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The effect of radionuclide solution volume on the detection rate of salivary aspiration in the radionuclide salivagram

A STROBE-compliant retrospective study

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Abstract

Despite the possibility that the methodological difference of this salivagram may influence the results for detection rate, there has been no study on the effect of the solution volume on detection rate. Moreover, to date, since the introduction of the nucleotide salivagram, there has been a tendency that a constant solution volume and nucleotide dose is not used in studies. Therefore, the aim of this study is to investigate the effect of solution volume on the detection rate of a salivagram in patients with brain lesion, and to determine the optimal solution volume of salivagram. We retrospectively reviewed clinical data and solution volume of radionuclide used in the salivagram of 77 patients with dysphagia, and the patients were divided into 2 groups according to the solution volume of the radionuclide (Group A-0.1 mL vs Group B-0.5 mL). Although, there was no significant difference between 2 groups in clinical data, there was a statistically significant difference in the detection rate of salivary aspiration between the 2 groups (3.3% vs 19.1%). Even a small difference of the solution volume of radionuclide in salivagram can affect the detection rate of salivary aspiration in patients with brain lesion. Further study with various solution volumes of radionuclide is warranted to determine the optimal solution volume of the radionuclide salivagram.

Abbreviations: DTPA = diethylenetriamine pentaacetic acid, GDS = Global Deterioration Scale, MBI = Modified Barthel Index, MMSE = mini mental state examination, PAS = penetration-aspiration scale, TBI = traumatic brain injury, VFSS = videofluoroscopic swallowing study.

Keywords: aspiration, deglutition, drooling, dysphagia, salivary glands

1. Introduction

Previous studies have reported that pneumonia is one of the major complications, which can be a cause of death especially in patients with oropharyngeal dysphagia owing to brain lesions, such as stroke and traumatic brain injury (TBI).[1–4] For diagnosing and evaluating dysphagia, VFSS is the gold standard in clinical practice.[5–7] However, a radionuclide salivagram is known to be a more useful tool for detecting salivary aspiration, which is another important cause of aspiration pneumonia, compared with the videofluoroscopic swallowing study (VFSS).[8–10]

The radionuclide salivagram involves placing a small volume of radionuclide in the patient's mouth, and then a series of images record radioactivity in the bronchial tree, thereby showing salivary aspiration.[8–12] However, in previous studies using a salivagram, there have been several conflicting results in the detection rate of salivary aspiration for patients with brain lesions. Baikie et al[13] reported that positive findings of aspiration of salivary aspiration occurred with 55.6% (35/63) of bedridden spastic quadriparetic cerebral palsy patients. However, Wu and Zhao[14] reported that the positive response of saliva aspiration by radionuclide salivagram was 21.9% (7/32) in bedridden patients with brain lesion. Although the patients included in these studies were different, these conflicting results may be due to differences in the methods of implementing salivagrams as well as differences in the patient population involved.

In Baikie's study, they performed the salivagram in the supine position and then 99mTc-sulfur solution (0.5–1 mCi in a 20 mL of normal saline) was instilled into the patient's mouth over 1 hour using a feeding tube.[13] In contrast, in Kang's study, they used a different volume of solution (1 mCi in only a drop of saline) which was instilled into the mouth while the patient was in the supine position during the salivagram.[14] Despite the possibility that the methodological difference of this salivagram may influence the results for detection rate, there has been no study on the effect of the solution volume on detection rate. Moreover, to date, since the introduction of the nucleotide salivagram by Heyman et al[9,10] in 1989, there has been a tendency that a constant solution volume and nucleotide dose is not used in studies.

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Therefore, to evaluate the effect of solution volume on the detection rate of a salivagram in patients with brain lesion and to determine the optimal solution volume of the radionuclide salivagram, we compared the detection rate of radionuclide salivagrams with varying solution volumes.

2. Materials and methods

2.1. Subjects

We retrospectively reviewed the medical records of 123 patients with dysphagia who underwent both radionuclide salivagrams and VFSS between March 2013 and January 2017. Among them, those with brain lesion, such as stroke, TBI, and hypoxic ischemic encephalopathy, were included. The following patients were excluded: those with neuromuscular disorders, spinal cord injury, and non-brain tumors. Patients were also excluded when the interval between the VFSS and the salivagram was >3 days. In addition, patients with insufficient medical records were also excluded. This study received Institutional Review Board approval of Daegu Fatima Hospital.

2.2. Clinical parameters

Sex, age, mini mental state examination (MMSE), Global Deterioration Scale (GDS), total score of Modified Barthel Index (MBI), and each subscore of MBI were reviewed.

2.3. VFSS

The VFSS were performed using sequential swallowing of the following materials mixed with barium: thin fluids, thick fluids, pureed rice, and solids. Patients were evaluated in an upright seated position and were not instructed about any compensation techniques. The dynamic fluoroscopic images were obtained at the lateral and anterior–posterior positions, stored at 30 frames per second. The dynamic fluoroscopic images were reviewed by experienced 2 physicians. The degree of aspiration during VFSS was described using penetration-aspiration scale (PAS). (Table 1).

2.4. Radionuclide salivagram

In radionuclide salivagram, patients were evaluated in a supine position under the gamma camera. All salivagram conducted in the department of nuclear medicine at our hospital. Tc-99m diethylenetriamine pentaacetic acid (DTPA) (3 mCi) was mixed with a different volume of normal saline (0.1 and 0.5 mL) and solution was administered into the mouth using a syringe. Sequential supine posterior images were obtained for 2 hours routinely; at 1, 5, 10, 20, 30, and 60 minutes after the instillation, images were taken by the gamma camera. Visual interpretation of the images was performed by an experienced nuclear medicine physician. Aspiration was reported to be present when radiopharmaceutical activity was detected in tracheobronchial fields (Fig. 1).

2.5. Reliability of VFSS and radionuclide salivagram

To assess the inter-rater reliability of VFSS, the PAS of VFSS was analyzed by 2 experienced physiatrists. In addition, radionuclide salivagram was re-analyzed by a physiatrist who blinded to results of salivagram, and the results were compared with salivagram analysis of a nuclear medicine physician to assess the inter-rater reliability of the radionuclide salivagram. The inter-rater reliability (Crombach α value) of PAS was measured as 0.987, and that of the radionuclide salivagram was measured as 0.998.

3. Results and analysis

3.1. Statistical analysis

The comparison between the 2 groups was performed with either an independent sample *t* test or a Wilcoxon sum test, depending on the distribution of the continuous variables. A Chi-squared test was used to assess the independence of the categorical variables. Statistical analyses were performed using SPSS software, version 22.0 (SPSS, Chicago IL).

3.2. Patient characteristics

In total, 77 patients with brain lesion were enrolled in the study, with an average age of 70.36 ± 12.07 years. Of these, 47 (61.0%) were men and 30 (39.0%) were women (Table 2). Of 77 patients with brain lesion, there were 67 patients with stroke (87.0%), 4 patients with TBI (5.20%), 1 patient with a brain tumor (1.30%), and 2 patients with hypoxic ischemic encephalopathy (HIE) (2.60%).

In group A (n = 47), there were 40 patients with stroke (85.1%), 2 patients with TBI (4.26%), 1 patient with a brain tumor (2.13%), 2 patients with HIE (4.26%), and 2 patients with Parkinson disease (4.26%). In group B (n = 30), there were 27 patients with stroke (90.0%), 2 patients with TBI (6.67%), and 1 patient with Parkinson disease (3.33%).

The duration of dysphagia onset was 5.25 ± 21.10 months in group A, and 2.18 ± 1.92 month in group B. However, there was no significant difference between groups A and B ($P < .05$)

3.3. Comparison of results of VFSS

In group A, there were 3 patients with penetration in VFSS (10.0%), and 27 patients with aspiration on VFSS (90.0%). In

Table 1

The penetration-aspiration scale (PAS).

Category	Score	Description
Negative	1	Material does not enter the airway
Penetration	2	Material enters the airway, remains above the vocal folds, and is ejected from the airway
	3	Material enters the airway, remains above the vocal folds, and is not ejected from the airway
	4	Material enters the airway, contacts the vocal folds, and is ejected from the airway
	5	Material enters the airway, contacts the vocal folds, and is not ejected from the airway
Aspiration	6	Material enters the airway, passes below the vocal folds and is ejected into the larynx or out of the airway
	7	Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort
	8	Material enters the airway, passes below the vocal folds, and no effort is made to eject

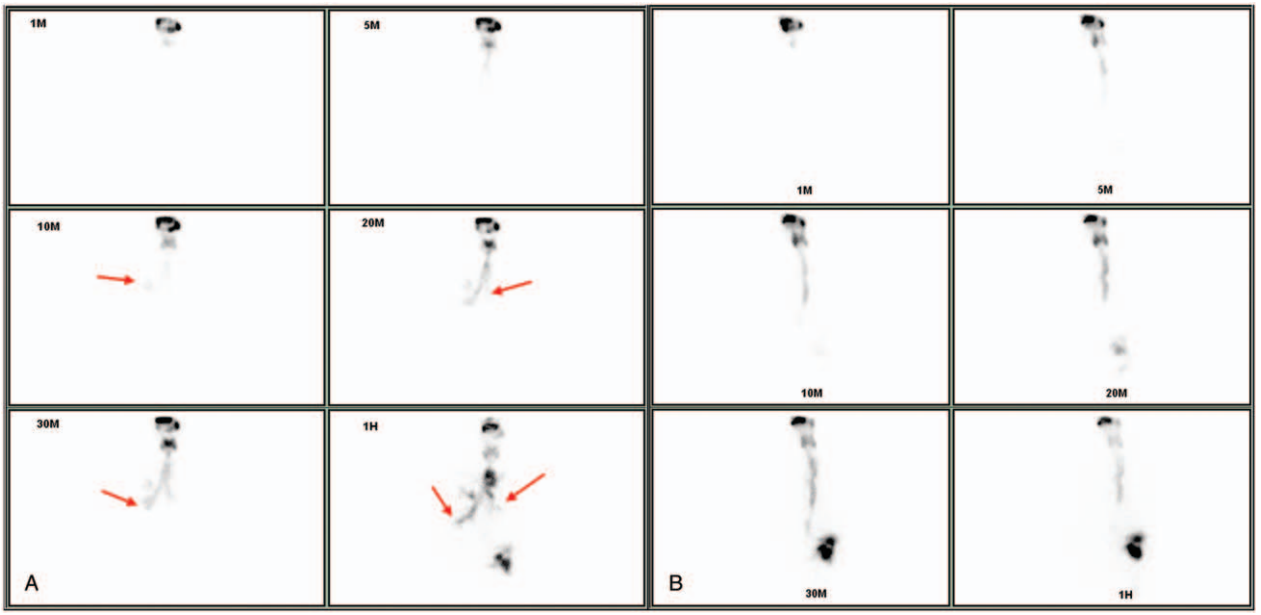

Figure 1. Sequential images of radionuclide salivagram throughout 1 hour after oral administered of technetium 99m sulfur colloid solution. (A) The presence of radiotracer in trachea and bilateral bronchi demonstrates positive for salivary aspiration (arrows). (B) Uptake of radiotracer noted only in oropharynx, esophagus and stomach demonstrate negative for salivary aspiration.

group B, there were 8 patients with penetration in VFSS (17.0%), and 39 patients with aspiration on VFSS (83.0%). The PAS of group A was 6.50 ± 1.23, and the PAS of group B was 6.26 ± 1.73 (Table 2). However, there was no significant difference between the 2 groups in PAS ($P > .05$).

Table 2

Patient characteristics and comparison of the patients in the 2 groups.

Characteristic	Group A (n = 30)	Group B (n = 47)	*P*-value
Age, y	69.10 ± 12.23	71.09 ± 12.12	.487
Sex			
Male	24	23	
Female	6	24	
Duration of dysphagia, d	208.17 ± 595.11	102.81 ± 463.05	.420
Duration of dysphagia, mo	5.25 ± 21.10	2.18 ± 1.92	.321
PAS	6.50 ± 1.23	6.26 ± 1.73	.483
MMSE	12.00 ± 10.19	9.15 ± 9.82	.369
GDS	5.13 ± 1.89	5.44 ± 1.45	.550
MBI score			
Total MBI score	31.64 ± 27.15	16.04 ± 21.21	.068
Personal hygiene	1.91 ± 1.92	1.20 ± 1.500	.239
Bathing	1.82 ± 1.60	0.88 ± 1.36	.080
Feeding	3.45 ± 3.70	2.12 ± 2.98	.258
Toilet	3.36 ± 3.30	1.44 ± 2.02	.095
Stair climbing	0.45 ± 1.51	0.52 ± 1.85	.919
Dressing	3.91 ± 3.27	1.68 ± 2.41	.060
Defecation	5.51 ± 4.01	3.08 ± 4.22	.191
Voiding	3.91 ± 4.35	1.80 ± 3.42	.126
Ambulation	1.91 ± 3.62	1.28 ± 2.91	.583
Wheelchair	0.32 ± 0.92	0.24 ± 0.44	.586
Chair/bed transfer	5.36 ± 4.76	2.44 ± 3.04	.082

Values are presented as mean ± standard deviation.
GDS = Global Deterioration Scale, MBI = Modified Barthel Index, MMSE = mini-mental state examination, PAS = penetration-aspiration scale.

3.4. Comparison of clinical variables between 2 groups based on solution volume

There was no significant difference between the 2 groups in areas such as age, MMSE, GDS, MBI, and history of aspiration pneumonia, except for the sex ratio ($P > .05$). However, there was a statistically significant difference in detection rate of salivary aspiration between group A (3.3%, 1/30) and group B (19.1%, 9/47) in the Chi-squared test ($P < .05$).

4. Discussion

To the best of our knowledge, there is no research investigating the difference in detection rate in salivary aspiration by radionuclide solution volume in radionuclide salivagrams. Salivary aspiration refers to saliva that is spilled over the tongue through the faucial isthmus.[8] It can lead to substantial respiratory morbidity, including unexplained lung diseases and recurrent pneumonia.[8] Although VFSS is a very important tool for evaluating aspiration of food and liquids, it may not detect salivary aspiration. Therefore, the radionuclide salivagram may have an important role in assessing the cause of aspiration pneumonia, such as salivary aspiration, compared with VFSS.

Presently, however, there are no definite guidelines for solution volume in radionuclide salivagram. The previous studies about radionuclide salivagrams have not shown consistency, especially in solution volumes of radionuclide.[8–10,13] Therefore, despite the usefulness of the salivagram, it was not uncommon to find different conflicting results in the detection rate of salivary aspiration in previous studies. Interestingly, in the results of our study, the detection rate of the high solution volume group (0.5 mL) was significantly higher than that of the low solution volume group (0.1 mL). These results are probably due to the fact that an excessive volume of radionuclide tends to produce the same effect as swallowing thin water, rather than pure salivary aspiration.

In normal subjects, saliva secretion increases from 0.3 mL/min during un-stimulation to 1 to 2 mL/min during stimulation.[15,16]

Considering the amount of saliva secretion, it is believed that a large solution volume can induce a swallowing reaction and have a significant effect on the outcome of radionuclide salivarigram. Although additional research may be necessary to find an appropriate solution volume of nucleoclide in salivagrams, it seems necessary to minimize the solution volume in order to distinguish false positive salivary aspiration by the swallowing reaction due to a large amount of solution volume.

Our study has a few limitations. First, we could not compare solution volumes of various capacities: instead, only 2 solution volumes (0.1 mL vs 0.5 mL) were studied. So further prospective studies with more patients and various capacities of solution volume will be necessary to certify the results of our study. Second, this was a retrospective study with various diseases. Therefore, the effects of disease on the outcome of the salivagram could not be completely ruled out, although there were no significant differences in clinical variables, such as age, MMSE, GDS, total MBI score, PAS, and history of aspiration pneumonia between the 2 groups. However, it is obviously the first study which showed that solution volume may affect the results of a salivagram, so it seems to be sufficient as a preliminary study. Nevertheless, additional prospective research is considered to be necessary for patients with the same disease to completely eliminate the influence of diseases on salivagram results. In conclusion, even a small difference of the solution volume of radionuclide (0.1 mL vs 0.5 mL) in salivagram can affect the detection rate of salivary aspiration in patients with brain lesion. Therefore, it seems necessary to minimize the solution volume in order to distinguish false positive salivary aspiration caused by the swallowing reaction due to excessive solution volume. Further study with various solution volumes of radionuclide is warranted to establish the optimal solution volume of radionuclide salivagram.

Author contributions

Conceptualization: Jong Min Kim, Zeeihn Lee, Donghwi Park.
Data curation: Donghwi Park.
Writing – original draft: Dae Hee Lee, Donghwi Park.
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