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ORIGINAL ARTICLE

Relationship Between Subcortical Hemorrhage Size and Characteristics of Dysphagia

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Abstract
The subcortex is an important region in terms of swallowing function that passes fibers from the swallowing center to the cortex. However, studies on the relationship between the hemorrhage size and characteristics of dysphagia were lacking. In the present study, the relationship between subcortical hemorrhage size and characteristics of dysphagia was assessed in patients with subcortical hemorrhage. This study recruited retrospectively 49 subcortical hemorrhage patients with dysphagia. The hemorrhage size was measured and the clinical dysphagia scale (CDS) was used to evaluate the severity of dysphagia. The relationship between CDS score and hemorrhage size was analyzed. Subjects were divided into 2 groups according to average hemorrhage size of the subjects. The CDS scores of the 2 groups were compared and the relationship between each CDS item and hemorrhage size was analyzed. A significant positive correlation was observed between hemorrhage size and total CDS score. Also, a significant correlation was observed when patients over 70 years of age were excluded. The total CDS score in the large hemorrhage group was significantly higher than the CDS score in the small hemorrhage group. The CDS items including tracheostomy, lip sealing, tongue protrusion, laryngeal elevation, and reflex coughing were significantly correlated with hemorrhage size. In this study, the hemorrhage size in patients with subcortical hemorrhage correlated with the severity of dysphagia. In addition, the hemorrhage size was correlated with specific CDS items. These findings should be considered when treating subcortical hemorrhage patients with dysphagia in a clinical setting.

Keywords Subcortical hemorrhage · Dysphagia · Clinical dysphagia scale (CDS)

Abbreviations

CDS	Clinical dysphagia scale
CT	Computed tomography
VFSS	Videofluoroscopic swallowing study
IQR	Interquantile range

Introduction

Dysphagia is a common complication of stroke. The incidence of dysphagia after stroke ranges from 23% to 50% according to numerous previous studies [1]. Additionally, dysphagia following stroke increases the risk of aspiration pneumonia [2, 3] which causes an approximate 6-fold increase in patient mortality [4].

Most of the previous research regarding dysphagia following stroke attempted to clarify the relationship between location of stroke lesion and clinical characteristics of dysphagia. According to the previous studies, swallowing dysfunction was associated with MCA territory stroke as well as involvement of the brain stem [5, 6]. Left cortical stroke was associated with an increased risk of oral dysfunction and right cortical stroke was associated with an increased risk of pharyngeal dysfunction [7]. Additionally, the impairment of tongue movement was more associated with involvement of the frontal lobe than the parietotemporal lobe [7, 8]. Buccofacial apraxia was associated with supratentorial lesions and dysfunction of the upper esophageal opening was associated with brain stem lesions [9].

The subcortex, especially the basal ganglia, is an important region in the neural pathway controlling swallowing function which passes from the brainstem as

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swallowing center to the cortex [10]. The previous studies have shown that subcortical region plays an important role in the control of swallowing function [11]. Additionally, basal ganglia stroke was associated with buccofacial apraxia [9] and can progress to pneumonia due to frequent aspiration [12].

As mentioned above, the relationship between location of stroke lesion and clinical characteristics of dysphagia was relatively well reported. However, studies regarding the correlation between stroke lesion size and characteristics of dysphagia were lacking. Paciaroni et al. reported that stroke lesion size was the most important factor for the incidence of dysphagia rather than location of stroke lesion and reported that dysphagia was more frequent in patients with hemorrhagic stroke [6]. However, most of the previous researches regarding dysphagia after stroke were conducted with cerebral infarction patients and studies with hemorrhagic stroke patients were limited.

In the present study, the relationship between subcortical hemorrhage size and clinical characteristics of dysphagia was investigated. Numerous techniques have been introduced to measure the volume of brain hemorrhage [13–16]. Kothari et al. found the simple formula ABC/2 can accurately estimate intraparenchymal hemorrhage volume within 1 minute. This measurement correlated significantly with the volume calculated using planimetric methods for all hemorrhage locations [17]. The derivation of the ABC/2 formula is as follows: The simplified formula for the volume of an ellipsoid is '$4/3 \times \pi \times (A/2)(B/2)(C/2)$,' where A, B, and C are the 3 diameters as length, width, and height, respectively. If π is estimated to be 3, then the volume of an ellipsoid becomes $ABC/2$. In this study, we measured the hemorrhage size using the simplified formula for the volume of an ellipsoid: $4/3 \times \pi \times (\boldsymbol{A}/2)(\boldsymbol{B}/2)(\boldsymbol{C}/2)$ instead of the $\boldsymbol{ABC}/2$ formula. When measuring the hemorrhage size, π was estimated to be 3.14 for more accurate measurement.

In this study, we hypothesized that a large subcortical hemorrhage size was associated with poor swallowing function. And, we hypothesized that swallowing dysfunction in subcortical hemorrhage might appear as a characteristic dysphagic pattern different from other lesions through CDS.

Methods

Subjects

The present study retrospectively reviewed the electric medical records and recruited 49 subjects who visited our hospital from January 2010 to June 2016 for rehabilitation treatment of dysphagia in the acute phase of subcortical hemorrhage and were evaluated. Subcortical hemorrhage was identified based on brain computed tomography (CT). Concurrent with brain CT, each subject was evaluated using a clinical dysphagia scale (CDS) test conducted by trained clinicians.

Individuals who met the following criteria were included: (1) a first stroke episode with dysphagia within 6 months, (2) subcortical hemorrhage confirmed on brain CT, and (3) good compliance in performing the CDS test. Exclusion criteria included a history of traumatic brain injury, previous brain surgery, poor mental status, or inability to perform the CDS test due to severely impaired cognition.

Measurement of Hemorrhage Size

In this study, 1 physician measured hemorrhage size using the simplified formula for the volume of an ellipsoid (Fig. 1). The radiuses of length, height, and width axis were measured on brain CT images using StarPACS Piview Star 5.0.8.1 software (INFINITT Co, Ltd, Seoul, Korea). And π was estimated to be 3.14.

Clinical Evaluation of Dysphagia

The CDS test consisting of 8 items was used to evaluate the severity of dysphagia. The CDS is a dysphagia rating scale that can be easily conducted at bedside [18]. The CDS can predict the possibility of aspiration more precisely and quantify the severity of dysphagia [19]. The CDS test showed excellent sensitivity and specificity and had a significant correlation with videofluoroscopic swallowing study (VFSS) findings [20].

The 8 CDS evaluating items included lesion location, tracheostomy, history of aspiration, lip sealing, chewing and mastication, tongue protrusion, laryngeal elevation, and reflex coughing [18]. Lesion location was confirmed using brain CT findings. The patients were examined for tracheostomy by inspection. The physician evaluated the history of aspiration by asking the patient or caregiver in detail whether the patient had experienced suspicious symptoms of aspiration (e.g., reflex coughing or choking) during the past week. If the patient had not attempted swallowing certain foods or liquids during past week due to nasogastric tube feeding or total parenteral nutrition, this item could not be evaluated. The physical examination was performed to assess the function of lip sealing, chewing and mastication, tongue protrusion, and laryngeal elevation. These items were evaluated according to 3 choices such as intact, inadequate, and none. The patient can take 3 mL of sterile water twice to examine if the patient had a reflex cough. The maximum score on the CDS test that included these 8 rating items was 100 points [19]. A higher

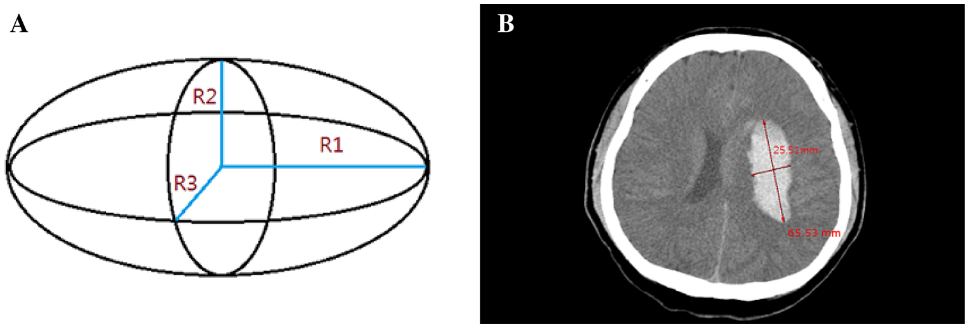

Fig. 1 Subcortical hemorrhage size was estimated using the simplified formula for the volume of an ellipsoid. **a** The simplified formula for the volume of an ellipsoid is $V = 4/3 \times \pi \times (R1 \times R2 \times R3)$ (*V* volume of an ellipsoid, *R1* length axis radius, *R2* height axis radius, *R3* width axis radius). **b** Brain CT image of left subcortical hemorrhage

CDS score is considered an increased risk for aspiration and severity of dysphagia.

Statistical Analysis

Continuous variables were expressed as mean ± SD, median, and interquantile range (IQR). The CDS score was used to evaluate the relationship between subcortical hemorrhage size and severity of dysphagia. The correlation between the CDS score and the hemorrhage size was assessed using Spearman's correlation. Patients were divided into a large or small hemorrhage group according to average hemorrhage size. The independent *t* test was used to compare CDS scores between the 2 groups. Additionally, the correlation between each CDS item and the hemorrhage size was assessed using Spearman's correlation (r_s). Data were analyzed using SPSS 22.0. Statistical significance was set at $p = 0.05$.

Results

Study participants included 32 males and 17 females between 33 and 93 years of age. The frequency of subcortical hemorrhage on both sides was similarly distributed. The mean total CDS score for all subjects was 17.43 and the mean hemorrhage size was 44.40 cm^3 (Table 1).

Table 1 Demographics and clinical characteristics of study participants

Variable	Participants ($n = 49$)
Age (mean ± SD), years	60.8 ± 13.1
Range, years	33–93
Sex (F/M), *n*	17/32
Lesion location (Rt./Lt.), *n*	25/24
Total CDS score (mean ± SD)	17.43 ± 19.32
Hemorrhage size (mean ± SD), cm^3	44.40 ± 44.42

SD Standard deviation, *CDS* clinical dysphagia scale

Correlation Between Hemorrhage Size and Total CDS Score

Based on Spearman's correlation, a significant positive correlation was observed between subcortical hemorrhage size and total CDS score ($r_s = 0.531$, p value < 0.001). Additionally, a strong correlation was observed in subjects under 70 years of age ($r_s = 0.650$, p value < 0.001; Table 2). For reference, the average hemorrhage size and the average total CDS score in 2 groups categorized by aged 70 years are shown in Table 2.

Subjects were divided into 2 groups according to the average subcortical hemorrhage size (44.40 cm^3), large hemorrhage group ($n = 20$) and small hemorrhage group ($n = 29$). The large hemorrhage group consisted of patients with hemorrhage size greater than or equal to 44.40 cm^3. The median hemorrhage size and median CDS score in the 2 groups are presented in Table 3. According to independent *t* test, the total CDS score in the large hemorrhage group was significantly higher than the total CDS score in the small hemorrhage group (p value = 0.008).

Correlation Between Hemorrhage Size and Each CDS Item

Among the CDS items, tracheostomy, lip sealing, tongue protrusion, laryngeal elevation, and reflex coughing were significantly correlated with hemorrhage size (p value < 0.05; Table 4). In particular, tracheostomy, tongue protrusion, and laryngeal elevation had significantly moderate correlation with hemorrhage size based on Spearman's rho. However, aspiration, chewing and mastication did not show a statistically significant correlation with hemorrhage size in the present study.

Table 2 Hemorrhage size, total CDS score, and correlation between hemorrhage size and total CDS score in the subgroups

Group	Hemorrhage size, (mean ± SD), cm^3	Total CDS score (mean ± SD)	Correlation coefficient (r)	
Total subjects ($n = 49$)	44.40 ± 44.42	17.43 ± 19.32	r_s	0.531
			p value	< 0.001
Under aged 70 years ($n = 35$)	52.84 ± 49.51	23.31 ± 14.30	r_s	0.650
			p value	< 0.001
Aged 70 years and older ($n = 14$)	17.69 ± 21.43	16.79 ± 13.25	–	

SD Standard deviation, *CDS* clinical dysphagia scale

Table 3 Hemorrhage size and total CDS score in the 2 groups categorized by hemorrhage size

Variable	Large hemorrhage group ($n = 20$)	Small hemorrhage group ($n = 29$)
Hemorrhage size (median [IQR]), cm^3	70.67 [58.26–98.05]	14.23 [7.66–25.01]
Total CDS score (median [IQR])	22 [6.5–48.25]	6 [0–16.5]

CDS Clinical dysphagia scale, *IQR* interquantile range

Table 4 Correlation between hemorrhage size and each CDS item

CDS item	Subjects ($n = 49$)	Correlation coefficient (r)	p value
Lesion location	Subcortex	N/A	N/A
Tracheostomy	42/7 (no/yes)	0.408	0.002**
History of aspiration	35/14 (no/yes)	0.172	0.118
Lip sealing	25/21/3 (intact/inadequate/none)	0.326	0.011*
Chewing and mastication	25/20/4 (intact/inadequate/none)	0.193	0.092
Tongue protrusion	27/17/5 (intact/inadequate/none)	0.444	0.001**
Laryngeal elevation	24/21/4 (intact/inadequate/none)	0.421	0.001**
Reflex coughing	44/5 (no/yes)	0.300	0.018*

CDS Clinical dysphagia scale, *N/A* not applicable

*p value < 0.05; **p value < 0.01

Discussion

Swallowing disorder is a common complication in acute stroke patients; however, the mechanism of swallowing function remains unclear. The previous anatomic studies have identified several sites important for swallowing function, including the primary sensorimotor cortices, insula, anterior cingulate, internal capsule, basal ganglia, and thalamus [21–24]. Daniels and Foundas established an anatomic model of swallowing function defined as a distributed neural pathway involving bilateral input from the sensorimotor cortex to the medulla oblongata known as swallowing center [21]. Disruption of this distributed neural pathway, specifically cortical and subcortical white matter connecting region, appeared to increase the risk of dysphagia and aspiration by lowering the threshold of input to the medullary swallowing center [25]. Therefore, the subcortex is an important region in the anatomic model of swallowing function defined as a neural pathway that passes from the sensorimotor cortex to the swallowing center. These findings were also seen in other previous studies [10, 25].

The results from the present study showed that hemorrhage size was significantly associated with total CDS score in patients with subcortical hemorrhage. The CDS score indicates the severity of dysphagia, and therefore subcortical hemorrhage size was significantly correlated with the severity of dysphagia. As mentioned above, the subcortex is an important region implicated in swallowing control; thus, a larger subcortical hemorrhage size was possibly associated with more severe dysphagia.

The CDS items associated with subcortical hemorrhage size included tracheostomy, lip sealing, tongue protrusion, laryngeal elevation, and reflex coughing. In particular, tracheostomy, tongue protrusion, and laryngeal elevation had significantly moderate correlation with subcortical hemorrhage size.

Steinhagen et al. reported that basal ganglia stroke was associated with buccofacial apraxia [9] and Cola et al. reported that a specific swallowing impairment, longer oral transit time, was associated with subcortical stroke [25]. These findings are consistent with our study findings showing a relationship between subcortical hemorrhage size and concrete oral phase function such as lip sealing and tongue protrusion.

Lee et al. reported that discoordination of the tongue, oropharynx, and laryngopharynx was predominant in the subcortical lesion rather than brainstem lesion groups [26]. Cola et al. reported that subcortical lesions were also associated with larger vallecular residue in addition to longer oral transit time. Vallecular residue is generally associated with decreased base of tongue retraction. Tongue base retraction can be considered part of the pharyngeal phase in swallowing function [25]. Consequently, subcortical lesions have an adverse effect on the pharyngeal phase as well as the oral phase of the swallowing function. Therefore, the results from the present study showing that tracheostomy, laryngeal elevation, and reflex coughing were associated with the subcortical hemorrhage size are plausible.

The history of aspiration was not significantly associated with subcortical hemorrhage size. This result might be due to the fact that the item, history of aspiration, was subjective and could not be measured exactly. Although the history of aspiration item was subjective, we sought to obtain objective findings by asking patients or caregiver about definite aspiration event in detail.

Besides that, a multivariable association between various factors should be considered when interpreting the result of this study. For example, laryngeal elevation might be more affected in patients who have tracheostomy. In this regard, we could not use a multivariate analysis because the data did not follow a normal distribution. This is one of the limitations in the present study and could act as a bias to the result.

In the previous studies regarding dysphagia after stroke, the relationship between location of stroke lesion and clinical characteristics of dysphagia was the main focus. However, studies focusing on the relationship between stroke lesion size and characteristics of dysphagia were limited. In several previous studies, dysphagia and aspiration in patients with stroke were independent of stroke size [21, 27]. Conversely, Paciaroni M. et al. reported that the most important factor for dysphagia following stroke was lesion size rather than lesion location [6]. According to the result of the present study, subcortical hemorrhage lesion size was associated with dysphagia severity. Particularly, the relationship between lesion size and severity of dysphagia in the subcortex, which is important for swallowing function, was significant.

Most previous studies investigating dysphagia after stroke included ischemic stroke rather than hemorrhagic stroke patients. Paciaroni et al. reported that dysphagia was more frequent in patients with hemorrhagic stroke [6] which may be related to stroke severity because swallowing difficulty is associated with high fatality and poor functional outcome. The study by Paciaroni M. et al. is the only previous report focusing on patients with hemorrhagic stroke and the relationship between stroke lesion size and dysphagia severity. Therefore, the present study contributes needed confirmation of the previous study.

In this study, dysphagia was assessed using the CDS test which can be easily performed at bedside. The CDS test is an adequate screening tool that can be easily applied in dysphagia treatment for reliable detection of dysphagia and for the selection of patients who should receive VFSS [19]. Additionally, the CDS, which was developed to screen dysphagia after stroke, correlated with the VFSS findings in various disease groups [20]. In the previous study, correlations between the CDS and VFSS findings were evident for all disease and age groups, indicating the CDS correlated with the clinical findings of dysphagic patients irrespective of the causal disorders or patient age [28]. In this regard, the CDS is regarded as an objective test to be applied for patients with dysphagia in clinical practice. Therefore, the result of this study using the CDS might be valuable.

However, Splaingard et al. reported that only 42% of the patients who manifested aspiration on VFSS were diagnosed with abnormalities using the bedside CDS test [29]. According to this previous study, the severity of dysphagia can be underestimated based on the CDS test because VFSS can evaluate the existence of aspiration and impairment of oral, pharyngeal, and laryngeal swallowing stages more sensitively and quantitatively. However, to date, no report exists focusing on the relationship between CDS items and subcortical hemorrhage size, and to the best of our knowledge, the present study is the first report.

Several studies have been performed using VFSS for stroke patients with dysphagia. If the relationship between cerebral hemorrhage size and clinical characteristics of dysphagia is shown using VFSS rather than the CDS test in further study, then defining management strategies that will improve patient swallowing safety or efficiency can be more helpful clinically. Also, it would be better to investigate the relationship between hemorrhage size and other residual deficits in addition to dysphagia in further study.

Study Limitations

The present study had several limitations. First, the sample size was small. Second, a selection bias existed because only subjects who could perform the CDS test were included. In many patients with stroke, evaluating swallowing function using the CDS test is difficult; therefore, our sample might not be representative of the general subcortical hemorrhage population. Third, some items of CDS can be subjective and the CDS was not conducted by the same clinician. However, the CDS showed excellent inter-rater agreement according to the previous study [19]. Fourth, multivariable association between various factors should be considered because it can be a potential cause of bias. Finally, several patients had already received swallowing rehabilitation treatment and this might have affected the results.

Conclusions

In this study, the hemorrhage size in patients with subcortical hemorrhage correlated with the severity of dysphagia. In addition, the hemorrhage size correlated with insertion of a T-cannula, impairment of lip sealing, tongue protrusion, laryngeal movement, and reflex coughing. These findings should be considered when treating subcortical hemorrhage patients with dysphagia.

Compliance with ethical standards

Conflicts of interest The authors declare no conflicts of interest.

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