ABSTRACT

Objective: Ultrasonography can be used to assess both the morphology and movement of the muscles of deglutition. This study investigated the intratester, intertester, and retest reliability of ultrasonic assessments of the suprahyoid muscle group.

Methods: Three testers performed ultrasonographic measurements of the length and area of the geniohyoid muscle in 10 healthy adults, and the contraction ratio during swallowing. Results were compared using intraclass correlation coefficients (ICCs) to determine intratester, retest, and intertester reliabilities.

Results: Intratester and retest reliabilities were very good, with ICCs ≥0.8 for all assessment parameters. In intertester reliability, ICCs were ≥0.8 for geniohyoid muscle length and area during swallowing and ≥0.6 for geniohyoid muscle length at rest and contraction ratio.

Discussion: These results indicate high reliability of this assessment method for assessments made by the same individual, with reliability of the method remaining high for assessments performed at intervals.

Key words: ultrasonography, geniohyoid muscle, retest reliability, intertester reliability

Introduction

The suprahyoid muscles play an extremely important role in swallowing, moving the hyoid bone anterosuperiorly, and contributing to epiglottic inversion and wide opening of the esophageal orifice [1–3]. These muscles are generally assessed using videofluorography to measure vertical and horizontal hyoid bone movement [4–6]. X-rays can thus be used to assess muscle function by measuring bone movement, but cannot be used to assess the thickness, cross-sectional area, or other aspects of muscle morphology. Computed tomography (CT), magnetic resonance imaging (MRI), or other imaging modalities can be used for this purpose, but do not provide a means of assessing muscle movement in swallowing [7, 8]. Use of 3-dimensional CT for assessing swallowing movements has recently been reported, but involves limitations in available examination facilities and subject postures, and problems relating to radiation exposure [8, 9].

In contrast, ultrasonography permits ready delineation of muscles and bones in the submental region and assessment of their movements during swallowing. This modality is also minimally invasive and relatively inexpensive, does not limit subject posture, and is suitable for bedside use.

A report of ultrasonographic assessment of swallowing function by Shawker et al. in 1984 [10] led to a number of reports on related techniques and methods [11–25], but little has been reported on reliability, which is essential for both research and clinical applications. For methods of assessment that have not been standardized, reliability must be investigated prior to clinical application. Although Macrae et al. [15] reported high levels of intratester and intertester reliability for ultrasonic assessment of the geniohyoid muscle length and shortening ratio during swallowing, reliability was determined with the testers all measuring the same sonogram and thus did not include ultrasonographic reproducibility. Hsiao et al. [13] reported high intra- and intertester reliabilities in the use of ultrasound to measure the distance from the hyoid bone to the mandible in swallowing, but did not include determinations of reliability on retesting. Retesting is a means of investigating the stability of a test method, by

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performing the same test at intervals in the same subjects, and this value is important in terms of assessment reproducibility. In many cases, assessment of swallowing function is repeated over time for the same patient to investigate changes in signs or symptoms or the effects of training.

The present study was performed to investigate the intratester, intertester, and retest reliabilities for ultrasonographic assessment of suprahyoid muscles.

Methods

1. Subjects

The subjects in this study comprised 10 healthy volunteers (5 men, 5 women; age, 21–27 years; mean age, 21.7 years) with no history of eating or swallowing disorder, respiratory dysfunction, or otorhinolaryngologic disease. All subjects received a full explanation of the study and agreed to participate prior to enrollment. This study was approved by the Research Ethics Committee of Kawasaki Medical School and Hospital (Approval No. 1917).

2. Testers

Three testers participated in this study. Tester 1 was a physician with 7 years of clinical experience, and Testers 2 and 3 were speech-language-hearing therapists with 7 and 10 years of clinical experience, respectively. All three testers received a full explanation and sufficient practice in performing the assessment method in advance of study initiation.

3. Ultrasonography

Ultrasonography was performed based on the methods described by Macrae et al. [15], with minor modifications. The subject assumed a comfortable posture on a reclining bed with a backrest angle of 30°. A pillow measuring 30×44×7 cm was placed in contact with the subject’s shoulder to stabilize the head and neck.

A 2- to 5-MHz convex probe (SonoSite M turbo; FUJIFILM Sonosite, Tokyo, Japan) was placed in alignment with the midline of the floor of the mouth and perpendicular to the submental surface, the hyoid bone (H) and mandible (M) are delineated by their acoustic shadows. Between the hyoid bone and mandible, the mylohyoid muscle (MM) is seen in the surface layer and the geniohyoid muscle (GM) in the deep layer.

With the ultrasonic probe aligned with the mouth-floor midline and perpendicular to the submental surface, the subject next swallowed 3 mL of apple jello (Engelead®; Otsuka Pharmaceutical Factory, Tokushima, Japan) at room temperature. The swallowing was tipper-type and was performed on command. Contraction of the geniohyoid muscle and movement of the hyoid bone during swallowing were clearly observable during swallowing (Figure 1b). Swallowing was performed, recorded, and saved as videos three times.

The three testers each performed ultrasonography for all 10 subjects. Tester 1 repeated the procedure for the same subjects 1 week later. The measurement results obtained in the assessments by any one of the three testers were carefully controlled to prevent disclosure to the other two testers, and the results obtained by a tester in the first session of assessments were kept unknown to that tester through the second series.

4. Data reduction

Parameter measurements were made on a personal computer using the saved ultrasonographic images. All of the following video analyses and measurements were performed by Tester 1. Data processing was performed on the same day as the ultrasonography. Image J version 1.43 software (NIH, Bethesda, MD, USA) was used for measurements, and videos were played and edited at 15 frames/s using Adobe Premiere Elements version 4.0 software (Adobe Systems Inc., San Jose, CA, USA).

4.1 Length of the geniohyoid muscle at rest

Still images of the rest state were used. Length of
the geniohyoid muscle was measured as the distance between landmarks on the hyoid bone and mandible in their respective surface-layer regions of geniohyoid muscle attachment (Figure 2a).

4.2 Area of geniohyoid muscle at rest

The area enclosing the muscle and fascial boundary of the geniohyoid muscle was measured using still images of the rest state (Figure 2b).

4.3 Length of geniohyoid muscle in swallowing

The time of maximal geniohyoid muscle contraction was identified by frame-advance playback of the swallowing video, and the image at that time was extracted as a still image (Figure 2c) and used to measure the distance between landmark points on the hyoid bone and the mandible.

4.4 Geniohyoid muscle contraction ratio

With the length of the geniohyoid muscle at rest and at the time of maximal contraction in swallowing denoted by A and B, respectively, the contraction ratio was calculated as \((A - B)/(A \times 100)\).

5. Analysis

Reliability was determined using intraclass correlation coefficients (ICCs). Intratester reliability was determined from the values of three measurements in the first session by Tester 1, as ICC (1,1). Retest reliability was determined from the values obtained in the first and second sessions of measurement by Tester 1, as ICC (1,1). Intertester reliability was determined from the results of measurements by the three testers, as ICC (2,1). Each measurement value was obtained as the average of three measurements. The level of significance was 0.05. All statistical analysis was performed using SPSS Statistics version 22 (IBM, New York City, NY, USA).

**Results**

Clear ultrasonographic images were obtained for all subjects. Interference of the ultrasonic probe with larynx elevation in swallowing was eliminated in cases where this occurred by increasing the amount of ultrasound gel applied.

Intratester reliability (single-measure ICC) was \(\geq 0.9\) for geniohyoid muscle length at rest and in swallowing, shortening ratio, and area at rest (Table 1). Retest reliability was ICC=0.83 for the geniohyoid muscle length at rest, ICC=0.87 for the geniohyoid muscle area at rest, and ICC\(\geq 0.9\) for all other parameters (Table 2).

Intertester reliability was ICC=0.66 for geniohyoid muscle length at rest, ICC=0.87 for geniohyoid muscle length in swallowing, ICC=0.68 for geniohyoid muscle shortening ratio, and ICC=0.88 for the geniohyoid muscle area at rest (Table 3).

**Discussion**

In ICC for assessing reliability in continuous data, ICC \(\geq 0.6\) is considered necessary and ICC \(\geq 0.8\) is considered preferable [26]. In the present study, intratester reliability for the assessment method was \(\geq 0.9\) for all assessment parameters and thus extremely good, showing that the reliability is high in single measurements by the same tester. Intratester reliability on retesting was also found to be good (ICC \(\geq 0.8\)) and

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**Figure 2.** Submental ultrasonic still images: (a), (b) at rest and (c) at maximum geniohyoid muscle contraction. The images show: measurement landmarks in the regions of the surface layer attachment of the geniohyoid muscle to the hyoid bone (H) and mandible (M); the distance between these two points, taken as the length of the geniohyoid muscle at rest (A) and at maximum contraction (B); and the area of geniohyoid muscle at rest, as the area (dashed line) enclosing the muscle and fascial membrane boundary. H, hyoid bone; M, mandible; GM, geniohyoid muscle.

**Table 1.** Intratester reliability (Tester 1).

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<tr>
<th></th>
<th>ICC</th>
<th>95% CI</th>
<th>p Value</th>
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<tbody>
<tr>
<td>GM length at rest</td>
<td>0.916</td>
<td>0.742–0.983</td>
<td>0.000</td>
</tr>
<tr>
<td>GM length at maximum contraction</td>
<td>0.938</td>
<td>0.829–0.984</td>
<td>0.000</td>
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<tr>
<td>GM contraction ratio</td>
<td>0.938</td>
<td>0.802–0.988</td>
<td>0.000</td>
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<tr>
<td>GM area at rest</td>
<td>0.941</td>
<td>0.812–0.988</td>
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GM, geniohyoid muscle.
therefore in the category of “almost perfect reliability”. This shows that the reliability of the method remains high when assessments are performed at intervals, which is highly important in clinical applications.

An intertester reliability of ICC ≥0.6, a level known as “substantial reliability”, was found for the assessment method and was thus lower than the intratester and retest reliabilities. This indicates an overall decrease in the reliability of this assessment method when performed by different testers. Performance of multiple assessments by the same tester is thus desirable.

Further increases in the reliability of this method will require consistency in subject posture, type and amount of simulation food, and swallowing pattern. Changes in subject posture during swallowing (e.g., sitting or recumbent position and cervicofacial angle or rotation) are known to affect the results of swallowing assessment [14, 21, 27–30]. In some reports, head, neck, and ultrasonic probe positions have been fixed during swallowing assessment with ultrasound [20, 22, 25], but immobilization of the head and neck region may strongly affect swallowing movements. Furthermore, use of an immobilization system is generally impracticable in clinical settings. In the present study, which used a reclining bed as a backrest together with a pillow rather than an immobilization system, high reliability was obtained when multiple assessments were performed by the same tester. For application to bedridden patients, similar consideration must be given to fixing the backrest angle and pillow type.

Swallowing movements have also been reported to vary with the amount, food texture, taste, and temperature of the food bolus to be eaten and swallowed [31, 32]. The present study was performed throughout using the same jelly type, amount, and temperature.

Finally, swallowing movements are known to vary with swallowing pattern. For example, tongue pressure and hyoid bone and laryngeal movements reportedly differ between command swallowing and non-command swallowing, and between tipper and dipper types of oral swallows [33, 34]. Throughout the present study, the oral phase was tipper-type with swallowing initiation on command. This consistency presumably tended to increase assessment reliability.

Comparisons between the assessment reliabilities found for the different parameters are also of interest. Intertester ICCs were lower for geniohyoid muscle length at rest and contraction ratio in swallowing than for the other parameters. This was presumably related to the absence of a system to fix head and neck positions in the present study, and differences between testers in the angle of the subject’s neck region during testing may thus have affected length of the geniohyoid muscle at rest and the contraction ratio. In contrast, good intertester reliability was found for assessments of geniohyoid muscle area at rest and length at maximum shortening. The high reliability found for muscle area suggests that large variations in muscle area were effectively precluded by variations in muscle thickness accompanying the variation in muscle length. The high reliability found for geniohyoid muscle length at maximum shortening suggests that with fixed food types and amounts, reproducibility can be obtained for movements of swallowing-related muscles. In summary, intertester reliability was generally found to be inferior to intratester reliability, but the ICCs of ≥0.8 for geniohyoid muscle area at rest and length at maximum shortening indicate that high reliability is retained for these parameters despite application of the assessment method by different testers.

In many cases, assessment of suprathyroid muscle

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<th>Table 2. Retest reliability (Tester 1).</th>
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<tr>
<td>ICC</td>
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<tr>
<td>GM length at rest</td>
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<td>GM contraction ratio</td>
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<td>GM area at rest</td>
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GM, geniohyoid muscle.

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<th>Table 3. Intertester reliability (Testers 1–3).</th>
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GM, geniohyoid muscle.
mass is performed by CT. Feng et al. [7] reported measurement of the cross-sectional area of the geniohyoid muscle by CT, and geniohyoid muscle atrophy was associated with aging and aspiration. In contrast, reports on the use of ultrasonography for measurement of muscle mass relating to swallowing have generally focused on the tongue, with little investigation of the peripheral muscles associated with the hyoid bone. This may be related to the difficulty of identifying the bellies of these muscles because of their small size despite the relative ease of muscle delineation by ultrasonography, and also to the difficulty of placing the probe vertically in alignment with the muscle fibers. Macrae et al. [14] reported that the cross-sectional area of the anterior belly of the digastric muscle can be measured using ultrasound, that the results correlated closely with measurement on MRI, and that muscle cross-sectional areas varied with posture, but did not include investigations of assessment reliability. Feng et al. [21] measured the cross-sectional area of the geniohyoid muscle using ultrasound, again without investigating assessment reliability.

The present study measured the area of the geniohyoid muscle in the median sagittal plane. Identification was more readily obtained than measurement of the cross-sectional area. The assessment reliability for this parameter was found to be high, and clinical application as a method for determining the mass of the suprahyoid muscles seems likely to be effective.

One limiting factor in the present study was the incomplete verification of the measurement methods. Hsiao et al. [13] reported a high correlation between ultrasonographic and videofluorographic measurements of the distance from the hyoid bone to the mandible in 12 stroke patients. Ultrasonographic measurement of this distance in the present study appears valid, but definitive verification awaits further study.

Further studies will be necessary to clarify means of increasing the intertester assessment reliability. We are also contemplating extending this method to measurement of the speed of hyoid bone movement in swallowing as an indicator of muscle performance, and echo intensity as an indicator of disuse muscle atrophy.

Acknowledgments

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References


17. Yabunaka K, Sanada H, Sanada S, Konishi H, Hashimoto