Accuracy and Reliability of Physical Signs as a Diagnostic Tool for Cervical Cord Compression: A Cross-Sectional Study

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Abstract:

Introduction: Cervical myelopathy diagnosis is based on specific symptoms, physical signs, and imaging findings. However, information on the accuracy and reliability of physical signs, particularly the Wartenberg reflex and the finger escape sign (FES), is lacking. Therefore, this study aimed to assess the validity and reliability of the Hoffmann and Trömner signs, FES, Wartenberg reflex, and combination of any one positive of these four physical signs.

Methods: We reviewed the Hoffmann and Trömner signs, FES, and Wartenberg reflex from the medical records of patients with cervical cord compression who underwent surgery. We included those who underwent lumbar spine surgery as controls, except those with upper extremity symptoms or a history of cerebrospinal disease. Subsequently, we calculated the sensitivity and specificity of cervical cord compression. The primary and secondary observers performed two and one trial, respectively, to measure the intra- and interobserver reliabilities.

Results: This study included 46 cases and 42 controls. The diagnostic sensitivities for the Hoffmann sign, Trömner sign, Wartenberg reflex, FES, and combination of any one positive were 46%, 72%, 63%, 22%, and 83%, respectively; the diagnostic specificities were 98%, 79%, 95%, 98%, and 79%, respectively; the intraobserver kappa value (κ) was 0.80, 0.82, 0.86, 0.66, and 0.95, respectively; and the interobserver κ was 0.84, 0.51, 0.51, –0.02, and 0.60, respectively. Notably, all κ values, except the interobserver κ for the FES, were obtained with $P<0.01$.

Conclusions: Each physical sign had high specificity but low sensitivity in predicting cervical cord compression. Therefore, they may be useful for definitive diagnosis but not for screening tests. The combination of the four physical signs exhibited improved sensitivity and may be useful for screening tests. However, the results of these physical signs should be carefully interpreted owing to the low level of interobserver reliability.

Keywords:

cervical myelopathy, cervical cord compression, physical sign, diabetes mellitus

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Introduction

Cervical myelopathy (CM) is a spinal cord dysfunction that may result in clinical symptoms, such as loss of dexterity, poor coordination, motor weakness, sensory loss, and/or bladder dysfunction[1,2)]. Thus, an accurate CM diagnosis is essential owing to its associated significant morbidity and disability.

The definitive diagnosis of CM is often based on specific symptoms, physical signs, and imaging findings. Notably, CM diagnosis is confirmed via magnetic resonance imaging (MRI), which shows a reduced anteroposterior width of the spinal cord, cross-sectional evidence of cord compression, and obliteration of the subarachnoid space[3)]. However, MRI is available in limited facilities; thus, confirmation of the MRI findings in all symptomatic patients is challenging.

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Consequently, screening for physical signs and then performing MRI on patients with positive results is a common approach.

The incidence of radiological and symptomatic tandem lumbar spinal stenosis is 32%-84% and 0.9%-33%, respectively[4]. Cases of quadriplegia following lumbar spine surgery have been reported[5,6]. Neurologic deficits can occur in patients with unrecognized cervical cord compression, which may result from neck extension during endotracheal intubation, prone positioning, or loss of muscle support when anesthetized[7]. Therefore, screening for physical signs might be useful.

The physical signs for CM include the Hoffmann and Trömner signs; Wartenberg, inverted radial, deep tendon, Babinski, and Chaddock reflexes; finger escape sign (FES); and clonus[8-11]. Previous studies have investigated the utility and reliability of specific physical signs. Rhee et al. reported that the sensitivity and specificity of the Hoffmann sign were 59% and 84%, respectively[12]. Another study reported diagnostic sensitivities of 76% and 94% and specificities of 93% and 82% for the Hoffmann and Trömner signs, respectively[13]. The Hoffmann sign[14] and Babinski reflex[10,15-18] have been explored for their reliability; however, information on reliability and repeatability is scarce.

A previous study demonstrated that the Hoffmann and Trömner signs were significantly diminished in patients with severe diabetes mellitus (DM)[19]. However, only a few studies have reported on the association between these physical signs and DM; therefore, such information remains unclear.

The Hoffmann and Trömner signs, FES, and Wartenberg reflex can be examined only in the upper extremities and easily observed in clinical settings. The reflex center is located at the cervical spinal cord level; therefore, it is not influenced by the thoracic or lumbar spinal cord, which facilitates CM diagnosis. Accordingly, we aimed to assess the validity and reliability of the Hoffmann and Trömner signs, Wartenberg reflex, and FES in patients who underwent surgery for cervical cord compression lesions.

Materials and Methods

1. Patients

Our institutional review board approved this observational cross-sectional study. We retrospectively reviewed the medical records of all patients who underwent cervical spinal surgery at a single institution between July 2020 and June 2022. The inclusion criteria were objective findings and/or symptoms consistent with upper motor neuron dysfunction owing to cervical cord compression and MRI findings indicating cervical cord compression. A total of 85 patients underwent cervical surgery between July 2020 and June 2022. Those with any of the following conditions were excluded: os odontoideum (n=2), atlantoaxial subluxation (n=4), spinal injury (n=9), spinal tumor (n=1), radiculopathy (n=7), prior cerebrovascular accident (n=4), brain tumor (n=1), epilepsy (n=1), previous spinal surgery (n=2), cerebral palsy (n=1), peripheral neuropathy (n=2), contraction of the finger joints (n=1), or insufficient medical records (n=4). A total of 20 consecutive patients were investigated to confirm the reliability of physical signs.

For the control group, patients who underwent lumbar spinal surgery between September 2021 and June 2022 were included. Those with any of the following conditions were excluded: upper extremity symptoms (n=14), history of cerebrospinal disease (n=21), peripheral neuropathy (n=1), contraction of finger joints (n=1), decreased comprehension due to dementia (n=1), emergency surgery (n=3), or insufficient medical records (n=10). A total of 20 consecutive patients were investigated to confirm the reliability of physical signs.

Notably, all participants underwent cervical spine MRI with the use of standard protocols. Spinal cord compression was defined as a more significant deformation of the cord contour than mild ventral flattening, corresponding to grade 2 or 3 on the scale of Singh et al.[20].

2. Data collection

We collected information such as age, sex, and presence of the Hoffmann and Trömner signs, Wartenberg reflex, and FES. We regarded patients as having DM if they were on DM treatments or their glycated hemoglobin (HbA1c) level was ≥7.0%. We selected 7.0% as the cutoff value as a previous report regarded this percentage as severe DM, causing the disappearance of some neurological findings[19].

To test for the Wartenberg reflex, the examiner placed their index finger across the base of the patient's fingers while using their thumb to support the patient's fingers. Thumb flexion was considered positive when the reflex hammer was struck with the examiner's index finger. The FES involves involuntary flexion and abduction of the extended and adducted fingers within 1 min when held statically. This sign is classified into five grades[21], with grades ≥1 considered as positive. Physical signs were considered present if they were present unilaterally or bilaterally. The observers were provided with written and pictorial instructions on how to conduct the examinations. Furthermore, they were instructed to repeat the procedure as many times as necessary.

3. Data and statistical analysis

The primary investigator examined each patient at "moment F1" and "moment F2," which was 2 weeks after F1. A secondary investigator employed similar techniques to examine the same patient 1 day preoperatively (moment Fa).

We calculated the sensitivity and specificity of each physical sign using F1 results. In addition, we examined the sensitivity and specificity when one or more of the four signs were positive.

Intraobserver reliability was tested by comparing the examination results from F1 and F2. The primary and secondary investigator findings for each patient (F1 and Fa) were compared and used to calculate the interobserver reliability.

Kappa values (κ) were utilized to evaluate intra- and interobserver reliabilities. We considered κ<0.00 as poor agreement, 0.00-0.20 as slight agreement, 0.21-0.40 as fair agreement, 0.41-0.60 as moderate agreement, 0.61-0.80 as substantial agreement, and 0.81-1.00 as almost-perfect agreement[22].

The effect of DM was evaluated by calculating the positivity rate of the cervical surgery group.

The patients in the cervical surgery group were stratified into two groups, mild (score >13) and moderate/severe (scores 9-13 and <9, respectively), according to the Japanese Orthopaedic Association (JOA) scoring system[23].

Differences in quantitative and qualitative characteristics were analyzed using Student's *t*-test and chi-squared test, respectively. All statistical analyses were conducted using IBM SPSS Statistics (ver. 28, SPSS Inc., Chicago, IL, USA). Statistical significance was set at a *P* value <0.05.

Results

1. Patient characteristics

Among the 85 surgically treated patients, 46 met the inclusion criteria (28 men; mean age, 69 years [range: 36-86 years]). Multilevel (four or more) surgeries were performed in all cases using a posterior approach. Of the 46 cases, 26 showed cord signal change on MRI. The specific levels are listed in Table 1. Among the patients, 41 had cervical spondylotic myelopathy and 5 had ossification of the posterior longitudinal ligament. Furthermore, 14 patients had DM.

For the control group, 93 patients underwent lumbar spinal surgery between September 2021 and June 2022. A total of 42 patients met the inclusion criteria (26 men; mean age, 73 years [range: 54-86 years]).

No significant differences were observed in the mean age and sex ratio between the groups.

2. Sensitivities and specificities of physical signs relative to cervical cord compression

The diagnostic sensitivities of the Hoffmann sign, Trömner sign, Wartenberg reflex, and FES were 46%, 72%, 63%, and 22%, respectively. Their diagnostic specificities were 98%, 79%, 95%, and 98%, respectively. When any one of the four signs was positive, the sensitivity was 83% and the specificity was 79%. Values for any two, three, or four positives are presented in Table 2.

3. Reliability of physical signs

The κ values are listed in Table 3. The Trömner sign and Wartenberg reflex had an almost-perfect strength of intraobserver agreement, and the Hoffmann sign and FES had substantial strength of intraobserver agreement. Furthermore, the Hoffmann sign had an almost-perfect strength of interobserver agreement, whereas the Trömner sign and Wartenberg reflex had a moderate strength. The FES had a poor strength of interobserver agreement. Being positive for any one of the four signs had an almost-perfect strength of intraobserver agreement and a moderate strength of interobserver agreement.

Table 1. Level of Cord Signal Change in 46 Patients.

Level	No. of patients
C3–4	4
C4–5	10
C5–6	8
C6–7	1
C3–4, C4–5	2
C4–5, C6–7	1
No signal change	20

4. The effect of diabetes on the positivity ratio of physical signs

The Trömner sign was significantly diminished in patients with DM. However, the FES was significantly diminished in those without DM. No significant differences were observed in the Hoffmann sign and Wartenberg reflex between patients with or without DM. According to the JOA score, 11 cases were classified as mild, 32 as moderate, and 3 as severe. In the FES of moderate or severe myelopathy, the sensitivity of the FES in patients with DM was significantly higher than that in patients without DM (Table 4).

5. The effect of severity on physical sign positivity ratio

The cervical surgery group was stratified based on the JOA score, and the sensitivity is presented in Table 5.

Discussion

We determined the sensitivity and specificity of the physical signs in patients who underwent surgery for cervical cord compression. We found that the specificities of the Hoffmann sign, Wartenberg reflex, and FES were fairly high and that of the Trömner sign was relatively high, indicating their potential use for definitive diagnosis. However, they have relatively low sensitivity, which prevents their use for screening tests. Nevertheless, the combination of these findings could greatly improve sensitivity and may be useful in screening tests. Our results also indicated that all physical signs, except for the Hoffmann sign, had a relatively high intraobserver reliability but a relatively low interobserver reliability.

The sensitivity of the Hoffmann sign in patients with CM who underwent surgery ranged from 59% to 83%[12,24,25]. To our knowledge, only one study reported about the specificity of the Hoffmann sign among patients with CM who underwent surgery, which showed a specificity of 84%[12]. Therefore, the Hoffmann sign has high specificity but low sensitivity, making it a poor screening tool. This finding is consistent with our results. This study also demonstrated that the Trömner sign has the highest sensitivity among the four

Table 2. Prevalence of Physical Signs in the Cervical Surgery and Control Groups.

	CS n=46	Control n=42	Sensitivity	Specificity	*P**
Hoffmann sign	21	1	46%	98%	<0.01†
Trömner sign	33	9	72%	79%	<0.01†
Wartenberg reflex	29	2	63%	95%	<0.01†
FES	10	1	22%	98%	<0.01†
1 of 4	38	9	83%	79%	<0.01†
2 of 4	30	4	65%	90%	<0.01†
3 of 4	22	0	48%	100%	<0.01†
4 of 4	3	0	7%	100%	0.138

*Chi-squared test.

†, Statistical significance at the 0.05 level.

FES, the finger escape sign; CS, cervical surgery

1 of 4, positive for any one of four signs; 2 of 4, positive for any two of four signs; 3 of 4, positive for any three of four signs; 4 of 4, positive for all four signs.

Table 3. κ Values for Intraobserver and Interobserver Reliabilities.

	Intraobserver	*P*	Interobserver	*P*
Hoffmann sign	0.80	<0.01†	0.84	<0.01†
Trömner sign	0.82	<0.01†	0.51	<0.01†
Wartenberg reflex	0.86	<0.01†	0.51	<0.01†
FES	0.66	<0.01†	−0.02	0.80
1 of 4	0.95	<0.01†	0.60	<0.01†

†, Statistical significance at $P<0.05$.

FES, the finger escape sign

1 of 4, positive for any one of four signs.

Table 4. Effect of Diabetes on Sensitivities of Physical Signs in the Cervical Surgery Group.

				JOA >13			JOA ≤13		
	DM+ n=14	DM− n=32	*P**	DM+ n=2	DM− n=9	*P**	DM+ n=12	DM− n=23	*P**
H	43%	47%	0.801	0%	44%	0.38	50%	48%	0.90
T	50%	81%	0.041†	0%	89%	0.06	58%	78%	0.20
W	43%	72%	0.061	0%	67%	0.18	50%	74%	0.15
F	43%	13%	0.047†	50%	11%	0.35	42%	9%	0.03†

*Chi-squared test.

†, Statistical significance at $P<0.05$.

DM, diabetes mellitus; H, Hoffmann sign; T, Trömner sign; W, Wartenberg reflex; F, the finger escape sign; JOA, Japanese Orthopaedic Association

physical signs.

Similarly, Chang et al. showed that the diagnostic sensitivity of the Trömner sign was higher than that of the Hoffmann sign[9]. This difference could be attributed to the increased sensitivity of direct skin stimulation over the volar aspect of the distal finger as opposed to stimulation on the nail[9]. The reasons for this are also inferred in this study.

Tejus et al. found that the sensitivities of the Wartenberg reflex and Hoffmann sign were 67% and 75%, respectively, for patients with spinal cord compression[11]. We simultaneously tested the sensitivity and specificity of the Wartenberg reflex and obtained the values of 63% and 95%, respectively. This suggests that the Wartenberg reflex, similar to the Hoffmann sign, had high specificity but low sensitivity, making it a poor screening tool.

Wong et al. reported that the sensitivities of the Hoffmann sign and FES were 82% and 55%, respectively[26]. Therefore, the latter sign could have a lower sensitivity than the former. In this study, the sensitivity and specificity were 22% and 98%, respectively.

Table 5. Physical Sign Sensitivities in the Cervical Surgery Group Stratified by the JOA Score.

	JOA >13 n=11	JOA ≤13 n=35	*P**
Hoffmann sign	36%	49%	0.49
Trömner sign	73%	71%	0.63
Wartenberg reflex	55%	66%	0.37
FES	18%	23%	0.55
1 of 4	91%	80%	0.37
2 of 4	55%	69%	0.31
3 of 4	36%	51%	0.38
4 of 4	0%	9%	0.43

*Chi-squared test.

FES, the finger escape sign; JOA, Japanese Orthopaedic Association

1 of 4, positive for any one of four signs; 2 of 4, positive for any two of four signs; 3 of 4, positive for any three of four signs; 4 of 4, positive for all four signs.

Each physical sign has low sensitivity in predicting cervical cord compression. A systematic review showed that the clinical signs had high specificity but low sensitivity, making them poor screening tools[27]; consequently, no single physical sign can be used to rule out in- or out-of-cord compression. Tejus et al. reported that a combination of the finger flexion, Hoffman sign, and Babinski reflex had a sensitivity of 91.7% and specificity of 87.5% and could serve as an accurate and reliable marker of spinal cord compression in persons symptomatic for cervical spine disease[11]. Cook et al. reported that the selected combinations of clinical findings, such as (1) gait deviation, (2) +Hoffmann test, (3) inverted supinator sign, (4) +Babinski test, and (5) age >45 years, improved sensitivity and were effective in ruling out and ruling in cervical spine myelopathy[28]. In this study, when any one of the four physical signs was positive, the sensitivity was 83% and higher than when two or more were positive. As the number of positive findings increased, the sensitivity decreased and specificity increased (Table 2). Therefore, the combination of any one of the four signs being positive could greatly improve sensitivity and may be useful in screening tests.

To our knowledge, the reliability of the Hoffmann sign has been reported but not those of the other three findings. Our results indicated that the Trömner sign, Wartenberg reflex, and combination of the four physical signs had an almost-perfect level of intraobserver reliability and that the Hoffmann sign had a moderate level. As regards the interobserver reliability, the Hoffmann sign had an almost-perfect level, whereas the Trömner sign, Wartenberg reflex, and combination of any one of the four signs being positive had a moderate level. The FES had few positive cases, and no significant result for interobserver reliability was obtained. Similarly, Annaswamy et al. reported that the intraobserver and interobserver κ of the Hoffmann sign were 0.89 and 0.65, respectively[14]. The results indicated a relatively high intraobserver reliability but a low interobserver reliability. Therefore, individual differences exist in how the tests are interpreted.

A previous study that compared the preoperative neurological findings between patients with CM and those with no, mild, and severe DM reported that the Hoffmann and Trömner signs significantly diminished in patients with severe DM. Positive Hoffmann and Trömner signs are caused by the same physiological mechanism as that of deep tendon hyperreflexia; therefore, these two signs decreased owing to diabetic neuropathy[19]. The Wartenberg reflex is also considered to represent hyperreflexia[29]. In this study, the Trömner sign was significantly absent and the Wartenberg reflex tended to be absent in patients with DM. In this study, the FES was significantly positive in patients with DM. A similar result was obtained in moderate and severe cervical surgery group, but in the other groups no significant differences were found. There are no previous reports on the FES and DM; therefore, the underlying mechanisms remain unclear.

As regards the severity of CM using JOA scores, we found no significant difference in the sensitivity of physical signs. Notably, the sensitivity of the Trömner signs remained consistently high across different degrees of myelopathy, which led to a relatively high sensitivity of the combination. However, different results were reported regarding the sensitivity of the Hoffmann sign and its correlation with the JOA scores[24,30]. Chaiyamongkol et al. reported the tendency of the Trömner sign to exhibit high sensitivity even in mild cases[13], a trend we also observed in our study. To our knowledge, no previous reports have associated the Wartenberg reflex and the FES to JOA scores.

This study has some limitations. First, it was a retrospective study, and the number of cases was insufficient. Second, the sensitivities were considered to be high as the CM group was defined as patients who had undergone surgery. Third, furthermore, the observers were not blinded to patients, other medical history, or examination elements. Fourth, two cases with cord signal change at C6-C7 were not excluded. In this series, multilevel stenosis was typical, and the effects were complicated. A study on 275 patients with CM reported that the lack of the Hoffmann sign was not necessarily associated with cord compression at C6/C7 or C7/T1, where the reflex center is presumed to be located[24]. A study on 20 patients with C6-C7 myelopathy reported that two patients (10%) had a positive Hoffmann sign[31]. Therefore, the effects of the level of cord compression can be uncertain. Our two cases also showed positive findings. Fifth, the control group was not evaluated via cervical MRI. Cao et al. reported that the incidence of a positive Hoffmann sign is approximately 0.7%-3% in the general population[32]. In this study, the positivity rate was similar to that of the general population, and the control group might be similar to the general population.

In conclusion, each physical sign had high specificity but low sensitivity in predicting cervical cord compression. Therefore, they can be useful for definitive diagnosis but not

for screening tests. Consequently, no single physical sign can be used to rule out cervical cord compression. The combination of any one of four physical signs being positive improved sensitivity and may be useful for screening tests. The results of these physical signs should be carefully interpreted owing to their relatively low level of interobserver reliability.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: Yoshinobu Kato and Eiichiro Iwata designed the study; Eiichiro Iwata and Yudai Yano performed the experiments and analyzed the data; Munehisa Koizumi, Masafumi Araki, Takuya Sada, Takahiro Mui, Keisuke Masuda, Sachiko Kawasaki, Akinori Okuda, Hideki Shigematsu, and Yasuhito Tanaka supervised the experiments; Yoshinobu Kato and Eiichiro Iwata wrote the manuscript.

Ethical Approval: The ethics committee waived ethical approval due to the retrospective study design.

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