Time Course and Characteristics of the Nutritional Conditions in Acute Traumatic Cervical Spinal Cord Injury

Tetsuo Hayashi[1)2)], Yuichi Fujiwara[3)], Muneaki Masuda[2)], Kensuke Kubota[1)2)], Hiroaki Sakai[2)], Osamu Kawano[2)], Yuichiro Morishita[2)], Kazuya Yokota[2)] and Takeshi Maeda[2)]

1) Department of Rehabilitation Medicine, Japan Organization of Occupational Health and Safety, Spinal Injuries Center, Fukuoka, Japan
2) Department of Orthopaedic Surgery, Japan Organization of Occupational Health and Safety, Spinal Injuries Center, Fukuoka, Japan
3) Nursing Department, Japan Organization of Occupational Health and Safety, Spinal Injuries Center, Fukuoka, Japan

Abstract:

Introduction: This retrospective cohort study aimed to examine the nutritional time course and elucidate the critical period of undernutrition following acute traumatic cervical spinal cord injury (CSCI).

Methods: The study was performed at a single facility that treated spinal cord injuries. We examined individuals with acute traumatic CSCI admitted to our hospital within 3 days of injury. Both prognostic nutritional index (PNI) and controlling nutritional status (CONUT) scores, which objectively reflect nutritional and immunological conditions, were assessed at admission and 1, 2, and 3 months after the injury. The American Spinal Injury Association impairment scale (AIS) categorizations and severity of dysphagia were evaluated at these time points.

Results: A total of 106 patients with CSCI were evaluated consecutively for 3 months after injury. Individuals with AIS categorizations of A, B, or C at 3 days after injury were significantly more undernourished than those with an AIS categorization of D at 3 months after injury, indicating that individuals with mild paresis better maintained their nutritional condition after injury. Nutritional conditions, as assessed by both PNI and CONUT scores, improved significantly between 1 and 2 months after injury, whereas no significant differences were found between admission and 1 month after injury. Nutritional status and dysphagia were significantly correlated at each time point ($p<0.001$), indicating that swallowing dysfunction is an important factor associated with malnutrition.

Conclusions: Nutritional conditions showed significant gradual improvements from 1 month after the injury. We must pay attention to undernutrition, which is associated with dysphagia, especially in individuals with severe paralysis during the acute phase following injury.

Keywords:

Nutrition, Dysphagia, Paresis, Cervical spinal cord injury, Complication

Spine Surg Relat Res 2023; 7(3): 219-224
dx.doi.org/10.22603/ssrr.2022-0158

Introduction

Traumatic spinal cord injury (SCI) is a global health problem associated with high disability and mortality rates and carries a heavy social and economic burden[1)]. Cervical spinal cord injury (CSCI), particularly, not only is related to tetraplegia but also leads to many secondary adverse events such as malnutrition[2)], dysphagia[3)], pneumonia[4)], and urinary tract infections.

Malnutrition is a major concern following SCI, and individuals with SCI are at risk of undernutrition and weight loss[5)]. A recent study reported that the prevalence of undernutrition in those sustaining SCI was in the range of 40%-50%[2)]. Since immunonutritional status after CSCI is related to infections and the prognosis in individuals with CSCI[6)], it is very important to assess the immunonutritional status from the acute to the chronic phase.

We previously reported that pneumonia in persons with

Corresponding author: Tetsuo Hayashi, tetsuo884hayashi@yahoo.co.jp
Received: August 17, 2022, Accepted: September 12, 2022, Advance Publication: October 28, 2022

CSCI frequently occurs within 1 month after injury[4]. The immunonutritional condition worsens and leads to vulnerability during this period. To the best of our knowledge, no previous study has reported the clinical time course of SCIs regarding nutritional status, and the period when nutritional improvement is clinically important is not well understood. We hypothesized that nutritional conditions might deteriorate temporally during the acute phase following injury. This study aimed to elucidate the serial changes and nutritional status in individuals with CSCI after injury.

Material and Methods

Participants

Between January 2016 and February 2021, 170 individuals with acute traumatic CSCI presenting with neurological deficits were admitted to a single facility that treated spinal cord injuries within 3 days of sustaining the injury. Individuals were followed consecutively for at least 3 months. Following our therapeutic protocol, we regularly examined the neurological status and swallowing function and collected blood samples for each individual after admission. Additionally, we retrospectively reviewed the collected data.

The exclusion criteria were as follows: switching hospitals within 3 months of the injury due to the deterioration of the general condition or request to transfer to a hospital close to their homes, difficulty communicating due to dementia or mental disease, and discharge to their homes at less than 3 months after hospital admission due to recovery of neurological status.

The Institutional Review Board at our institution approved this study, and all participants provided written informed consent before participating in the study.

Evaluation

The nutritional condition was assessed using both prognostic nutritional index (PNI)[7,8] and controlling nutritional status (CONUT) scores[8,9], which objectively reflect nutritional and immunological risks using findings from blood tests[10]. The PNI was calculated using the following formula: PNI=10×albumin g/dL+0.005×total lymphocyte count/mm^3. The CONUT score was calculated from the sum of the categorized score of the total lymphocyte count, serum albumin level, and cholesterol level. Peripheral blood was collected from each individual with CSCI at admission, which was within 3 days of the injury in this series and 1, 2, and 3 months after the injury.

Neurological evaluation for CSCI was performed according to international standards for neurological classification of spinal cord injuries 3 days after the injury[11]. The American Spinal Injury Association (ASIA) Impairment Scale (AIS) was used to evaluate the severity of paralysis. Neurological data were evaluated by a trained therapist and managed by ASIA members who had completed the International Standards Training E Program.

Swallowing dysfunction was classified using the dysphagia severity scale (DSS)[12] and the functional oral intake scale (FOIS)[13]. The DSS evaluates aspiration or dysphagia using the following scoring system: 1, saliva aspiration; 2, food aspiration; 3, water aspiration; 4, occasional aspiration; 5, oral problems; 6, minimum problems; and 7, within normal limits. The FOIS evaluates the functional intake of food or liquid using the following scores: 1, nothing by mouth; 2, tube-dependent nutrition with minimal attempts at food or liquid intake; 3, tube-dependent nutrition with consistent oral intake of food or liquid; 4, total oral diet of a single consistency; 5, total oral diet with multiple consistencies but requiring special preparation or compensations; 6, total oral diet with multiple consistencies, without special preparation but with specific food limitations; and 7, total oral diet with no restrictions. We also examined individuals experiencing aspiration using fiberoptic endoscopic evaluation of swallowing or videofluoroscopy for a detailed classification of DSS and FOIS; these evaluations were conducted by TH (1st author) and YF (2nd author). DSS and FOIS were evaluated 1, 2, and 3 months after the injury.

Statistical analysis

Differences in PNI and CONUT scores 3 months after the injury were assessed using Mann-Whitney U tests according to AIS categorizations 3 days after the injury. Differences in PNI and CONUT scores between each time point were assessed using Wilcoxon signed-rank tests. Correcting for Bonferroni inequality, a p-value of less than 0.0125 (0.05/4) was considered statistically significant in these analyses. Correlations between nutritional status and dysphagia were assessed using Spearman's rank correlation coefficients. Statistical analyses were performed using the JMP 13 software (SAS Institute Inc., Cary, NC, USA).

Results

A total of 170 individuals with traumatic CSCI were admitted to the spinal injury center within 3 days of sustaining a spinal cord injury during the study period. Of these, 27 individuals who were discharged within 3 months of the injury due to mild paresis were excluded. Additionally, 27 individuals who switched to a different hospital due to deterioration of their general condition, 6 who requested a hospital close to their homes, and 4 who had difficulty communicating (3 with dementia and 1 with Down syndrome) were excluded. Finally, 106 individuals with CSCI met the inclusion criteria and were followed up for at least 3 months after sustaining trauma (Fig. 1). Table 1 summarizes the medical and demographic characteristics of the enrolled individuals.

The nutritional condition, assessed using both PNI and CONUT scores 3 months after the injury, was compared among individuals within each AIS categorization 3 days after the injury (Fig. 2A, 2B). Individuals with AIS categorizations of A, B, and C were significantly more undernour-

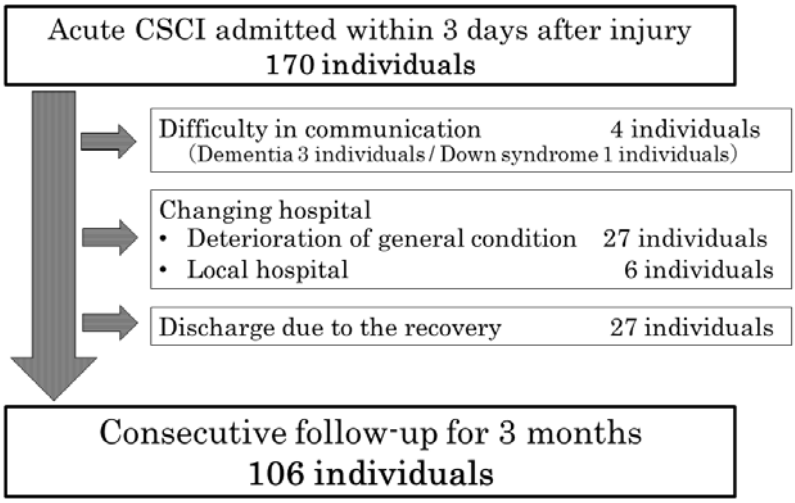

Figure 1. Flow chart of the study CSCI: cervical spinal cord injury.

Table 1. Summary of Demographic Data of 106 Individuals at Admission.

Age (years)	66 (58–74)
Sex (female/male)	18/88
PNI	40.9 (37.5–44.3)
CONUT score	3 (1.5–4.5)
ASIA impairment scale (%)	
A	27 (25)
B	17 (16)
C	40 (38)
D	22 (21)
Surgical treatment (%)	
A	17 (63)
B	10 (59)
C	10 (25)
D	9 (41)

Values are given as the number of patients (%) or median (interquartile range)

Abbreviations: PNI, prognostic nutritional index; CONUT, controlling nutritional status; ASIA, American Spinal Injury Association

Sixteen patients with pneumonia within 3 months after injury were included in this series.

ished than those with an AIS categorization of D ($p<0.01$), indicating that individuals with mild paresis better maintained their nutritional condition after injury.

Fig. 3A, 3B show the time course of the nutritional condition based on PNI and CONUT scores. Fig. 3C, 3D show the time course of the nutritional condition for each AIS categorization. As assessed by both scales, the nutritional conditions improved significantly between 1 and 2 months after the injury. By contrast, no statistically significant differences were found between admission and 1 month after the injury. Additionally, only the CONUT score significantly improved between 2 and 3 months after the injury.

Table 2 shows the correlations between nutritional status and dysphagia at each time point. Statistically significant correlations were observed at each time point, indicating that swallowing dysfunction is an important factor associated with malnutrition. Additionally, all correlation coefficients for the PNI were greater than those for the CONUT score at each time point, indicating that the PNI was more strongly correlated with dysphagia than the CONUT score.

Discussion

To the best of our knowledge, the time course of patients' nutritional condition after SCI has not been reported previously, although some studies have reported nutritional findings for different forms of trauma[14]. For example, in a study evaluating patients hospitalized in the intensive care unit with a traumatic head injury, nutritional parameters significantly reduced from hospital admission to hospitalization days 7 and 13[14]. Our study demonstrated that nutritional status deteriorated until 1 month after injury; however, it gradually improved until 3 months after injury. As the CONUT score includes cholesterol level in the formula, significant improvement of the CONUT score between 2 and 3 months after the injury would be reflected by the improvement of the lipid metabolism.

Many studies have reported the issue of metabolic syndrome and being overweight in individuals with chronic SCI[2]. By contrast, few studies[15] have reported the relationship between paralysis and undernutrition in acute SCI. Our study demonstrated that severe paralysis 3 days after injury resulted in undernutrition 3 months after injury. As severe paralysis has been reported to be a significant factor for dysphagia[16,17], severe dysphagia is likely to result in a poor nutritional condition, as shown in Table 2.

In this study, the nutritional condition of individuals with CSCI was significantly correlated with dysphagia. Swallowing dysfunction due to CSCI decreases the amount of nutritional intake and can cause aspiration pneumonia[4], which exhausts physical energy. In these ways, dysphagia can cause malnutrition. In traumatic brain injury, most patients

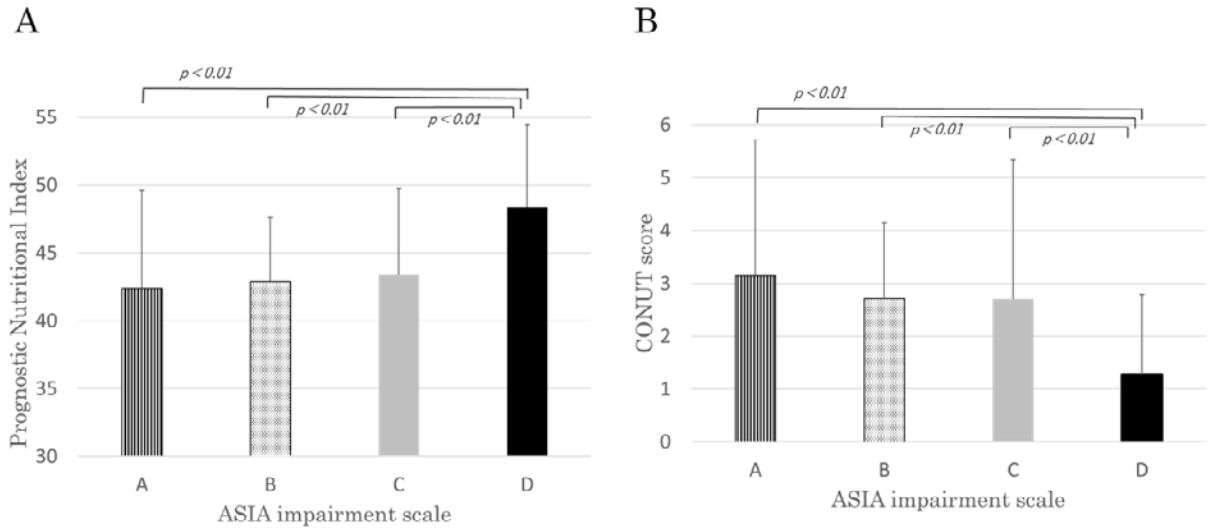

Figure 2. Prognostic nutritional index (A) and CONUT (B) score 3 months after injury in each AIS categorization at admission. The nutritional conditions 3 months after injury in individuals with an AIS categorization of D were significantly better than that in individuals with AIS categorizations of A, B, and C.
AIS: American Spinal Injury Association impairment scale; CONUT: controlling nutritional status

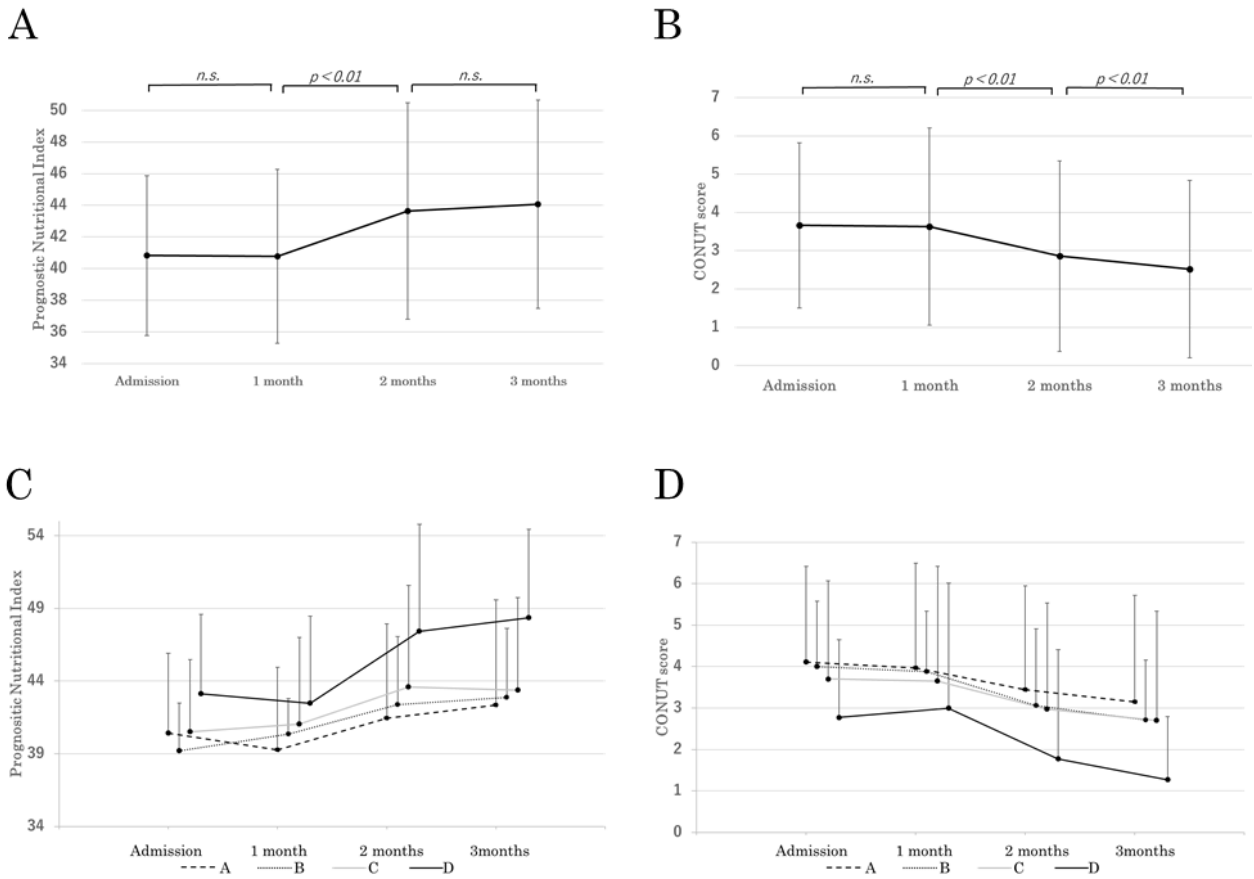

Figure 3. Time course of the nutritional condition. The nutritional condition, evaluated using PNI and CONUT scores (A, B), improved significantly from 1 month after the injury. PNI and CONUT scores within each AIS categorization (C, D) also gradually improved 3 months after the injury.
AIS: American Spinal Injury Association impairment scale; CONUT: controlling nutritional status; PNI, prognostic nutritional index

Table 2. Correlation Coefficients between Nutritional Condition and Dysphagia.

	1 month PNI/CONUT	2 months PNI/CONUT	3 months PNI/CONUT
DSS	0.40/–0.36	0.38/–0.35	0.45/–0.37
FOIS	0.61/–0.55	0.62/–0.53	0.57/–0.48

All the values were significantly correlated (P<0.001) using Spearman's rank correlation coefficient

Abbreviations: PNI, prognostic nutritional index; CONUT, controlling nutritional status; DSS, dysphagia severity scale; FOIS, functional oral intake scale

develop moderate dysphagia immediately after the removal of the nasogastric tube. However, thereafter, the percentage of persons recovering from dysphagia increases, and the serum albumin levels of patients with dysphagia significantly improve[18]. Therefore, proper dietary patterns should be considered depending on the degree of dysphagia in individuals with CSCI to avoid undernutrition in the acute phase.

This study has a limitation. We followed only individuals with acute CSCI. Although obesity and overweight are metabolic concerns in individuals with chronic CSCI[2], our study demonstrated undernutrition in the acute phase. Therefore, future studies must investigate nutritional changes from the acute to the chronic phase.

In clinical practice, medical care providers should pay attention to undernutrition due to dysphagia to prevent pneumonia[4] or other infections following CSCI. This is because individuals with CSCI are vulnerable to malnutrition and immunological risks. Additionally, as the activities of daily living may improve because of a good nutritional condition[6], frequent nutritional controls may play an important role in enhancing the potential for recovery after the injury.

In conclusion, the nutritional condition showed significant gradual improvements from 1 month after the injury. The nutritional condition at 3 months after injury in individuals with mild paresis was significantly better than in those with severe paresis. However, undernutrition was significantly correlated with severe dysphagia. Therefore, attention should be paid to undernutrition, which is associated with dysphagia, especially in individuals with severe paralysis in the acute phase following injury.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest. The submitted manuscript does not contain any information about medical device(s)/drug(s).

Sources of Funding: Dr. Hayashi's work was supported by the Japan Society for Promotion of Science (JSPS; KAKENHI Grant No. 19K19861), and by a medical research grant on traffic accidents from The General Insurance Association of Japan. These funders had no role in the design, conduct, or reporting of this work.

Author Contributions: TH was responsible for designing the study, writing the protocol and reporting, extracting and analyzing data, screening potentially eligible studies, interrupting results, updating reference lists, and creating "Summary of Findings" tables. YF was responsible for designing the study, conducting the literature search, extracting and analyzing data, and screening potential eligible studies. MM contributed to designing the study and interpreting results. KK contributed to designing the study and interpreting the results. HS contributed to designing the study and extracting data. OK contributed to interpreting the results. YM contributed to interpreting the results. KY contributed to interpreting the results and extracting data. TM contributed to interpreting the results as well as providing feedback on the final version of the manuscript.

Ethical Approval: The study protocol was approved by the Institutional Review Board of the Spinal Injuries Center (Fukuoka Japan).

Informed Consent: All participants provided written informed consent before participating in the study.

References

1. National Spinal Cord Injury Statistical Center. Annual Statistical Report for the Spinal Cord Injury Model Systems. December 2020 ed. University of Alabama at Birmingham, Birmingham, AL, 2020.
2. Wong S, Kenssous N, Hillier C, et al. Detecting malnutrition risk and obesity after spinal cord injury: a quality improvement project and systematic review. Eur J Clin Nutr. 2018;72(11):1555-60.
3. Hayashi T, Fujiwara Y, Ariji Y, et al. Mechanism of dysphagia after acute traumatic cervical spinal cord injury. J Neurotrauma. 2020;37(21):2315-9.
4. Hayashi T, Fujiwara Y, Kawano O, et al. Incidence and risk factors of pneumonia following acute traumatic cervical spinal cord injury. J Spinal Cord Med. 2022:1-7. Online ahead of print.
5. Lynch AC, Palmer C, Lynch AC, et al. Nutritional and immune status following spinal cord injury: a case controlled study. Spinal Cord. 2002;40(12):627-30.
6. Tanaka M, Momosaki R, Wakabayashi H, et al. Relationship between nutritional status and improved ADL in individuals with cervical spinal cord injury in a convalescent rehabilitation ward. Spinal Cord. 2019;57(6):501-8.
7. Onodera T, Goseki N, Kosaki G. [Prognostic nutritional index in gastrointestinal surgery of malnourished cancer patients.] Nihon Geka Gakkai Zasshi. 1984;85(9):1001-5. Japanese.
8. Shirakabe A, Hata N, Kobayashi N, et al. The prognostic impact of malnutrition in patients with severely decompensated acute heart failure, as assessed using the prognostic nutritional index (PNI) and Controlling Nutritional Status (CONUT) score. Heart Vessels. 2018;33(2):134-44.
9. Ignacio de Ulíbarri J, González-Madroño A, de Villar NG, et al. CONUT: a tool for controlling nutritional status. First validation in a hospital population. Nutr Hosp. 2005;20(1):38-45.
10. Han X, Cai J, Li Y, et al. Baseline objective malnutritional indices as immune-nutritional predictors of long-term recurrence in patients with acute ischemic stroke. Nutrients. 2022;14(7):1337.
11. Kirshblum SC, Burns SP, Biering-Sorensen F, et al. International

standards for neurological classification of spinal cord injury (revised 2011). J Spinal Cord Med. 2011;34(6):535-46.
12. Pongpipatpaiboon K, Iy AY, Shibata S, et al. Clinical evaluation of dysphagia. 1st ed. (Germany): Springer, 2018. Inamoto Y, Kagaya H (eds). Dysphagia Evaluation and Treatment. Saitoh E PK. p. 35-98.
13. Crary MA, Mann GD, Groher ME. Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. Arch Phys Med Rehabil. 2005;86(8):1516-20.
14. Gubari MIM, Norouzy A, Hosseini M, et al. The relationship between serum concentrations of pro- and anti-inflammatory cytokines and nutritional status in patients with traumatic head injury in the Intensive Care Unit. Medicina (Kaunas). 2019;55(8):486.
15. Dufoo M, Jr., Oseguera AC, Dufoo-Olvera M, et al. Metabolic changes and nutritional status in the spinal cord injured patient ASIA A. Evaluation and monitoring with routine laboratories, a feasible option [in Spanish]. Acta Ortop Mex. 2007;21(6):313-7.
16. Hayashi T, Fujiwara Y, Sakai H, et al. Risk factors for severe dysphagia in acute cervical spinal cord injury. Spinal Cord. 2017;55(10):940-3.
17. Seidl RO, Nusser-Müller-Busch R, Kurzweil M, et al. Dysphagia in acute tetraplegics: a retrospective study. Spinal Cord. 2010;48(3):197-201.
18. Kim H, Suh Y. Changes in the dysphagia and nutritional status of patients with brain injury. J Clin Nurs. 2018;27(7-8):1581-8.