Practical concepts

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Five-step dynamic ultrasonographic assessment of swallowing for dysphagia

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Abstract

This paper presents a five-step dynamic ultrasonography (US) technique aimed at diagnosing oropharyngeal dysphagia, which encompasses the analysis of tongue-palate contact, hyoid movement, upper esophageal sphincter opening, vocal fold closure and post-swallow residue. This protocol is implemented in a sequential manner, intending to methodically evaluate the essential phases of swallowing function. By mirroring the natural process of swallowing, this sequential method may provide a full understanding of possible dysfunctions at each stage. Considering the advantages of US in dysphagia diagnosis, we believe that this method will provide clinicians with a perspective for bedside dysphagia evaluation.

Keywords: dysphagia; ultrasound; swallow; assessment

Introduction

A sequential and comprehensive assessment of swallowing-related components is crucial for diagnosing dysphagia and planning appropriate treatment options. Various tools are utilized to assess swallowing. While videofluoroscopic swallowing study (VFSS) and fiberoptic endoscopic evaluation of swallowing (FEES) are considered the gold-standard methods for evaluating dysphagia, ultrasound (US) has emerged as a non-invasive, rapid, and accessible alternative. US has the advantages of being radiation-free, well-tolerated, applicable to all ages from neonates, low cost, and applicable in various clinical settings [1].

In this paper, we describe a five-step procedure for the diagnosis of oropharyngeal dysphagia using US. Sequential evaluation of these five steps can provide a comprehensive view of swallowing function and improve diagnostic accuracy.

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Protocol

These steps are defined as Tongue-Palate Contact, Hyoid Elevation, upper esophageal sphincter (UES) Opening, Vocal Fold Closure, and Post-swallow Residue. Each phase allows for a dynamic examination of the primary components of swallowing function, which may enhance diagnostic accuracy and facilitate standardization in clinical practice. In this dynamic protocol, evaluation is performed by swallowing 3 cc of water. The bolus appears as a hyperechoic object on US.

1. Tongue-Palate Contact

During the oral phase of swallowing, the pressure generated between the tongue and palate, also known as tongue pressure, is the key contributor to bolus transfer [2]. Additionally, tongue pressure against the palate serves as an indicator of the function of other muscles involved in swallowing [3]. During the oral phase, the anterior part of the tongue presses the bolus against the

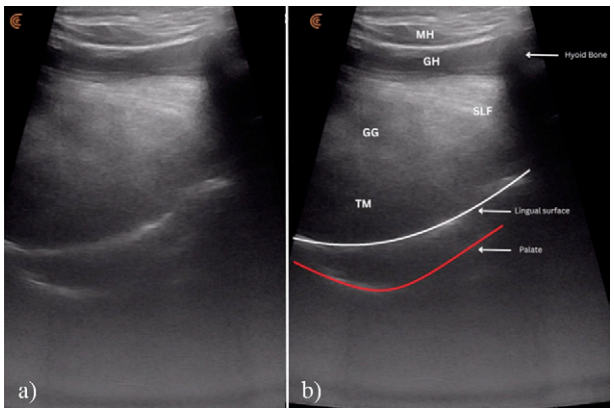

Fig 1. Ultrasonographic images of the oral cavity and pharyngeal region: a) Baseline image showing the anatomical structure without labels.; b) Labeled structures include the mylohyoid muscle (MH), geniohyoid muscle (GH), genioglossus muscle (GG), sublingual fat (SLF), tongue mass (TM), lingual surface, and palatal surface. The lingual surface is marked with a white line and the palatal surface with a red line, highlighting reference points essential for evaluating tongue-palate contact during swallowing.

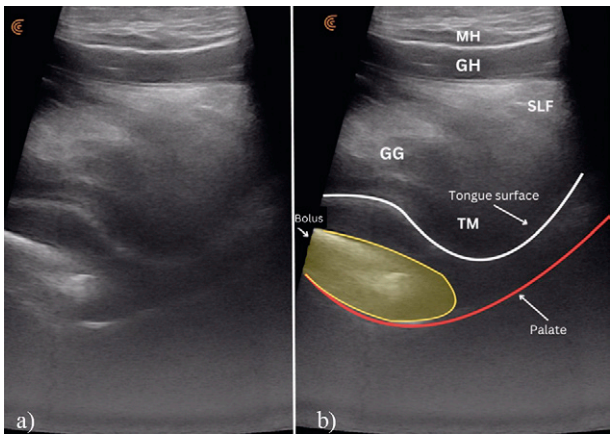

Fig 2. Ultrasonographic images of the pharyngeal region during swallowing: a) Image showing the bolus within the pharyngeal area, illustrating its position relative to surrounding anatomical structures; b) Labeled structures include the bolus, tongue surface, and palate. The tongue surface is marked with a white line, the palate with a red line, and the bolus outlined in yellow, providing key reference points for assessing bolus progression and tongue-palate contact.

hard palate and propels it toward the tongue base. Subsequently, during the pharyngeal phase, the swallowing reflex is triggered, and the suprahyoid muscles contract. Insufficient tongue-palate contact may lead to oral residue, resulting in dysphagia [4]. A study identified reduced tongue pressure against the palate as a significant predictor of dysphagia [5]. For this reason, tongue-palate contact is regarded as a fundamental parameter in dysphagia assessment.

To evaluate tongue-palate contact, the probe is positioned in the submental (submandibular) region in the longitudinal plane. This positioning allows visualization of the structures involved in tongue-palate contact (fig 1, fig 2). On the US screen, tongue-palate contact can be dynamically observed before, during, and after swallowing (Video 1, on the journal site).

2. Hyoid Elevation

Hyoid elevation refers to the upward and forward movement of the hyoid bone during swallowing. During this process, the hyoid bone first moves upward, then forward, and eventually returns to its original position. This movement is essential for safe and effective swallowing, as the upward and forward displacement of the hyoid bone facilitates laryngeal elevation and epiglottic closure [6]. This mechanism helps prevent aspiration and ensures the safe passage of food and liquid from the pharynx to the esophagus. Inadequate hyoid elevation can lead to food residue in the pharynx, an increased risk of aspiration, and other primary symptoms of dysphagia. Individuals with reduced hyoid movement have a 3.7-fold higher risk of aspiration [7]. Therefore, the movement of the hyoid bone is regarded as a critical parameter in dysphagia assessment. US is as reliable as the gold-standard VFSS for evaluating hyoid elevation [8]. In one study, submental US measurement of hyoid bone displacement distance demonstrated a threshold value of 13.5 mm, achieving a sensitivity of 83.9% and a specificity of 81% for predicting the presence of aspiration [9]. Another study found that individuals with hyoid displacement of less than 1.5 cm exhibited poor swallowing function and were more likely to require tube feeding [8].

To assess hyoid elevation, the probe is placed in the submental region, with imaging conducted in the longitudinal plane. This placement enables visualization of the upward and forward movement of the hyoid bone during swallowing (fig 3). As swallowing initiates, the starting position of the hyoid bone, its peak elevation, and its post-swallow position are dynamically monitored. This real-time imaging allows for an evaluation of the role of hyoid elevation during swallowing (Video 2, on the journal site).

3. Upper Esophageal Sphincter Opening

The UES is a muscular sphincter that plays a critical role in the passage of food and liquid from the pharynx to the esophagus. During swallowing, the temporary opening of the UES allows food and liquid to pass safely into the esophagus. Insufficient or delayed opening of the UES can obstruct food passage, leading to dysphagia and increasing the risk of aspiration [10,11]. Therefore, the effectiveness of UES opening is an important parameter in the diagnosis of dysphagia and a fundamental factor in the evaluation of the swallowing process. In pa-

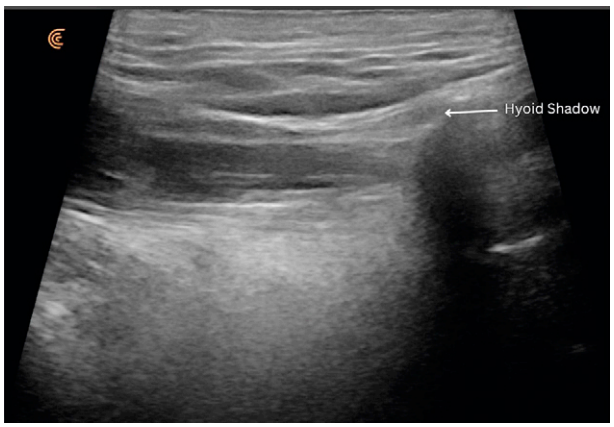

Fig 3. Ultrasonographic image showing the hyoid bone shadow at rest. The hyoid shadow serves as a reference point for assessing hyoid elevation during swallowing, which is essential for evaluating laryngeal elevation and airway protection mechanisms.

tients with dysphagia, UES function can be assessed by measuring the esophageal opening capacity and duration based on the type of ingested food [1]. In a study evaluating the UES using US in healthy volunteers, the average cross-sectional diameter of the closed UES was found to be 0.78±0.13 cm, while the average internal cross-sectional diameter of the open UES was 0.954±0.15 cm, and the average external cross-sectional diameter was 1.413±0.16 cm. The average duration of UES opening was 415±51.66 ms, and the average duration of UES displacement was 937±120.98 ms [12].

To evaluate UES opening, the patient should be comfortably positioned in a seated or slightly reclined posture to allow easier access to the neck region. For longitudinal imaging of the UES, the probe is placed on the anterior neck, just below the thyroid cartilage (approximately at the level of the cricoid cartilage) and as close as possible to the UES region, with the probe positioned at a sagittal or slightly oblique angle. For transverse imaging, the probe is positioned just below the thyroid cartilage at the level of the cricoid cartilage. During swallowing, parameters such as the opening-closing mechanism and the internal cross-sectional diameter of the UES in the transverse view are evaluated. Optimal imaging is achieved by holding the probe steady with gentle pressure (fig 4). The function of the upper esophagus is dynamically assessed in both longitudinal and transverse planes (Video 3, Video 4, on the journal site).

4. Vocal Fold Closure

Timely and complete closure of the vocal folds is critical for a successful swallow [13]. Any disruption in the abduction or adduction of the vocal folds poses a significant risk to the airway. Patients with vocal fold paralysis are at an increased risk of penetration, aspiration, and aspiration pneumonia, with unilateral vocal fold paralysis being the most common presentation. It can occur due to neurological disorders, trauma, or as a complication following surgery [14]. In cases of vocal fold paralysis, symptoms such as dysphonia, stridor, and weak cough production often accompany dysphagia. Therefore, US evaluation is of great importance. This method allows for the assessment of the vocal folds along with the surrounding structures.

The probe is placed transversely on the anterior surface of the neck, just above the thyroid cartilage, to evaluate vocal fold movement. In this position, transverse sections of the vocal folds and the glottic opening can be visualized (fig 5). The patient may be asked to produce the "eee" sound, allowing observation of the abduction and adduction of the vocal folds. Additionally, the function of the vocal folds can be assessed during swallowing (Video 5, on the journal site). Aspirated material can be evaluated by placing the probe longitudinally along the midline of the thyroid cartilage to visualize the vocal fold and the tracheal wall (fig 6). Prior to the examination, the structure of the tracheal wall should be assessed to determine the presence of aspirated materials. The flow of aspirated material can be observed after swallowing as a movement distinct from surrounding structures, appearing as a hazy hyperechoic area over the vocal fold and as

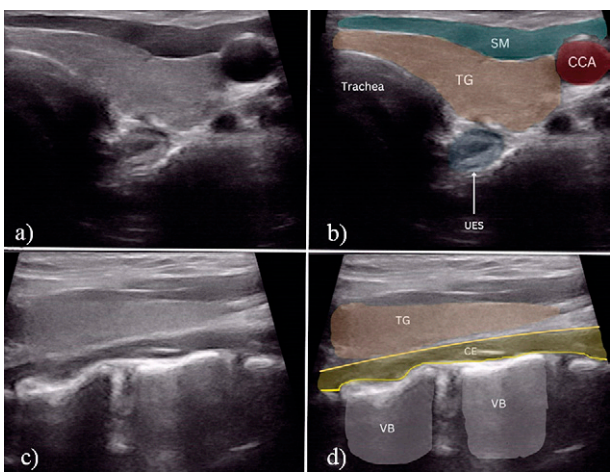

Fig 4. Ultrasonographic images of the upper esophageal sphincter (UES) region: a) Image showing the anatomical landmarks without labels, including the strap muscle (SM), thyroid gland (TG), and common carotid artery (CCA), providing a baseline view for locating the UES; b) Labeled image highlighting the UES, with the thyroid gland, strap muscle, and common carotid artery identified as reference points for assessing UES function; c) Image showing the cervical esophagus (CE) and vertebral bodies (VB) in an unmarked view, displaying surrounding anatomical structures; d) Labeled image with the CE, TG, and VB highlighted as reference points for evaluating UES and esophageal function during swallowing.

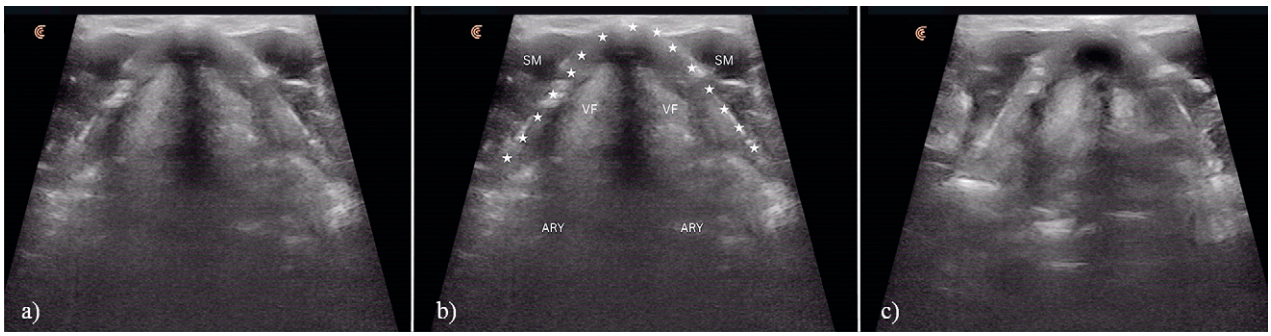

Fig 5. Ultrasonographic images of the thyroid cartilage and vocal folds during different phases of swallowing: a) Image showing the unmarked anatomy of the thyroid cartilage and surrounding structures, providing a baseline view; b) Labeled image highlighting the thyroid cartilage (indicated by stars), strap muscles (SM), vocal folds (VF), and arytenoid cartilages (ARY), serving as key reference points for assessing vocal fold dynamics; c) Image showing the adduction of the vocal folds, indicating their closed position during phonation or breath-holding.

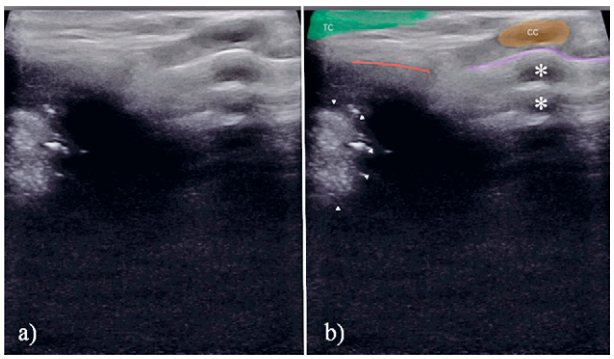

Fig 6. Ultrasonographic images of the laryngeal region. (6a) Baseline image showing the anatomical structure without labels. (6b) Labeled structures include the vocal folds (arrowheads), thyroid cartilage (TC; green-shaded area), cricoid cartilage (CC; orange-shaded area), air-mucosa interface (red line), and the tracheal wall (purple line), repetition artifacts (white star). Aspiration material can be visualized as hyperechoic beneath the air-mucosa interface.

a hyperechoic line along the tracheal wall toward the tracheal lumen [1]. A systematic review and meta-analysis conducted in 2021 determined that the estimated sensitivity and specificity of US in detecting aspiration were 0.82 (95% CI: 0.72-0.89) and 0.87 (95% CI: 0.81-0.92), respectively, and concluded that it has good sensitivity and specificity [15].

5. Post-Swallow Residue

Post-swallow residue refers to food or liquid remnants remaining in the pharynx or UES region after the swallowing process is complete. The presence of post-swallow residue indicates that swallowing was not fully effective and that food was not sufficiently transferred from the pharynx to the esophagus. Residue is a significant indicator of dysphagia and is critical for assessing aspiration risk [16]. Therefore, the evaluation of post-swallow residue is essential in diagnosing dysphagia and determining the severity of swallowing disorders. Ultrasonography allows for the detection of residues in the pyriform sinus and epiglottic vallecula [17].

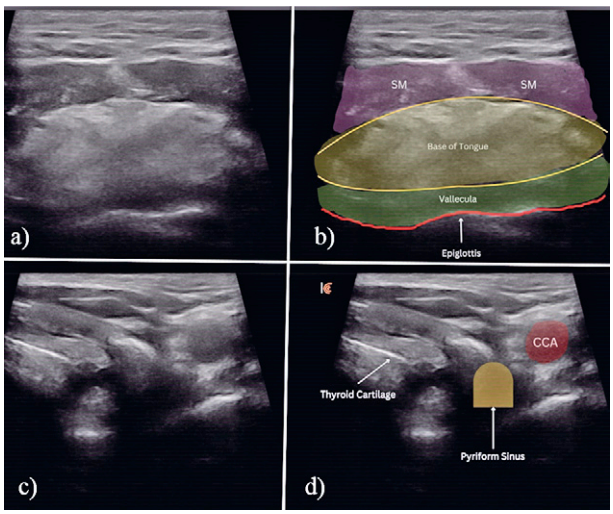

Fig 7. Ultrasonographic images of the vallecula and pyriform sinus: (7a) Image showing the base of the tongue and the vallecula without any labels, providing an unmarked baseline view for anatomical orientation; b) Labeled image of the strap muscle (SM), vallecula, with the base of the tongue and the epiglottis indicated, serving as reference points for assessing post-swallow residue in the vallecular space; c) Image showing the pyriform sinus area, providing an unmarked view of surrounding structures; d) Labeled image of the pyriform sinus, with the thyroid cartilage and common carotid artery (CCA) identified as reference points, useful for evaluating swallowing dynamics.

To visualize the vallecula, the probe is positioned horizontally at the level of the hyoid bone. For imaging the pyriform sinus, the probe is placed horizontally at the level of the laryngeal prominence. The thyroid cartilage and common carotid artery serve as reference points (fig 7). Residue can appear as a hyperechoic area. Dynamic US imaging enables real-time observation of the amount of post-swallow residue.

Conclusion

This sequential application of the five-step ultrasound (US) protocol could be important in the diagnosis of dysphagia for several reasons. Firstly, swallowing is a highly coordinated process that occurs in a specific sequence. Sequential evaluation of each phase allows clinicians to observe the dynamic interactions between different anatomical structures and physiological functions by reflecting the natural progression of swallowing. Dysphagia can result from impairments across multiple phases of swallowing, and isolated evaluations may overlook subtle dysfunctions contributing to overall swallowing difficulty. A comprehensive, step-by-step approach can ensure that no aspect of the swallowing mechanism is neglected, offering a holistic perspective on the patient's swallowing function.

Although various studies have examined individual components of swallowing using US, there is a lack of protocols that sequentially integrate all five critical parameters. Our protocol offers a consistent and reproducible method by providing a standardized sequence that can be widely adopted in clinical practice. By considering the interdependence of swallowing phases, we emphasize the importance of sequential evaluation. Further studies are needed to establish standards for the parameters evaluated in US assessment and to develop reliable benchmarks that will enhance the diagnostic accuracy and clinical applicability of ultrasonographic evaluation in dysphagia.

Conflict of interest: none

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