 8 (7.2%) out of 111 patients switched from voiding without catheter to intermittent

Table 3. Switch of bladder emptying method between time of admission and discharge in patients with AIS-D

At admission		n	At discharge		n
Group 1 (n=26)	Voiding without catheter	22	Voiding without catheter	22	
	Intermittent catheterization	4	Intermittent catheterization	3	
Group 2 (n=164)	Voiding without catheter	111	Voiding without catheter	103	
			Intermittent catheterization	8	
	Intermittent catheterization	26	Intermittent catheterization	20	
			Voiding without catheter	4	
	Urethral indwelling catheter	24	Urethral indwelling catheter	1	
			Suprapubic indwelling catheter	1	
			Intermittent catheterization	15	
			Voiding without catheter	6	
			Urethral indwelling catheter	2	
			Suprapubic indwelling catheter	1	
Suprapubic indwelling catheter	3	Suprapubic indwelling catheter	2		
		Intermittent catheterization	1		

Group 1, patients admitted from 1994 to 1998; Group 2, patients admitted from 2012 to 2016; AIS-D, American Spinal Injury Association impairment scale grade D.

Table 4. Changes in the trend in bladder emptying method by level of injury over the study period at discharge

Bladder emptying method	Tetraplegia			Paraplegia		
	Group 1 (n=97)	Group 2 (n=226)	p-value	Group 1 (n=97)	Group 2 (n=247)	p-value
Voiding without catheter	69 (71.1)	70 (31.1)	0.001	61 (62.9)	72 (29.0)	0.001
Intermittent catheterization	23 (23.7)	103 (45.8)		29 (29.9)	156 (62.9)	
Urethral indwelling catheter	1 (1.0)	28 (12.4)		4 (4.1)	12 (4.8)	
Suprapubic indwelling catheter	4 (4.1)	24 (10.7)		3 (3.1)	8 (3.2)	

Values are presented as number (%).

Group 1, patients admitted from 1994 to 1998; Group 2, patients admitted from 2012 to 2016.

catheterization during hospitalization. According to the medical records of these 8 patients, 4 had small bladder volume (<300 mL), 4 had substantial residual urine (>200 mL), 1 had high detrusor pressure above 40 cmH₂O (>68 cmH₂O), 1 had low compliance below 10 mL/cmH₂O (2.8 mL/cmH₂O), 1 had uncontrolled incontinence, and 1 had urgency. All 8 patients switched from voiding without catheter to intermittent catheterization for one or more reasons.

Comparison of bladder emptying methods between patients with tetraplegia and paraplegia at discharge

To analyze the impact of the level of injury, we analyzed patients with tetraplegia and paraplegia separately. There

was a significant difference in bladder emptying methods at discharge between groups ($p=0.001$) in both patients with tetraplegia and paraplegia.

In patients with tetraplegia, the proportion of those using voiding without catheter at discharge decreased from 71.7% to 31.1%, the proportion of those with intermittent catheterization increased from 23.7% to 45.8%, and the proportion of those with indwelling catheter increased from 5.1% to 23.1% (urethral, 12.4%; suprapubic, 10.7%) over the last 20 years. In patients with paraplegia, the proportion of those using voiding without catheter at discharge decreased from 62.9% to 29.0%, the proportion of those with intermittent catheterization increased from 29.9% to 62.9%, and the proportion of those with indwell-

ing catheter increased from 7.2% to 8.0% over the last 20 years (Table 4).

DISCUSSION

Changes in the trend in bladder emptying methods over the study period

Very few studies have investigated changes in the trend in bladder emptying methods in recent decades in Korea. Up to the mid-1990s, patients with SCI mainly used percussion, Valsalva, or Crede methods in Korea and used a condom urine bag and vinyl urine sheath (Fig. 2) as collecting devices. Management by intermittent catheterization was rare, including at our center [10,11].

A study conducted in two United Kingdom spinal cord centers over a 20-year period, beginning in 1990, reported that the proportion of patients with intermittent catheterization increased from 4% to 18.8% and that the sum of voluntary control, straining/expression, and condom drainage, which is equivalent to the use of “voiding without catheter”, decreased from 82.3% to 50.6%. Further, the proportion of patients using indwelling catheters increased from 8.8% to 25.9% over this period, while the proportion of patients using indwelling urethral catheter did not differ significantly, increasing only from 6.3% to 10.6%. The use of a suprapubic indwelling catheter increased significantly from 2.5% to 15.3% [16].

In addition, from a national database containing bladder emptying methods data from 1972 to 2005 in the United States [17], the proportion of patients with intermittent catheterization increased from 12.6% between

1972 and 1975 to 49.6% between 2001 and 2006. Conversely, the proportion of those using condom catheters steadily decreased from 34.6% between 1972 and 1975 to 1.5% between 2001 and 2006. Meanwhile, the use of an indwelling catheter initially decreased from 33.1% between 1972 and 1975 to 16.5% between 1991 and 1995 but increased to 23.1% between 2001 and 2006.

Hansen et al. [18] reported that the proportion of patients with intermittent catheterization increased from 26% at discharge to 44% at follow-up after 10 or more years. Intermittent catheterization is currently the most commonly used method in Denmark.

Over the last 20 years at our center, the proportion of patients using voiding without catheter decreased dramatically from 67.0% to 30.0%, and the proportion of those with intermittent catheterization increased from 26.8% to 54.8%. This may be because, after the mid-1990s, many studies on the safety of intermittent catheterization were published, and intermittent catheterization was recommended as the treatment of choice for bladder emptying management [19]. Thus, due to the risk of upper urinary tract impairment, the percussion, Valsalva, and Crede methods used in the mid-1990s were no longer recommended [13]. Hence, all patients at our center underwent UDS within 3 months of admission, and we have actively recommended the use of intermittent catheterization since the mid-1990s. This treatment protocol might explain the differences between group 1 and group 2. Conversely, the proportion of those with indwelling catheters increased from 6.2% to 15.2% over the last 20 years.

Changes in the trend in bladder emptying methods according to severity of injury (AIS)

To our knowledge, there has been no study on the differences in bladder emptying management according to severity of injury (AIS) in Korea. In a 2012 Japanese study, the proportions of patients with AIS-B using the bladder emptying methods voiding without catheter, intermittent catheterization, and indwelling catheter were reported to be 13%, 26.1%, and 60.9%, respectively, whereas patients with AIS-C and AIS-D showed corresponding percentages of 37.8%, 34.5%, and 27.7% and 80.2%, 13.2%, and 6.6%, respectively. Only patients with AIS-D used voiding without catheter in over 50% of cases [3].

Furthermore, ischemic patients with SCI classified



Fig. 2. Vinyl urine sheath used as a collecting device.

as AIS-D may have fewer urodynamic abnormalities and a greater possibility of having normal voiding [20]. Similarly, our center also showed differences in bladder emptying methods, which varied according to the severity of injury (AIS). Intermittent catheterization was more prominent in patients with AIS-A, AIS-B, and AIS-C. Conversely, in patients with AIS-D, voiding without catheter was the most frequently used bladder emptying method (68.9%). However, 31.1% of patients still used intermittent or indwelling catheter at discharge.

A Japanese study comparing bladder emptying methods at patient admission and discharge found that the use of intermittent catheterization increased at discharge. A comparison between bladder emptying methods at admission and discharge from 2003 to 2009 in a Japanese hospital [3] indicated that the proportion of intermittent catheterization use, voiding without catheter use, and indwelling catheter use at admission were 8.1%, 42.7%, and 49.2%, respectively, whereas the rates at discharge were 22.7%, 57.2%, and 20.1%, respectively. Thus, the proportion of patients using an indwelling catheter decreased, while the proportion of patients with intermittent catheterization increased at discharge.

This trend is in line with the trends observed in our study, except for the proportion of patients using “voiding without catheter”. In our study, in patients with AIS-A, AIS-B, and AIS-C in group 2, the use of indwelling catheter and voiding without catheter decreased, whereas the use of intermittent catheterization increased at discharge. However, in patients with AIS-D in group 2, the use of voiding without catheter and intermittent catheterization increased, while the use of indwelling catheter decreased at discharge compared to that used at admission. The reason for the differences between patients with AIS-A, AIS-B, and AIS-C and patients with AIS-D may be that due to low urodynamic abnormality exhibited by patients with AIS-D many patients continue to use voiding without catheter [20]. However, even in patients with AIS-D, some patients switched from voiding without catheter to intermittent catheterization at discharge. Among patients with AIS-D in group 2, 8 (7.2%) out of 111 patients switched from voiding without catheter to intermittent catheterization as the bladder emptying method during hospitalization.

Lee recommended that the bladder emptying method be chosen according to the AIS grade [21]. In particular,

intermittent catheterization should be selected for patients with AIS-A, AIS-B, and AIS-C, and natural voiding training should be attempted for patients with AIS-D. Furthermore, even patients with AIS-D are often required to choose intermittent catheterization rather than voiding without catheter due to uncontrolled incontinence or urgency, deformity of the bladder, or increased detrusor pressure, which is a risk factor for vesicoureteral reflux. Thus, patients with AIS-D who present with these risk factors (urgency, uncontrolled incontinence, deformity of bladder, and/or high detrusor pressure) should be recommended for intermittent catheterization.

Comparison of bladder emptying methods between patients with tetraplegia and paraplegia at discharge

In a 2017 Dutch study, suprapubic indwelling catheter was the most commonly used method (20.7%) in patients with tetraplegia, while intermittent catheterization was the most commonly used method (60%) in patients with paraplegia [2]. In addition, Cameron et al. [17] reported that female sex, age >43 years at injury, and presence of tetraplegia significantly increased the proportion of patients managed with an indwelling catheter versus intermittent catheterization at initial discharge from rehabilitation.

In this study, differences in bladder emptying methods at discharge were significant over a 20-year period in both patients with tetraplegia and with paraplegia with a decrease in the use of voiding without catheter and an increase in the use of intermittent catheterization. Furthermore, consistent with previous studies, the proportion of indwelling catheter use in patients with tetraplegia was higher than that in patients with paraplegia, which may be due to impaired hand function in patients with tetraplegia who require assistance for intermittent catheterization.

In addition, among patients with tetraplegia in group 2, a similar proportion of patients was managed with transurethral and suprapubic indwelling catheters at discharge. Currently, suprapubic indwelling catheters are recommended more often than transurethral indwelling catheters because they lead to fewer complications, such as epididymitis and urethral stricture [4]. However, transurethral indwelling catheters are still frequently used, potentially because patients usually have negative opinions on the intervention necessary for the use suprapubic

indwelling catheters.

This study has several strengths. First, to our knowledge, this was the first study to report on changes in bladder emptying methods among patients with SCI in Korea over a period of 20 years. Second, our study evaluated bladder emptying methods according to severity of injury (AIS) in patients with SCI. This study will provide fundamental data to aid clinicians in choosing the most suitable bladder emptying method for patients with SCI according to severity of injury (AIS). Third, this study reported that among patients with AIS-D in group 2, approximately 26.8% chose the intermittent catheterization approach at discharge, indicating a direction away from “voiding without catheter”.

This study has several limitations. First, it was a single-center study and so, multicenter studies are required in the future. Second, because of its retrospective design, follow-up data after discharge were unavailable. A previous study showed that compliance with intermittent catheterization after discharge was 85.5% in our center [22]. Compliance with other methods may also require future study. Third, in addition to the comparison of AIS grade and level of injury, it is necessary to make a comparison according to whether there is an intermittent catheterization capable hand function. Fourth, there were differences in several demographic factors between the two groups. According to a recent study analyzing patients who visited a single center in Japan from 1995 to 2013, the proportion of older and non-traumatic injury patients has increased over the years [23]. For this reason, the length of stay and duration of injury might be affected and such differences might have impacted the results of this study in unknown ways.

In conclusion, during the study period, the use of voiding without catheter decreased, whereas the use of intermittent catheterization increased. This was especially prominent in patients with AIS-A, AIS-B, and AIS-C. In patients with AIS-D, voiding without catheter was still the most frequently used bladder emptying method. However, the proportion of patients with intermittent catheterization increased in recent decades in Korea. These results will be helpful for clinicians in choosing the most suitable bladder emptying method according to the severity of injury (AIS).

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

AUTHOR CONTRIBUTION

Conceptualization: Lee BS. Methodology: Lee BS. Formal analysis: Cho IK, Lee HJ. Project administration: Cho IK, Kwon SH, Lee HJ. Visualization: Oh SW, Jung JH. Writing - original draft: Oh SW, Jung JH, Lee BS. Writing - reviewing and editing: Oh SW, Lee BS. Approval of final manuscript: all authors.

REFERENCES

1. Ginsberg D. The epidemiology and pathophysiology of neurogenic bladder. *Am J Manag Care* 2013;19(10 Suppl):s191-6.
2. Adriaansen JJ, van Asbeck FW, Tepper M, Faber WX, Visser-Meily JM, de Kort LM, et al. Bladder-emptying methods, neurogenic lower urinary tract dysfunction and impact on quality of life in people with long-term spinal cord injury. *J Spinal Cord Med* 2017;40:43-53.
3. Gohbara A, Tanaka K, Kawaji K, Yokomizo Y. Urinary tract management in patients with incomplete cervical cord injury during the recovery phase. *Spinal Cord* 2013;51:310-3.
4. Weld KJ, Dmochowski RR. Effect of bladder management on urological complications in spinal cord injured patients. *J Urol* 2000;163:768-72.
5. Pettersson-Hammerstad K, Jonsson O, Svennung IB, Karlsson AK. Impaired renal function in newly spinal cord injured patients improves in the chronic state: effect of clean intermittent catheterization? *J Urol* 2008;180:187-91.
6. Esclarin De Ruz A, Garcia Leoni E, Herruzo Cabrera R. Epidemiology and risk factors for urinary tract infection in patients with spinal cord injury. *J Urol* 2000;164:1285-9.
7. Ost MC, Lee BR. Urolithiasis in patients with spinal cord injuries: risk factors, management, and outcomes. *Curr Opin Urol* 2006;16:93-9.
8. Cameron AP, Rodriguez GM, Schomer KG. Systematic review of urological followup after spinal cord injury. *J Urol* 2012;187:391-7.

9. Peatfield RC, Burt AA, Smith PH. Suprapubic catheterisation after spinal cord injury: a follow-up report. *Paraplegia* 1983;21:220-6.
10. Song BD, Jang SJ, Moon HW, Kim YH, Yang HS, A follow-up study of neurogenic bladder management in spinal cord injury patients: a preliminary study. *J Korean Acad Rehabil Med* 1988;12:23.
11. Park CI, Shin JC, Kim SW, Jang SH, Chung WT, Kim HJ. Epidemiologic Study of Spinal Cord Injury. *J Korean Acad Rehabil Med* 1999;23:267-75.
12. Ord J, Lunn D, Reynard J. Bladder management and risk of bladder stone formation in spinal cord injured patients. *J Urol* 2003;170:1734-7.
13. Giannantoni A, Scivoletto G, Di Stasi SM, Silecchia A, Finazzi-Agro E, Micali I, et al. Clean intermittent catheterization and prevention of renal disease in spinal cord injury patients. *Spinal Cord* 1998;36:29-32.
14. Afsar SI, Yemisci OU, Cosar SN, Cetin N. Compliance with clean intermittent catheterization in spinal cord injury patients: a long-term follow-up study. *Spinal Cord* 2013;51:645-9.
15. Curt A, Rodic B, Schurch B, Dietz V. Recovery of bladder function in patients with acute spinal cord injury: significance of ASIA scores and somatosensory evoked potentials. *Spinal Cord* 1997;35:368-73.
16. Savic G, Frankel HL, Jamous MA, Soni BM, Charlifue S. Long-term bladder and bowel management after spinal cord injury: a 20-year longitudinal study. *Spinal Cord* 2018;56:575-81.
17. Cameron AP, Wallner LP, Tate DG, Sarma AV, Rodriguez GM, Clemens JQ. Bladder management after spinal cord injury in the United States 1972 to 2005. *J Urol* 2010;184:213-7.
18. Hansen RB, Biering-Sorensen F, Kristensen JK. Bladder emptying over a period of 10-45 years after a traumatic spinal cord injury. *Spinal Cord* 2004;42:631-7.
19. Wyndaele JJ, Bruschini H, Madersbacher H, Moore K, Pontari M, Wein A. Neurological patients need evidence-based urological care. *Neurourol Urodyn* 2010;29:662-9.
20. Gomelsky A, Lemack GE, Weld KJ, Dmochowski RR. Urodynamic patterns following ischemic spinal cord events. *J Urol* 2003;170:122-5.
21. Lee BS. Rehabilitation of spinal injury. In: Korean Neurotraumatology Society, editor. *Neurotraumatology*. 4th ed. Seoul: Koonja; 2019. p. 580-4.
22. Roh DK, Lee BS, Kim SK, Nam KY, Kim DA, Kim BS. Study on the changes of voiding methods of patients with SCI after discharge: focusing on the patients participating in the regular urinary tract surveillance program. *J Korean Acad Rehabil Med* 2007;31:92-6.
23. Toda M, Nakatani E, Omae K, Fukushima M, Chin T. Age-specific characterization of spinal cord injuries over a 19-year period at a Japanese rehabilitation center. *PLoS One* 2018;13:e0195120.