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Original Article

Inter-rater and intra-subject reliability for the evaluation of swallowing kinematics using 320-row area detector computed tomography

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ABSTRACT
Inamoto Y, Kagaya H, Saitoh E, Kanamori D, Shibata S, Fujii N, Katada K, Palmer J B. Inter-rater and intra-subject reliability for the evaluation of swallowing kinematics using 320-row area detector computed tomography. Jpn J Compr Rehabil Sci 2012; 3: 59−65.
Objective: The purpose of this study was to examine the inter-rater reliability and intra-subject reproducibility of 320-row area detector computed tomography (320-ADCT) for the evaluation of swallowing kinematics.
Methods: Eleven healthy volunteers were each instructed to sit on a reclining chair set at a 45° angle, hold a 10-ml portion of honey-thick liquid in the mouth, and swallow it when cued by the examiner. Scanning was performed for 3.15 s using a 320-ADCT device. Images were reconstructed at an interval of 0.1 s. Two raters measured the timing of each swallowing event, and inter-class correlation coefficient (ICC) analysis was performed to examine the inter-rater reliability. One week later, the same trial was repeated for each volunteer, and the ICC was obtained to analyze the intra-subject reproducibility.
Results: Average inter-rater ICC was 0.98, showing 'almost perfect' concordance. There were no differences among measured items and volunteers. Average intra-subject ICC was 0.75, indicating 'moderate' concordance of swallowing kinematics between two swallows.
Conclusion: Given the high inter-rater reliability and intra-subject reproducibility, 320-ADCT is a reliable tool for swallowing evaluation.
Key words: 320-ADCT, inter-rater reliability, intra-subject reproducibility, swallowing evaluation

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Introduction

Accurate evaluation and appropriate management of dysphagia is essential for the prevention of aspiration and aspiration pneumonia, and is an integral part of improving the patient's quality of life. To determine the most effective swallowing treatment and set reasonable goals, it is important to identify potential causative factors and fully understand the physiological nature of the patient's swallowing dysfunction by employing therapy-oriented evaluation, a methodology that requires a high level of objectivity. Therapy-oriented evaluation is effective not only in constructing consistent treatment principles among the medical teams, and in maintaining direction throughout the rehabilitation process, but also in promoting early recovery of the patient's condition.

Videofluoroscopic (VF) study, recognized as the most reliable tool in this field, is presently the standard procedure for dysphagia evaluation [1]. VF is useful as it allows for therapy-oriented evaluation; however, the examiners must assess three-dimensional swallowing kinematics using two-dimensional fluoroscopic images. It has been pointed out that the examiners' experience and subjectivity may influence their assessment of the images, bringing into question the objectivity and reproducibility of the study results [2−4].

In 2010, Fujii et al. reported on a new swallowing evaluation method using 320-row area detector computed tomography (320-ADCT), which allows for dynamic and stereological analysis of swallowing [5]. As the most recent CT technology in the world, the 320-ADCT device is equipped with 320 rows of 0.5-mm detectors along the body axis, and can acquire a volume data set covering a maximum range of 16 cm in one revolution 0.35 s in duration. A 16-cm range can cover the area from the base of the skull to the upper esophagus, which is the area required for swallowing analysis. Three-dimensional images of the oral cavity, pharynx, larynx, and upper esophagus are reconstructed by single-phase scanning (one revolution) and continuous three-dimensional images in this range are reconstructed at 0.10-s intervals (100 msec) by multiphase scanning (several revolutions), which makes it possible to acquire dynamic swallowing images. Detailed measurements of swallowing kinematics are feasible, allowing accurate study of the swallowing mechanism. However, there have been few reports of kinematic studies using 320-ADCT, and its reliability or objectivity for swallowing evaluation has not been examined. To ensure effective use of 320-ADCT in swallowing evaluation, it is indispensable to ascertain the potential for obtaining a consistent evaluation among raters and also to determine the reproducibility of swallowing evaluations.

The purpose of this study was to examine the inter-rater reliability and intra-subject reproducibility for swallowing kinematics using 320-ADCT and to verify the reliability of 320-ADCT as a tool for swallowing evaluation.

Methods

1. Subjects and conditions of scanning

This study was performed with the approval of the Institutional Review Board at Fujita Health University. Eleven healthy volunteers (5 male and 6 females, mean ± SD 46 years ± 15 years in age, 163 ± 9 cm in height, 58 ± 9 kg in weight) were recruited for this study. All subjects provided informed consent for participation in this study after receiving a thorough explanation of the purpose, procedure, and risk of radiation exposure of this study. Scanning was performed with a 320-row area detector computed tomography device (320-ADCT, Aquilion ONE; Toshiba Medical Systems Corporation, Tochigi, Japan) using a seat designed exclusively for CT examination of swallowing (Tomei Brace Co., Ltd., Seto, Japan and Aska Corp., Kariya, Japan). After tilting the CT scanning plane to a 22° angle, the subject was seated on the chair at the opposite side of the CT table and the chair was reclined to a 45° angle. The head to upper body of the subject was positioned within the scanning plane by sliding the chair posteriorly (Fig. 1). The subject was instructed to hold 10 ml of honey-thick liquid barium (5% v/w) in the oral cavity and to swallow when cued by the examiner. Each subject performed one swallowing trial followed by the same trial one week later. The scanning range was 160 mm from the base of the skull to the upper esophagus. Scanning parameters were set as follows: 1) duration 3.15 s (0.35 s × 9 rotations) per trial; 2) field of view 240 mm; and 3) tube voltage/current 120 kV/60 mA. CT images were restructured by the half-reconstruction method in 29 phases at 0.1-s intervals (10 images/s). Multiplanar reconstruction (MPR) images were created using scanner software to provide volume-rendering images. Barium (5% v/w) was used as the contrast agent, and the viscosity of the honey-thick liquid was adjusted using a commercially available thickening agent, *Neo-hai-trome-ru* (Food Care Inc., Sagamihara, Japan). Two raters, who were proficient in diagnostic imaging using 320-ADCT, performed the measurements. Rater 1 was an SLP with eleven years' experience and Rater 2 was a dentist with 6 years' experience. Both raters held certifications from the Japanese Society of Dysphagia Rehabilitation.

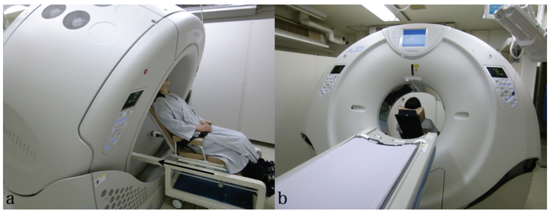


Figure 1. Scanning posture and CT reclining chair.
The CT scanner is tilted to a 22° angle. The CT reclining chair is placed on the opposite side of the CT table.
a. The chair is reclined to a 45° angle, and the head to upper body of the subject is positioned within the scanning plane by sliding the chair posteriorly in the direction of the arrow.
b. Scanning posture seen from the side of the CT table.

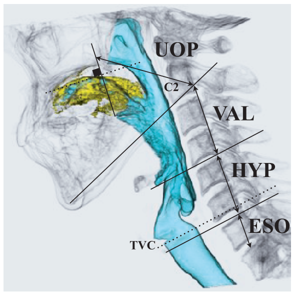
2. Measured items and methodology

MPR images at an interval of 0.1 s per image were used for timing measurements of each structure. Onset and termination of events of six structures were obtained: 1) rapid anterosuperior hyoid movement 2) elevation of soft palate; 3) inversion of epiglottis; 4) closure of laryngeal vestibule (LV); 5) closure of true vocal cords (TVC); and 6) opening of pharyngoesophageal segment (PES), according to the definitions shown in Table 1. Duration (from onset to termination) of continuous movement of the following six structures was calculated: 1) anterosuperior hyoid movement – hyoid descent; 2) velopharyngeal closure (termination of soft palate elevation – onset of soft

Table 1. Measured events and definitions of the oropharyngeal area.

Measured events		Definition
Hyoid anterosuperior movement	onset	Frame showing hyoid first rapid anterior-superior displacement from the horizontal plane defined by the left and right anterior inferior corner of C2 and anterior superior corner of C4
	termination	Frame showing hyoid first posterior-inferior displacement
Soft plate elevation	onset	Frame showing complete velopharyngeal closure following elevation of soft palate
	termination	Frame showing reopening of velopharynx
Epiglottis inversion	onset	Frame showing maximum inversion of epiglottis
	termination	Frame showing return to rest erect position
Laryngeal vestibule closure	onset	Frame showing complete closure of laryngeal vestibule at the arytenoids to epiglottis base
	termination	Frame showing reopening of laryngeal vestibule at the arytenoid to epiglottis base
TVC closure	onset	Frame showing complete adduction and closure of TVC with the guide of vocal process of arytenoid cartilage
	termination	Frame showing reopening of TVC
PES opening	onset	Frame showing the first presentation of air at the PES
	termination	Frame showing the passage of bolus and elimination of air or bolus

Oropharyngeal area		Definition
Upper oropharyngeal area	UOP	From the plane at the hard and soft palate injunction perpendicular to the hard palate to the plane made by the inferior margin of the lower jaw and left and right anterior inferior corner of C2
Valleculae area	VAL	From the plane made by the inferior margin of the lower jaw and left and right anterior inferior corner of C2 to the plane through valleculae parallel to the surface of TVC
Hypopharyngeal area	HYP	Beyond the valleculae area to the plane through the inferior edge of thyroid cartilage parallel to the surface of TVC
Esophageal area	ESO	Caudal region of the plane through the inferior edge of thyroid cartilage parallel to the surface of TVC



palate elevation); 3) epiglottis maximum tilt – return to rest erect position; 4) LV closure; 5) TVC closure; and 6) PES opening. To precisely indicate the location of the leading edge of the bolus, the oropharyngeal area was divided into the upper oropharyngeal (UOP), valleculae (VAL), hypopharyngeal (HYP), and esophageal (ESO) areas according to the measurement methodology using VF. The time when the bolus head reached each location in the oropharynx was measured.

All measurements were performed using the CT scanner's software. Frame-by-frame analysis and slow-motion analysis were performed. The raters had unlimited time for evaluating the images and could examine them as many times as necessary. Remeasurement was performed when necessary. Both raters (Rater 1 and Rater 2) performed measurements during the first swallow trial for all subjects. For the second trial, only Rater 1 performed the measurements. The raters were trained by measuring the swallowing of other subjects prior to this study so that they could ascertain and follow the specified definitions, criteria, and protocols for assessment using the device.

We examined the level of concordance for the results obtained separately by Rater 1 and Rater 2 as a measure of inter-rater reliability. Furthermore, we assessed the level of concordance between swallowing kinematics for each subject in the two swallowing trials. Since the onset of swallowing varied between trials (subjects were swallowing on cue), a reference time (“time zero”) was set at the timing of the onset of anterosuperior hyoid movement. The onset and termination of each of the other events were calculated relative to this reference time, and the timings of the two swallows were compared for each subject. The inter-rater and intra-subject reliability were assessed using an interclass coefficient (ICC) and calculated by ANOVA. Statistical significance was set at $p < 0.05$. Data analysis was conducted using SPSS Statistics 19 (IBM, Japan).

Results

All volunteers swallowed without difficulty when cued by the examiner. The movement of all structures and the bolus flow were captured during 3.15 s of scanning time. MPR and 3D-CT images were reconstructed in 29 phases at an interval of 0.10 s, and images of the full swallow were obtained by sequentially reproducing the 29 phases of the 3D-CT images. By using these images, both Rater 1 and Rater 2 were able to obtain measurements of the kinematics of each structure. Each trial required 30 min for the measurements. Table 2 shows the inter-rater and intra-subject reliability.

Table 2. Inter-rater and intra-subject reliability.

Interclass coefficient	Inter-rater	Intra-subject
Onset of hyoid anterosuperior movement	1.00	*
Onset of soft palate elevation	0.99	0.92
Termination of soft palate elevation	0.99	0.55
Onset of epiglottis inversion	0.98	0.71
Termination of epiglottis inversion	1.00	0.87
Onset of laryngeal vestibule closure	0.99	0.79
Termination of laryngeal vestibule closure	0.99	0.80
Onset of TVC closure	0.99	0.97
Termination of TVC closure	0.99	0.63
Onset of PES opening	1.00	0.56
Termination of PES opening	0.99	0.73
VAL	1.00	0.88
HYP	0.99	0.80
ESO	0.99	0.62
Duration of velopharyngeal closure	0.97	0.63
Duration of epiglottis inversion	0.95	0.81
Duration of laryngeal vestibule closure	0.91	0.60
Duration of TVC closure	0.97	0.88
Duration of PES opening	0.95	0.85
Average	0.98	0.76

*Since the swallowing starting time diffed between the two trials, the reference time was set at the timing of the onset of hyoid anterosuperior movement for the comparison of the onset and termination of each structure.

1. Inter-rater reliability

The average ICC for all measurement items to assess inter-rater reliability was 0.98, showing high concordance. With regard to the ICC of each structure, 1.0 was obtained for the onset of anterosuperior hyoid movement, the termination of epiglottis inversion, and the onset of PES opening, which showed complete concordance among all measurements. ICC above 0.9 was observed for all the other structures, where no variation occurred among structures. Variations were seen in only one or two items in a trial, caused by the variation of one frame in all cases. There were no cases of variations in more than three structures for each subject. This showed that the reliability of evaluation was stable regardless of innate variations in the subjects.

2. Intra-subject reliability

Ten out of the total of eleven subjects swallowed the 10-ml portion of liquid in one swallow for both trials. One subject took the portion in two swallows for both trials. Figure 2 shows the results for one subject (37-year-old female, 158 cm height). By setting a reference time (“time zero”) at the onset of anterosuperior hyoid movement, the timing was measured in the first and second trials for elevation of soft palate, inversion of epiglottis, closure of laryngeal vestibule, closure of TVC, and opening of PES. The onset time was the same for all movements of these structures in both trials, as well as the timing of the leading edge of the bolus reaching the VAL, HYP, and ESO. However, the timing of the bolus passing through the PES was slower by 0.1 s in the first trial. The timing of the termination of anterosuperior hyoid movement, soft palate elevation, epiglottis inversion, laryngeal vestibule closure, and PES opening were slower in the first trial relative to the second trial. The average ICC for all items to be measured for intra-subject reliability was 0.76, in which the ICC was more than 0.60 for all items, showing a high level of reproducibility. High ICC of more than 0.90 was observed for the onset of soft palate elevation and onset of TVC closure. The ICC for the onset of laryngeal vestibule closure and epiglottis inversion, the other two events of laryngeal closure, was 0.71 and 0.79, respectively. Relatively low concordance was found in the timing of the bolus

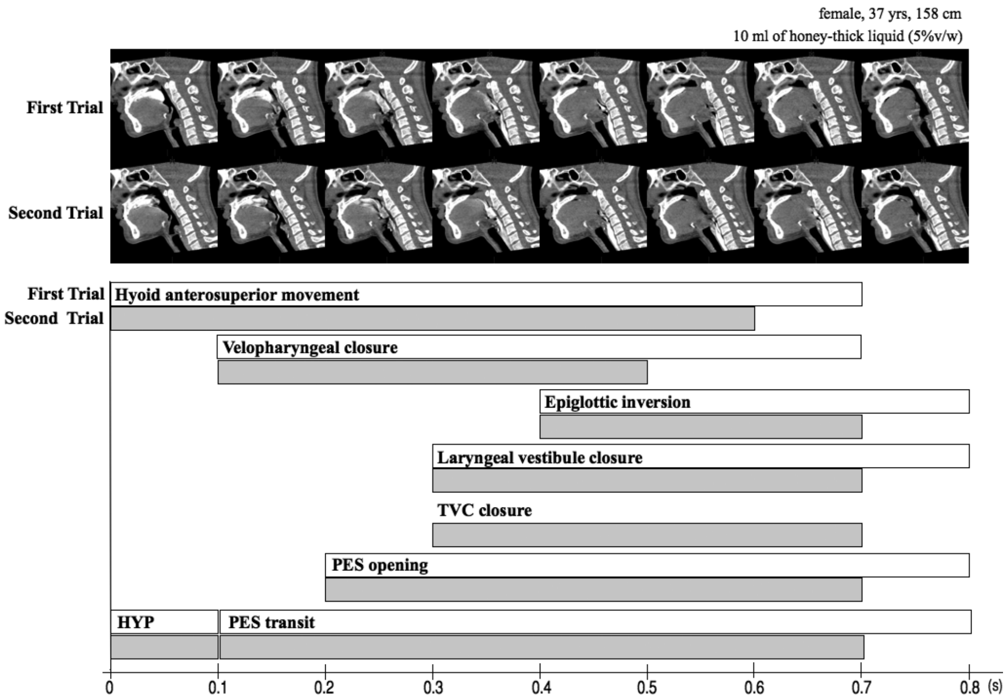


Figure 2. Comparison of two trials in one subject.
By setting a reference time (time zero) at the onset of anterosuperior hyoid movement, the timing of swallowing 10 ml of honey-thick liquid barium (5% v/w) was compared. Upper row is the first trial and lower row is the second trial.
The onset time was the same for all movements of the structures in both trials. However, the timing of the termination of each structure's movement was delayed in the first trial compared to the second trial.

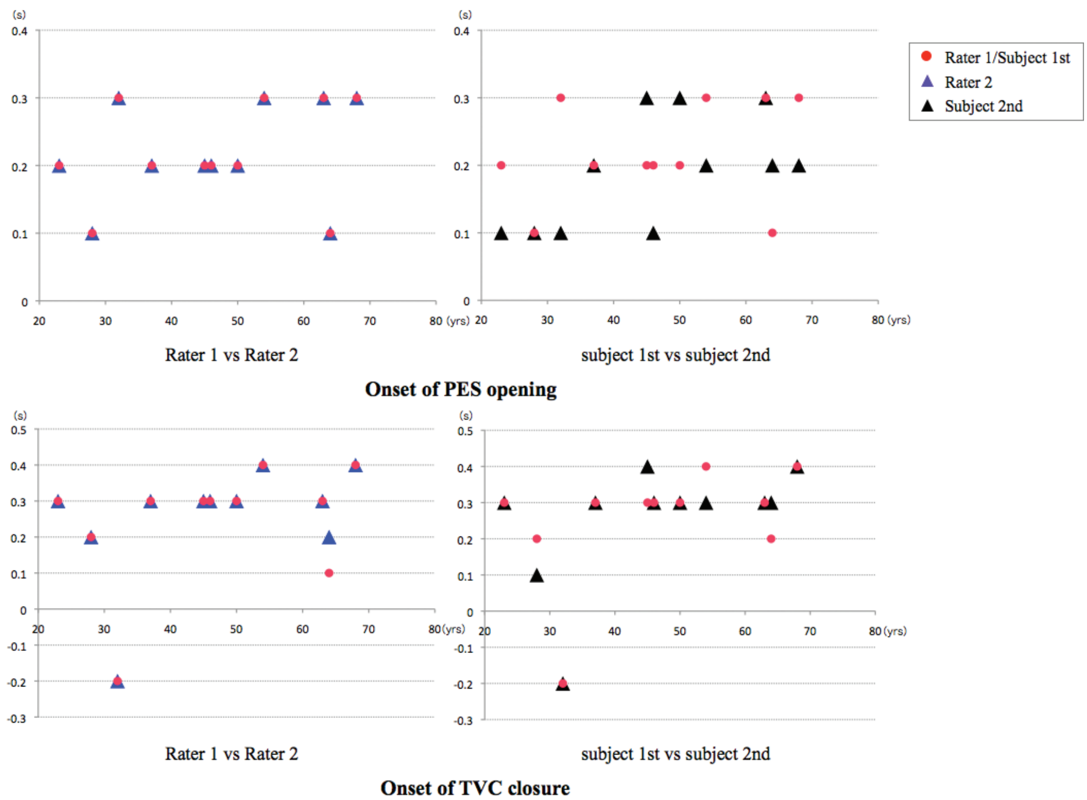


Figure 3. Inter-rater and intra-subject variations.
Inter-rater [Rater 1 (●) and 2 (▲)]) variations and intra-subject [Subject 1 (●) and 2 (▲)] variations in the onset of PES opening (upper row) and TVC closure (lower row) with the effect of age are plotted. Left figure shows inter-rater variations and right shows intra-subject variations.

reaching the ESO (0.62) and in the onset of PES opening (0.56).

Figure 3 shows the inter-rater and intra-subject variation for the onset of PES opening and TVC closure with the effect of age. A deviation was found in the onset of PES opening, in that inter-rater reliability was 100% while intra-subject reproducibility stood at 60%. On the other hand, as with the onset of TVC closure, a high level of concordance was seen in both inter-rater reliability and intra-subject reproducibility.

Discussion

This study examined the potential capability of 320-ADCT for evaluating swallowing kinematics in terms of inter-rater reliability and intra-subject reproducibility. Although the time resolution of the images acquired by 320-ADCT (10 images/s) is inferior to that with VF, it was possible to measure the timing of the onset and termination of the movement of each structure in the same way as with VF. The advantage of 320-ADCT is superior space resolution and three-dimensional images, which enables precise assessment of each structure's movement by observing the MPR images from any direction and with 0.5-mm slice thickness. This feature allowed us to accurately capture the closure of TVC and the opening of PES on the axial images, and to measure the kinematics of multiple structures simultaneously, which have been difficult to achieve with VF. We previously reported the measurements of swallowing kinematics of structures including the closure of TVC for healthy subjects using 320-ADCT. In that study, we established the usability of the device for assessing kinematics [6]. In addition, we have discussed measurement bias, and the impact of radiation exposure [7]. The next step was to examine the reliability and validity of evaluation using 320-ADCT so that the device can be used in the clinical setting.

Many studies have reported on the reliability of swallowing evaluation using VF. In one study, the reliability varied across six assessment variables according to rating difficulty; good reliability was seen in variables that were easy to rate and poor reliability was seen in variables that were difficult to rate [8]. Researchers have generally reported poor inter-rater reliability except in the evaluation of the presence/absence of aspiration [2−4]. Reasons for poor reliability include not using slow-motion views or not using repeat evaluation for image assessment; examiners viewed the image once in real-time according to standard clinical practice [2]. However, another study reported that the reliability was poor even when frame-by-frame analysis was performed by viewing images multiple times, or when examiners were informed of the medical history and screening results prior to VF [3]. Stoeckli et al. proposed that more specifically defined parameters are necessary given the poor inter-rater reliability even when using clinically standardized protocol [9].

The inter-rater reliability observed in this study using 320-ADCT was high. Smith reported that the level of concordance in evaluation improved when the raters discussed the manner of evaluation prior to performing the actual evaluation [10]. Hind et al. [11] reported that a trained group could make more reliable judgments than an untrained group. It is important for raters to have a coherent understanding of evaluation criteria, and thus it is necessary that raters use standardized evaluation criteria and that they train on a consistent basis and openly discuss evaluation methods. One of the reasons for this study's high reliability was that the raters had precisely defined the evaluation criteria in advance in accordance with the previous VF reports, and they had familiarized themselves with the evaluation criteria and procedures. It was also suggested that the high capacity of the CT device for spatial resolution contributed to the high level of reliability in this study. As previously mentioned, since VF images are two dimensional and limited in the area of observation, the assessment may rely on the rater's experience and subjective evaluation.

In contrast, 320-ADCT produces three-dimensional images of 0.5 mm in thickness for multidirectional evaluation, with which target structures can be captured with high precision. Thus, once the measurement methodology and procedures are established, it is highly probable that any rater can obtain measurement results in the same manner. It has been reported that low levels of concordance were generally observed among measured variables when observing each structure's movements using VF [12]. It has been demonstrated that the measurement methodology described in this study is sound with a high level of reliability, where most of the measured variables are designed to capture each structure's movements. Compared to VF, the number of frames captured in one trial is 29 due to the lower resolution capacity of the device. This resolution may have been reasonable for visual evaluation, and may be one factor for the good concordance.

On the other hand, the intra-subject reliability was lower than the inter-rater reliability in this study. This is a reasonable result given the individual variations in swallowing even under the same conditions. The lowest concordance was seen in PES opening. This could be explained by the low concordance in the timing of the bolus reaching the ESO, which caused a change in the timing of the onset of PES opening responding to different patterns in the flow of the bolus (speed and timing). In this study, although the movement of the tongue was not formally measured, it is possible that voluntary control of tongue propulsion might cause a change in bolus flow, possibly leading to a change in the timing of the onset of PES opening.

This type of adaptive change in the kinematics of structures as a response to variations in bolus flow is shown in Fig.2. In this case, the timing of the opening of PES, closure of larynx, and termination of closure of velopharynx has changed due to a difference in the timing of the bolus passing through the PES, while the timing of the bolus reaching the ESO was the same. This indicates that the kinematics of each structure could be precisely measured in accordance with different variables such as bolus consistency and size. Although individual variations in swallowing were observed, a relatively high level of concordance was observed in the ICC range of 0.5 to 0.9 in all items. It was suggested that the kinematics of each structure occurred as a fixed pattern in the same individual once the swallowing started. The result, in which one out of the eleven subjects required two swallows during both trials, supported the idea that each subject has their own swallowing pattern at certain levels.

This study demonstrated that swallowing evaluation using 320-ADCT could produce measurements with high inter-rater reliability when the raters have acquired a certain level of training in terms of the evaluation procedures. The methodology was also shown to be valid in accurately evaluating variations in swallowing in each individual. Sound evaluation can foster good clinical management with regard to selecting specific treatment strategies as well as judging the level of adaptability of training. The evidence that variations in swallowing kinematics in each individual can be assessed is important in identifying the causes of functional disorders and in determining the appropriate strategies to alleviate them. The analysis of swallowing kinematics using 320-ADCT generally requires approximately 30 min for measurement, which is considered reasonable. Moreover, this device has the advantage of being able to capture three-dimensional images of swallowing kinematics that were difficult to clarify by VF [6]. Since 320-ADCT is an effective measurement method in therapy-oriented evaluation, it is expected to be used more widely to identify the treatment for swallowing disorders. This study was limited to the swallowing kinematics of healthy subjects. In the future, it is necessary to validate the reliability for the evaluation of patients with swallowing disorders.

Conclusions

This study examined the inter-rater reliability and intra-subject reproducibility using 320-ADCT for swallowing evaluation. The level of concordance was higher than that reported in previous studies using VF. 320-ADCT produces three-dimensional images, enabling more accurate measurement. We confirmed that 320-ADCT is a reliable tool for swallowing evaluation that is less affected by the rater’s experience when adhering to precise evaluation criteria established in advance.

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References

1. Logemann JA. Evaluation and treatment of swallowing disorders. Texas: Pro ed; 2 Sub edition; 1988.
2. Kuhlemeier KV, Yates P, Palmer JB. Intra- and interrater variation in the evaluation of videofluorographic swallowing studies. Dysphagia 1998; 13: 142−7.
3. Wilcox F, Liss JM, Siegel GM. Interjudge agreement in videofluoroscopic studies of swallowing. J Speech Hearing Res 1996; 39: 144−52.
4. McCullough GH, Wertz RT, Rosenbek JC, Mills RH, Webb WG, Ross KB. Inter- and intrajudge reliability for videofluoroscopic swallowing evaluation measures. Dysphagia 2001; 16: 110−8.
5. Fujii N, Inamoto Y, Saitoh E, Baba M, Okada S, Yoshioka S, et al. Evaluation of swallowing using 320-detector-row multislice CT. Part I: single- and multiphase volume scanning for three-dimensional morphological and kinematic analysis. Dysphagia 2011; 26: 99−107.
6. Inamoto Y, Fujii N, Saitoh E, Baba M, Okada S, Katada K, et al. Evaluation of swallowing using 320-detector-row multislice CT. Part II: kinematic analysis of laryngeal closure during normal swallowing. Dysphagia 2011; 26: 209−17.
7. Kanamori D, Kagaya H, Fujii N, Inamoto Y, Nakayama E, Suzuki S, et al. Examination of the distance measurement error and exposed dose when using a 320-row area detector CT: A comparison with video fluoroscopic examination of swallowing. Jpn J Compr Rehabil Sci 2011; 2: 18−23.
8. Gibson E, Phyland D. Rater reliability of the modified barium swallow. Aust J Hum Comm Disord 1995; 23: 54−60.
9. Stoeckli SJ, Huisman TA, Seifert B, Martin-Harris BJ. Interrater reliability of videofluoroscopic swallow evaluation. Dysphagia 2003; 18: 53−7.
10. Smith CH, Logemann JA, Colangelo LA, Rademaker AW, Pauloski BR. Incidence and patient characteristics associated with silent aspiration in the acute care setting. Dysphagia 1999; 14: 1−7.
11. Hind JA, Gensler G, Brandt DK, Gardner PJ, Blumenthal L, Gramigna GD, et al. Comparison of trained clinician ratings with expert ratings of aspiration on videofluoroscopic images from a randomized clinical trial. Dysphagia 2009; 24: 211−7.
12. Tohara H, Chiba Y, Nakane A, Goto S, Ouchi Y, Teranaka S, et al. Inter- and intra-rater reliability in videofluoroscopic swallowing study. Jpn J Dysphagia Rehabil 2005; 9: 139−47.