Prediction of the outcome of bladder dysfunction based on electrically induced reflex findings in patients with cauda equina syndrome
A retrospective study
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Abstract
The evaluation of the electrically induced bulbocavernosus reflex (BCR) using electromyography (EMG) is a useful tool for evaluating the integrity of sacral spinal segments 2 to 4, and that of their afferent and efferent connections in the urogenital region. In the current retrospective study, the value of this technique in predicting the outcome of bladder dysfunction was investigated in patients with cauda equina syndrome (CES). Electrically induced BCR (E-BCR) was evaluated in 40 patients with bladder dysfunction due to CES at the subacute stage (7–90 days). Manually examined BCR, perianal pinprick sensation, and voluntary anal contraction were also investigated. The recovery of bladder function was evaluated 1 year after the onset of CES. All patients with the presence of E-BCR showed successful recovery of the bladder function, while all patients in whom E-BCR was absent showed poor recovery. E-BCR showed a higher positive predictive value than perianal pinprick sensation and voluntary anal contraction, and showed a higher negative predictive value than manually examined BCR. Results show that E-BCR has advantages in predicting the outcome of bladder dysfunction. Thus, this method can be used as a reference to predict the final outcome of bladder dysfunction at the subacute stage of CES.

Abbreviations: BCR = bulbocavernosus reflex, BCRL = bulbocavernosus reflex latency, CES = cauda equina syndrome, E-BCR = electrically induced bulbocavernosus reflex, EMG = electromyography, M-BCR = manually examined bulbocavernosus reflex, PPS = perianal pinprick sensation, VAC = voluntary anal contraction.

Keywords: bladder dysfunction, bulbocavernosus reflex, cauda equina syndrome, prognosis

1. Introduction
Cauda equina syndrome (CES) refers to a collection of symptoms that result from the compression of the lumbar, sacral, and coccygeal nerve roots distal to the end of the conus medullaris, at the level of the L1 to L2 vertebrae.\textsuperscript{[1,2]} Most frequently, it occurs due to a large lower lumbar disc herniation or a bursting fracture of the lumbar vertebrae.\textsuperscript{[3–5]} Impaired bladder function, which manifests as an areflexic neurogenic bladder characterized by bladder flaccidity and low sphincter tone, is one of the major symptoms seen in patients with CES.\textsuperscript{[6–7]} This bladder dysfunction can lead to urinary stone formation, recurrent urinary tract infections, vesicoureteral reflux, and kidney failure.\textsuperscript{[8]} To prevent these complications, clinicians perform bladder training and use an indwelling catheter or clean intermittent catheterization.\textsuperscript{[9,10]} Accurate prediction of the outcome of bladder function is important because it can provide useful information for establishing proper management strategies for bladder dysfunction in patients with CES.

Previously, the sensory examination of the sacral segments and the manually assessed bulbocavernosus reflex (BCR) was investigated to find out whether they could predict the recovery of a neurogenic bladder.\textsuperscript{[11,12]} However, significant correlations between these physical examinations and the recovery of bladder function were not found. In addition, these exams are limited in that the manual test is subjective, and thus cannot be considered reliable.\textsuperscript{[11,12]} Conversely, the assessment of the BCR using electromyography (EMG) is an objective technique.\textsuperscript{[13,14]} This method involves contraction of the bulbocavernosus muscle induced by electrical stimulation of the pudendal nerves. The BCR is conducted along the sacral reflex arc, and its latency reflects the integrity of the surrounding afferent nerves, sacral cord, and efferent motor fibers.\textsuperscript{[13]} Thus, a severely delayed bulbocavernosus reflex latency (BCRL) and absent BCR response indicate severe injury of the cauda equina or conus medullaris, which can lead to a poor outcome of bladder dysfunction in CES.\textsuperscript{[15]}

The results of an electrically induced BCR (E-BCR) assessment may be useful in the prediction of bladder function recovery after CES. In the current study, the value of the EMG-based BCR testing in predicting the outcome of bladder dysfunction in patients with CES was investigated.
2. Method

2.1. Subjects

Forty consecutive patients (30 men and 10 women; mean, 56.9 ± 13.5 years; range, 28–79 years; 20 patients with a bursting fracture of the lumbar vertebral body, 20 patients with a herniated lumbar or lumbosacral disc), among those admitted at the Department of Physical Medicine and Rehabilitation of a University Hospital, were recruited based on the following criteria (Table 1): (1) aged 20 to 79 years, (2) diagnosed to have CES, (3) had a lesion causing CES, confirmed by a neuroradiologist using lumbar magnetic resonance imaging, (4) had undergone an EMG-based BCR test between 1 week and 3 months after onset, (5) had voiding difficulties and using an indwelling catheter or clean intermittent catheterization for voiding, and (6) had areflexic neurogenic bladder, confirmed by a urodynamic study. The exclusion criteria were as follows: (1) presence of any other lesions in the nervous system (other than those causing CES), such as spinal cord injury, stroke, or diabetic peripheral neuropathy, and (2) a history of voiding dysfunction prior to CES onset. Based on a previous study,[15] we calculated the sample size. In that study, out of a total 40 patients, the proportion of the patients who showed both BCR (+) and poor recovery of bladder function was 47.5%, and that of the patients who presented with both BCR (+) and poor recovery of bladder function was 0%. We assumed a significance level of 5% and power of 95%, and performed 2-sided tests. Considering 10% as the dropout rate, we needed to recruit 20 subjects per group; thus, a total of 40 patients were required. This study was approved by the Institutional Review Board of Yeungnam University Hospital.

Table 1

| Good group | Poor group | P |
|------------|------------|---|
| Number (%) | 16 (40.0)  | 24 (60.0) |
| Age, y     | 62.0±11.0  | 53.5±14.1 | .054 |
| Male: Female | 13:3      | 17:7      | .456 |
| Days to evaluation, d | 51.6±23.7  | 47.4±29.1 | .503 |
| Bursting fracture: herniated disc | 6:10      | 14:10     | .197 |

2.2. Bulbocavernosus reflex

The mean duration from CES onset to BCR evaluation was 49.7 ± 26.8 days (range, 11–89 days). The skin temperature was kept above 32°C. Patients were placed in the lithotomy position with an earth electrode attached to their thigh. In men, ring electrodes were placed on the shaft of the penis with the cathode proximal to the anode. In women, a bar electrode was placed over the clitoris with the cathode proximal to the anode. A concentric needle electrode used for BCR recordings was inserted into the right and left bulbocavernous muscles. The stimulation intensity was 300 V, and the pulse duration was 0.5 ms.[16] An average value of 10 reflection waves was recorded, and the latency was calculated based on the distance between the wave and the baseline (Fig. 1). Delayed latency was defined as an average latency that exceeded 45.0 ms.[16] The patients were classified into 2 groups according to the presence of electrically induced BCR: the E-BCR (+) group—BCR was present either on the right or the left, or on both sides (16 patients), and the E-BCR (−) group—BCR was absent on either side (24 patients). In the E-BCR (+) group, all 16 patients showed abnormal results on the BCR test. Out of these 16 patients, 8 patients had delayed BCR on both the right and left sides. The other 8 patients had normal latency, with no response on the other; 2 out of these 8 BCRs had normal latency, and the remaining 6 had delayed latency. The mean latency of all

![](image-url)
the BCRs considered was 53.3 ± 7.0 ms. Adverse events or complications were not observed after BCR testing using EMG.

2.3. Physical evaluation

Physical examinations were conducted on the same day as the EMG-based BCR evaluation. The presence or absence of perianal pinprick sensation and voluntary perianal contraction was checked. The presence of BCR was manually examined by compressing the glans penis or clitoris and observing for anal sphincter or bulbocavernous contraction. Depending on the presence or absence of a manually examined BCR (M-BCR), perianal pinprick sensation (PPS), and voluntary anal contraction (VAC), the patients were classified into M-BCR (+) and (−) groups, PPS (+) and (−) groups, and VAC (+) and (−) groups, respectively.

2.4. Recovery outcome

Successful recovery from bladder dysfunction was defined as self-voiding without using clean intermittent catheterization or Valsalva, and without residual sensation after voiding, urgency, or urinary frequency. The outcome of the recovery from bladder dysfunction was evaluated 1 year after the onset of CES. The patients were classified into 2 groups based on their recovery outcome: Good group—patients who recovered successfully from bladder dysfunction, and Poor group—patients who did not successfully recover from bladder dysfunction.

2.5. Statistical analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 22.0 (IBM Corp., Armonk, NY). Summaries of the characteristic variables were obtained using descriptive analysis; quantitative and qualitative variables were represented as mean ± standard deviation and frequencies (percentages), respectively. The demographic data of the Good and Poor groups were compared using the Mann-Whitney U test and Chi-square test.

The predictive values of the E-BCR, M-BCR, perianal pinprick sensation, and anal contraction were compared using their statistical classification in the recovery outcome groups as well as the presence or absence of E-BCR, M-BCR, perianal pinprick sensation, and voluntary anal contraction. Also, the test for difference between proportions was performed to compare the predictive values of the E-BCR, M-BCR, perianal pinprick sensation, and anal contraction. A P value of less than .05 was considered statistically significant.

3. Results

At 1 year after the onset of CES, 16 patients (40%) showed successful recovery (Good group) and 24 patients (60%) did not (Poor group). Demographic data, such as time to EMG-based BCR evaluations and patient age, were not significantly different between the Good and Poor groups (P > .05, Table 1).

As for the correlation between the results of the electrically induced BCR and those of the outcomes of bladder dysfunction, all 16 patients (100%) in the E-BCR (+) group belonged to the Good group, and all 24 patients (100%) in E-BCR (−) group belonged to the Poor group (Table 2). When classified according to the physical evaluation outcome, it was observed that all 6 patients (100%) in the M-BCR (+) group belonged to the Good group. However, out of the 34 patients in the M-BCR (−) group, 24 (70.6%) were in the Poor group, and 10 (29.4%) were included in the Good group. Regarding perianal pinprick sensation and voluntary anal contraction, all 6 patients (100%) in the PPS (−) and VAC (−) groups belonged to the Poor group. Out of the 34 patients in the PPS (+) and VAC (+) groups, 16 (47.1%) belonged to the Good group, and 18 (52.9%) the Poor group.

Forty percent of all patients successfully recovered from bladder dysfunction. E-BCR showed strong positive and negative predictive values (1.00) for bladder function outcome (Table 3). M-BCR showed a strong positive value (1.00), but had a relatively lower negative predictive value (0.71) than E-BCR. As for PPS and VAC, they showed a strong negative predictive value (1.00) and a low positive predictive value (0.47). The positive predictive values (1.00) of E-BCR and M-BCR were significantly higher than those (0.47) of PPS and VAC (P < .001). Also, the negative predictive values (1.00) of E-BCR, PPS, and VAC were significantly higher than that (0.71) of M-BCR (P < .001).

4. Discussion

In the current study, the use of E-BCR during the subacute stage of CES to predict bladder dysfunction outcomes at 1-year follow-up was investigated. The presence of the BCR was evaluated, as bladder dysfunction is thought to be accompanied by a loss of this reflex. [15] The presence of the BCR, either delayed or normal in latency, indicates preserved integrity of sacral spinal segments 2,

| Classification | Recovery of bladder dysfunction |
|----------------|---------------------------------|
|                | Good (%) | Poor (%) |
| E-BCR (+) | 16 | 16 (100.0) | 0 (0.0) |
| E-BCR (−) | 24 | 0 (0.0) | 24 (100.0) |
| M-BCR (+) | 6 | 6 (100.0) | 0 (0.0) |
| M-BCR (−) | 34 | 10 (29.4) | 24 (70.6) |
| PPS (+) | 34 | 16 (47.1) | 18 (52.9) |
| PPS (−) | 6 | 0 (0.0) | 6 (100.0) |
| VAC (+) | 34 | 16 (47.1) | 18 (52.9) |
| VAC (−) | 6 | 0 (0.0) | 6 (100.0) |

E-BCR = electrically induced bulbocavernous reflex, M-BCR = manually examined bulbocavernous reflex, PPS = perianal pinprick sensation, VAC = voluntary anal contraction.

| Table 3 Comparison of electrically induced bulbocavernous reflex testing and physical evaluation in predicting the bladder dysfunction outcome. |
|---------------------------------------------------------------|
| Positive predictive value | Negative predictive value |
|---------------------------|----------------------------|
| E-BCR                    | 1.00     | 1.00 |
| M-BCR                    | 1.00     | 0.71 |
| PPS                      | 0.47     | 1.00 |
| VAC                      | 0.47     | 1.00 |

E-BCR = electrically induced bulbocavernous reflex, M-BCR = manually examined bulbocavernous reflex, PPS = perianal pinprick sensation, VAC = voluntary anal contraction.
3, and 4, and that of their afferent and efferent connections in the urogenital region.[14,17] In contrast, an absent BCR indicates that the conus or sacral radicular spinal nerves have been severely disrupted.[15] In the present study, abnormal E-BCR findings were observed in all recruited patients; this demonstrated that all the patients included in this study had cauda equina lesions. In addition, the E-BCR evaluation conducted in this study also showed that all the patients in whom the integrity of at least 1 side of the sacral arc was partially preserved could self-void 1 year after the onset, whereas all patients whose sacral arcs were not preserved on either side were unable to self-void 1 year after the onset. Based on these results, it is suggested that at least 1 side of the sacral reflex arc should be preserved for successful recovery from bladder dysfunction following a cauda equina lesion. Furthermore, if at least 1 sacral arc is preserved, the bladder function may eventually recover successfully. Therefore, the use of EMG-based BCR assessments during the subacute stages of CES may be useful in predicting bladder dysfunction recovery.

Regarding physical examination, all patients who had BCR when examined manually showed a good recovery from bladder dysfunction, and all patients with either absent PPS or VAC showed a poor recovery; that is, M-BCR has a strong positive predictive value, and PPS and VAC have strong negative predictive values. The current results concur with those of previous studies,[12,15] which demonstrated that the presence of BCR and the absence of PPS or VAC indicated a good and poor prognosis for bladder outcome, respectively. However, none of the previous studies evaluated more than 10 patients, and in the current study, the number of patients who showed the presence of M-BCR and absence of PPS and VAC was only 6. This seems to be too small to confirm whether these evaluations are useful in predicting the prognosis of bladder dysfunction. Additionally, the present results showed that M-BCR had a relatively good negative predictive value (0.71), but the accuracy was lower than that of E-BCR (1.00). Based on these results, clinicians may more accurately evaluate the preservation of the sacral reflex arc using EMG-based BCR examination compared with manual BCR examination. Additionally, the presence of PPS or VAC did not provide any information on the prognosis of bladder dysfunction in CES because its positive predictive value was 0.47. This is consistent with the result of a previous study, in which only approximately half the patients who initially had perianal pinprick sensation recovered from their voiding dysfunction following CES.[12] In summary, compared with physical examination, the E-BCR test has a better predictive value for the prognosis of bladder dysfunction in CES.

To the best of our knowledge, 3 studies on the prognosis of bladder dysfunction in CES have been previously reported.[11,12,15] In 1979, Ertekin et al[15] investigated the clinical value of E-BCR in 40 patients with CES. The BCR was absent in 19 patients, and present in 21 patients. They reported that the presence of BCR, delayed or not, was more favorable for improvement in the bladder function. However, they did not describe any data related to the BCR and the outcome of bladder function. In 1999, Kennedy et al[13] found that 5 out of 19 patients with CES had residual bladder dysfunction 2 years after the onset. These 5 patients showed complete perianal anesthesia and significant dysfunction of anal contraction. They reported that the absence of PPS and significant dysfunction of VAC were good predictors of a poor recovery from bladder dysfunction. In 2003, Schurch et al[12] investigated the prognosis of bladder dysfunction in 51 patients with thoracolumbar fractures. At an average of 481 days after the first evaluation, the bladder function of only 7 patients was normalized. In the first evaluation within the 3 months after the onset, 6 (85%) out of these 7 patients with good recovery had PPS, but out of 44 patients with poor recovery, 21 (45%) had initial PPS. These results indicate that perianal pinprick sensation has no significant positive predictive value. As Ertekin et al[15] did not present any data related to BCR and the outcome of bladder function, the present study is the first to show the outcome of bladder dysfunction in CES based on the results of BCR testing using EMG.

In conclusion, the results of E-BCR examination seemed to give excellent positive and negative predictive values for the recovery of bladder function in patients with CES. Determining the preservation of E-BCR in the subacute stage of CES is useful in predicting the eventual bladder dysfunction recovery. In comparison to physical examination, it was observed that the results of the E-BCR examination had superior predictive values for the outcome of bladder recovery. However, the limitations of the current study should be considered. First, the small sample of the recruited subjects was small. Second, this study was conducted retrospectively. Third, we did not perform follow-up urodynamic studies for confirming the recovery of bladder function. Therefore, further studies circumventing these limitations are warranted.

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