Revista Chilena de Fonoaudiología 23, 1-13. 2024
https://revfono.uchile.cl/
ISSN 0719-4692

Original Article

Design and Content Validation of an Ultrasound Swallowing Assessment Protocol

Roberto Rojas-Segovia [a,*] and Jorge Sepúlveda-Contreras [b]

[a] *Departamento de Fonoaudiología, Facultad de Salud y Ciencias Sociales, Universidad de las Américas, Sede Providencia, Chile.*
[b] *Escuela de Fonoaudiología, Facultad de Odontología y Ciencias de la Rehabilitación, Universidad San Sebastián, Sede Valdivia, Chile.*

ABSTRACT

Although evidence suggests that ultrasound can be used to evaluate and quantify various dynamic aspects of swallowing, no validated protocol currently exists for exploring the swallowing process specifically. This cross-sectional descriptive study aimed to design a swallowing assessment protocol with diagnostic utility for dysphagia and to validate its content through expert judgment. Seven national and international specialists participated in a survey, where Lawshe's statistical test was used, requiring a content validity index (CVI) of 0.99. In addition to this, a method for resolving controversies was used. The resulting items included: tongue characteristics, hyoid-thyroid approximation, vocal fold adduction, assessment of the upper esophageal sphincter, and hyoid bone movement. The experts also provided input on the type of transducer to use for the evaluation and the type of examination to perform for each item. The protocol was subsequently applied to three healthy subjects to determine measurement possibilities and establish technical conditions for the examination. The results were validated by a sonographer and an international specialist. Based on the findings of this study, future directions include proceeding to the criterion validity phase by piloting the protocol in a healthy population, as well as conducting studies to establish standard and normative values.

Keywords:
Assessment; Deglutition; Ultrasonography; Ultrasound; Validation

Diseño y validación de contenido de un protocolo de evaluación de la deglución mediante ultrasonido

RESUMEN

En la actualidad no existe un protocolo validado que permita explorar específicamente el proceso deglutorio, pese a que la evidencia indica que por medio del ultrasonido es posible evaluar y cuantificar diversos aspectos dinámicos de la deglución. Este estudio descriptivo transversal tuvo dos objetivos: 1. Diseñar un protocolo para la evaluación de la deglución que posea utilidad diagnóstica para disfagia y 2. Realizar la validación de contenido mediante juicio de expertos. Siete especialistas nacionales e internacionales respondieron una encuesta donde se utilizó la prueba estadística de Lawshe con una exigencia de 0.99 en el índice de validación de contenido. Con lo anterior más un método de discusión de controversias, los ítems incluidos corresponden a: características de lengua, aproximación hioides tiroides, aducción de cuerdas vocales, valoración de esfínter esofágico superior y movimiento de hueso hioides. Los expertos además opinaron sobre el tipo de transductor para el examen y el tipo de exploración a desarrollar en cada ítem. El protocolo diseñado fue aplicado en tres sujetos sanos para definir las posibilidades de medición y algunas condiciones técnicas del examen. Los resultados fueron validados por un médico ecografista y una especialista internacional. Las proyecciones tras los resultados obtenidos están relacionadas a continuar con la fase de validez de criterio a través de pilotaje en población sana, además de desarrollar estudios con el fin de obtener valores estándar y normativos.

Palabras clave:
Evaluación; Deglución; Ultrasonido; Ecografía; Validación

**Corresponding Author: Roberto Rojas-Segovia*
Email: roberto.rojas.segovia@gmail.com

Received: 11-24-2023
Accepted: 10-29-2024
Published: 12-16-2024

 https://doi.org/10.5354/0719-4692.2024.72834

INTRODUCTION

Evidence indicates that ultrasound (US) serves as a method to assess anatomical and physiological elements and quantify various dynamic aspects of the preparatory, oral, and pharyngeal stages of swallowing (Allen et al., 2021; Canata et al., 2021; Hsiao et al., 2012; Maeda et al., 2023; Potente et al., 2023, 2023; Sanz Paris et al., 2022; J. Sepúlveda et al., 2019). Additionally, sarcopenic dysphagia can be detected through US by measuring lingual muscle mass and its echogenic brightness (Ogawa et al., 2018). Lingual thickness can also be assessed in populations with dysphagia resulting from stroke or amyotrophic lateral sclerosis (ALS) (Hsiao et al., 2012; Nakamori et al., 2016).

Further studies have explored hyoid bone displacement toward the base of the oral cavity. Lee et al. (2016) and Hsiao et al. (2012) determined that, in stroke survivors, hyoid displacement toward the submental triangle correlates with the severity of dysphagia.

The hyolaryngeal complex has also been studied for its role in airway protection mechanisms during the pharyngeal phase of swallowing. Findings show that the distance between the hyoid bone and thyroid cartilage at rest and during swallowing is significantly different between populations with typical swallowing and those with neurogenic dysphagia (Ahn et al., 2015; Huang et al., 2009; Kuhl et al., 2003; Picelli et al., 2021).

Other aspects that can be examined using US include vocal fold mobility (Gambardella et al., 2020; Jadcherla et al., 2006), lateral pharyngeal wall displacement (Kim & Kim, 2012), and anatomical and dynamic aspects of the upper esophageal sphincter (UES) (Morinière et al., 2013).

Despite these possibilities, no validated US protocol was found in previous reviews that allows for a comprehensive assessment of the swallowing process while considering normative values.

Professionals in some countries suggest a conservative approach to US use in clinical settings (Allen et al., 2021; Picelli et al., 2021). The consensus in research is that, before broadly promoting the use of this method for diagnosing swallowing disorders, progress must be made in the following areas: (a) developing a protocol agreed upon by experts, (b) generating enough evidence to validate the most appropriate technique, (c) verifying its reliability, and (d) determining the protocol's diagnostic efficiency (Allen et al., 2021).

This study aims to design an ultrasound swallowing assessment protocol (PEVD-US for its acronym in Spanish) with diagnostic utility for dysphagia. Additionally, to conduct an initial content validation of the protocol through expert judgment. This approach addresses the need for methodological consensus and gathering sufficient evidence to expand and optimize the use of ultrasound in the evaluation of swallowing disorders.

METHOD

The results introduced in this publication correspond to the first phase of a research project approved by the Scientific Ethics Committee of Universidad San Sebastián, Chile (CEC-USS) under project number 29-23.

Protocol Design

The development of the protocol involved two literature reviews conducted by the researchers. The first narrative review (J. Sepúlveda et al., 2019) aimed to explore evidence on swallowing assessment using US. There, the researchers collected and contrasted qualitative and quantitative data on lingual mobility, laryngeal elevation, lateral pharyngeal mobility, hyoid mobility, geniohyoid muscle mobility, upper esophageal sphincter opening, and glottic closure. Additionally, they analyzed studies on the potential to detect episodes of laryngeal penetration and aspiration using US. All these elements were classified according to the stage of swallowing. The obtained evidence supports the creation of an assessment protocol that unifies criteria and standards.

A second review, not yet published but registered in the International Prospective Register of Systematic Reviews (https://www.crd.york.ac.uk/PROSPERO), was officially accepted on January 7, 2021. This review was registered under the title "Diagnostic efficiency of ultrasound (US) for detection of aspiration in neurogenic dysphagia: a systematic review," with the code CRD42021225008. The review protocol received no suggestions for modification and was immediately approved. This systematic review analyzed the diagnostic efficiency of US for detecting aspiration in cases of neurogenic dysphagia in adults. Following inclusion and eligibility criteria, six references corresponding to clinical trials were selected. Overall, the QUADAS-2 applicability domains did not reveal questionable outcomes; however, the bias domains showed that no article had a low total risk. It was concluded that the quality of the evidence supporting US as an appropriate method for detecting aspiration is variable and that further research is needed to enhance, strengthen, and delve into the diagnostic properties of US. This would include aspects such as predictive values and ROC curves, based on the quantitative data provided by ultrasound analysis.

Based on the two aforementioned reviews, the researchers determined what items should be included in a comprehensive diagnostic swallowing assessment. Considering the amount of congruent evidence for each parameter, the potential biases, and the concurrent validation of various ultrasound techniques with videofluoroscopy (VFC) or fiberoptic endoscopic evaluation of swallowing (FEES), it was decided that the ultrasound swallowing assessment protocol would undergo content validation by expert judges.

Considering the selected biomechanical elements of swallowing, the survey sought the experts' opinions on the relevance of incorporating anatomical and physiological elements into the protocol (Item 1). Additionally, it asked them to establish which ultrasound technique and type of data analysis (qualitative or quantitative) was preferred for each anatomical and physiological structure (Item 2). Finally, the participants were consulted on the degree of difficulty in exploring and identifying anatomical and physiological structures using US (Item 3).

Regarding Item 1, the response options were "Not relevant," "Slightly relevant," "Relevant," and "Highly relevant." For Item 2, related to technique, the experts were asked to specify the preferred type of transducer and suggested type of exploration (qualitative, quantitative, or mixed) for each structure. Finally, for Item 3, addressing feasibility, the experts were asked to indicate for each structure whether the exploration was "Difficult," "Moderately difficult," "Easy," or "Not applicable/Does not examine." Each participant was required to select one option for each biomechanical aspect, establishing how relevant they deemed its inclusion in the protocol, what technique should be used, and the degree of difficulty in identifying the structures based on their own experience. The final survey was reviewed by an external professional before being sent to the expert judges.

Protocol Content Validation

A cross-sectional descriptive study was conducted for content validation using expert judgment (non-probabilistic selection), with experts contacted remotely during the first quarter of 2023. Experts were required to have at least three years of experience in swallowing and its disorders, as well as some familiarity with ultrasound (US). Consequently, most of the participants were corresponding authors of published papers and experts in swallowing (with knowledge of ultrasound). In total, 19 international and national experts were contacted. Of these, 7 specialists completed the content validation procedure for the protocol. The remaining experts did not respond within the designated timeframe for this stage. Three of the experts had more than 3 years of experience in US, and the majority were speech-language therapists or held equivalent professions. The countries of origin were: England (1), Taiwan (1), Mexico (2), Spain (1), and Chile (2).

The judges completed a survey for content validation, which included a consent section addressing their participation, as well as another section containing the proposed items for the ultrasound protocol. The data were then entered into SPSS Statistics (IBM Corp., 2015), where descriptive analyses were performed, followed by the creation of frequency tables.

Content validation was conducted using Lawshe's statistical test (Lawshe, 1975), which proposes a content validity index (CVI) of 0.99 for our sample. This follows the method's formula, which requires the participation of at least 5 expert judges. Items that received a CVI of 0.71 (1 judge in disagreement) were compared and analyzed through the controversy discussion method. In this process, a consensus was reached regarding their inclusion in the protocol, based on previously gathered evidence and the experience of the researchers. Items with a CVI lower than 0.70 were completely excluded from the protocol. A 70% agreement rate across the survey was used as the cut-off criterion (equating to agreement from 5 experts).

Using the obtained data, a preliminary protocol for swallowing assessment via US was developed. This protocol was applied by 2 speech-language therapists (trained in ultrasound) to 3 healthy adult participants (recruited by convenience) in order to address final technical details and general examination conditions. Participants in this phase were required to sign informed consent forms. The final techniques and procedures of the protocol were subsequently validated by 2 experts: an ultrasound specialist experienced in US for speech-language therapists, and an external speech-language therapy researcher, with a well-established track record in ultrasound-related topics.

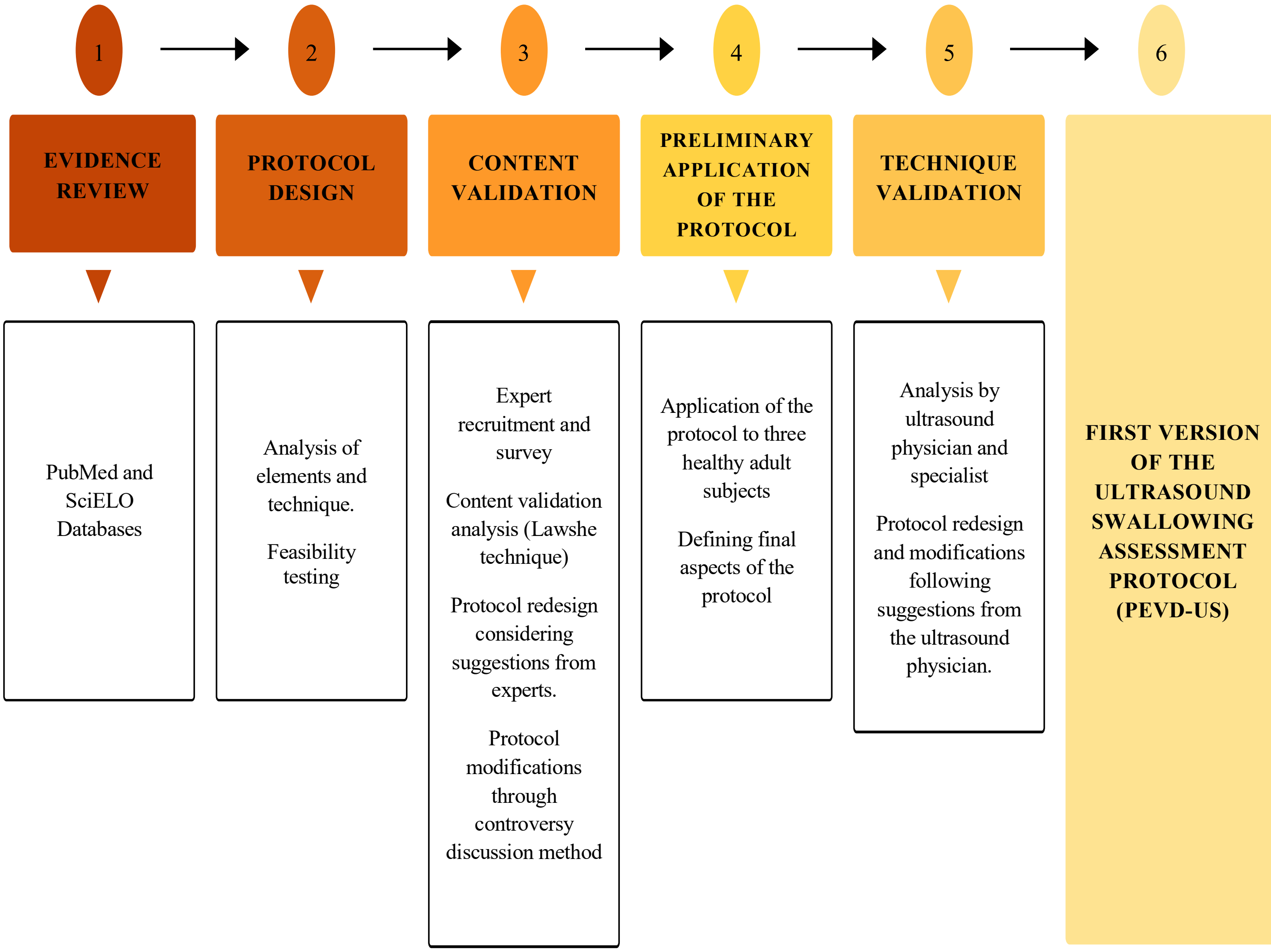


Figure 1. Flow chart for the design and creation of the ultrasound swallowing assessment protocol (PEVD-US).

RESULTS

The data from the survey were entered into SPSS Statistics (IBM Corp., 2015), where descriptive analyses were performed, and frequency tables were created (Tables 1 and 2 for items I and III, respectively). For content validation, the Lawshe (1975) statistical test was used.

The items necessary for the ultrasound assessment that obtained a CVI greater than .99 were lingual mobility, hyoid-thyroid approximation, vocal fold (VF) adduction, upper esophageal sphincter (UES), and identification of residue. Items with a CVI below .99 included hyoid mobility, pharynx, detection of aspiration (all with .71), and temporomandibular joint (TMJ) (with .14).

Regarding the difficulty level in using US to identify structures and biomechanical aspects of swallowing (Table 2), the items rated as "Easy" by more than 70% of the surveyed experts were the tongue and VFs. No item was rated as "Difficult" by more than two respondents. Items such as identifying residue and detecting aspiration were considered more complex to examine (57.1%).

As for the technique used for US, the only one where a consensus was reached (85.7%) was VF exploration using a linear transducer. For the remaining items, no agreement higher than 70% was reached on a specific preferred transducer. Additionally, a group of experts stated that they do not examine the TMJ (57.1%), pharynx (57.1%), UES (57.1%), or residue (71.4%) with US. There was no consensus on whether the data should be qualitative or quantitative for the suggested items.

Table 1. Response to item I: ("Regarding the clinical detection of a swallowing disorder (dysphagia, independent of its classification or type), how relevant would you deem the assessment of …").

Swallowing Structure or Finding	Score (By No. of Experts)			
	Not Relevant	Slightly Relevant	Relevant	Highly Relevant
Lingual Mobility and/or Thickness	0	0	5	2
Temporomandibular Joint	0	4	2	1
Pharynx	0	1	4	2
Hyoid Mobility	0	1	2	4
Hyoid-Thyroid Approximation	0	0	3	4
Vocal Fold Mobility and/or Adduction	0	0	3	4
Upper Esophageal Sphincter	0	0	4	2
Identifying Residue	0	0	3	4
Detecting Aspiration	0	1	2	4

Table 2. Response to item III: ("Regarding your experience with the use of B-mode ultrasound for swallowing, How easy has it been for you to identify…").

Swallowing Structure or Finding	Score (By No. of Experts)			
	Not Applicable / Does Not Examine	Difficult	Moderately Difficult	Easy
Lingual Mobility and/or Thickness	0	0	2	5
Temporomandibular Joint	5	0	1	1
Pharynx	3	2	1	1
Hyoid Mobility	0	0	5	2
Hyoid-Thyroid Approximation	1	0	3	3
Vocal Fold Mobility and/or Adduction	2	0	0	5
Upper Esophageal Sphincter	3	1	3	0
Identifying Residue	2	4	1	0
Detecting Aspiration	3	4	0	0

DISCUSSION

The discussion will follow the typical order used for upper digestive tract ultrasound exploration, starting with the cervical regions (known as the submental and submandibular triangles) and ending at the muscular triangle. In each section, the evidence will be contrasted with expert opinions on the relevance of the items and appropriate techniques for this protocol.

Exploration of the Submental/Submandibular Triangle

Based on the analyzed data, the two researchers strongly suggest that the submental triangle and the structures of the base of the mouth (Figure 2: A and B) are explored via ultrasound. According to experts, these regions are easily accessible, though there is no consensus on the type of transducer to be used. Available evidence shows that the choice of transducer depends on the goal of the assessment. However, the convex transducer seems to be preferred. Nakamori et al. (2016) and Hsiao et al. (2012) use a convex transducer to obtain the dimensions of tongue thickness (in medial sagittal, transverse, and longitudinal positions), while Ogawa et al., (2018) employ a mixed technique, and Söder & Miller (2002) use only the linear transducer.

The suggested transducer for this protocol is convex, as it facilitates visualization of the lingual surface (5-7 cm depth). One of the ultrasound experts in the final review also suggests performing an anteroposterior sweep of the submental triangle with a linear transducer based on qualitative analysis.

Regarding hyoid displacement, the available evidence and the CVI obtained from the expert survey show contrasting outcomes. This structure was not considered highly relevant or necessary to explore according to the experts, receiving a CVI of .71. This means that one of the seven respondents considered its relevance to be low. However, there is evidence of hyoid displacement analysis within the submental triangle. For instance, Chen et al. (2023), Hsiao et al. (2012), and Lee et al. (2016) use a convex transducer in a longitudinal medial position to measure hyoid bone displacement during swallowing, even establishing standard measurements. Additionally, Lee et al. (2016) conclude that hyoid bone displacement measured with ultrasound shows a statistically significant correlation with the VFC Penetration-Aspiration Scale (PAS) and the degree of pharyngeal residue.

Exploration of the Muscular Triangle

When it comes to the muscular triangle (Figure 2: C), the exploration of hyoid-thyroid approximation via ultrasound is highly recommended. However, the experts do not concur on the technique to use. Other authors (Ahn et al., 2015; Kuhl et al., 2003) agree on using a linear transducer placed between the hyoid and thyroid in a longitudinal medial plane, which allows for measuring the approximation of both structures during swallowing. On the other hand, Huang et al. (2009) use a convex transducer in patients with post-stroke dysphagia, finding a reduced hyoid-thyroid approximation compared to the control group. It is noteworthy that the choice of transducer will depend on the evaluation's objectives. In cases of diagnosed dysphagia or critical patients, the use of linear transducers may be more advantageous due to the level of detail they offer for superficial structures. This would, for instance, allow professionals to determine the measurements of endotracheal tubes (Señoret et al., 2022) or identify abnormal swallowing biomechanics, such as the presence of multiple swallows or muscular compensations (Sepúlveda et al., 2023).

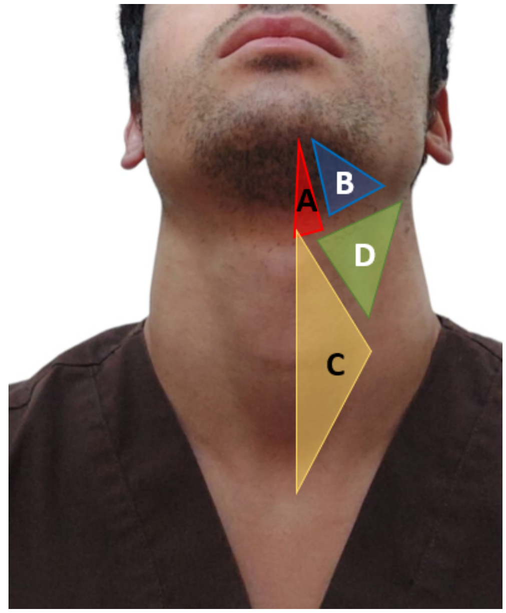


Figure 2. Cervical Sections.
Anatomical triangles are defined in both hemibodies of the anterior cervical region. The anterior triangle is composed of four segments: **A:** Submental Triangle (Located between the midline and the anterior belly of the digastric muscle, with the anterior apex at the jaw bone and the base at the hyoid bone); **B:** Submandibular Triangle (Located between the anterior belly of the digastric muscle and the edge of the jaw bone, with the anterior apex at the jaw bone and the base at the posterior belly of the digastric muscle); **C:** Muscular Triangle (Located from the midline of the laryngotracheal area, with the lateral boundary formed by the omohyoid and sternocleidomastoid muscles); **D:** Carotid Triangle (Located between the omohyoid muscle, sternocleidomastoid muscle, and the posterior belly of the digastric muscle).

Vocal fold mobility is explored by several instrumental examinations. The CVI obtained for this item shows that the experts consider it should also be explored with ultrasound, and they agree on using a linear transducer. Jadcherla et al. (2006) conducted a qualitative exploration of the vocal folds using a linear transducer, positioned transversally over the thyroid cartilage, and compared their results with nasofibroscopy, finding a high correlation in VF adduction.

UES exploration with ultrasound reached a high CVI among the experts, which aligns with clinical experience. This is because the opening of the sphincter at the end of the pharyngeal phase is one of the relevant milestones in swallowing biomechanics (Manabe et al., 2018; Morinière et al., 2013). However, evidence of US exploration for this structure is limited, and the experts in this study did not reach a consensus regarding technique, noting that it is difficult to access this structure using ultrasound. Morinière et al. (2013) suggest exploring the UES with a linear transducer, placing the probe on the left side of the neck in a transverse plane just below the cricoid cartilage. These authors even obtained morphological and functional measurements of the UES. Manabe et al. (2018) also use a linear transducer, placing it 1 cm below the lower edge of the cricoid cartilage.

The present protocol incorporates the UES, with the experts recommending a qualitative exploration and a linear transducer. One of the ultrasound experts participating in the final review suggests that in particular cases, a longitudinal section (anteroposterior axis) in the sagittal paratracheal plane can show additional aspects of the digestive tract morphology, such as diverticula or malformations that significantly affect UES opening.

Final Protocol

The TMJ, lateral pharyngeal wall and aspiration items did not obtain a sufficient CVI due to the number of experts surveyed (Lawshe, 1975). Furthermore, the experts noted that both the pharyngeal cavity and the presence of aspiration are difficult to explore with US.

According to their CVI, the items to be included are: 1) Tongue characteristics, 2) Hyoid-thyroid approximation, 3) Vocal fold adduction, and 4) Upper esophageal sphincter. The experts' judgment on the appropriate strategy for handling data (qualitative and/or quantitative) and the level of difficulty of the procedure are added to this. Finally, the researchers incorporate the item “Hyoid Bone Displacement”, based on available evidence and after applying the controversy discussion method.

The details for the evaluation of items included in the first version of the Ultrasound Swallowing Assessment Protocol (PEVD-US) are found in Appendix 1.

LIMITATIONS

The main limitation of this study is the reduced number of national speech-language therapists with experience and/or training in ultrasound techniques. Nonetheless, the participation and collaboration of international researchers with experience and publications related to the topic enriched the discussion and the data, ultimately making it possible to reach the stated objectives.

There is limited evidence regarding ultrasound protocols for swallowing assessment. This is also a limitation, especially when completing the discussion section, as there are no known structures or validity data available for similar instruments. However, this also represents a significant opportunity for future projections of this research.

CONCLUSIONS

A preliminary protocol for swallowing assessment via ultrasound (US) is created, whose content was validated using the Lawshe (1975) technique, along with a controversy discussion method. The items to be included in the PEvD-US are tongue, hyoid displacement, hyoid-thyroid approximation, vocal fold adduction, and upper esophageal sphincter (UES). The technique and measurement possibilities are also defined for each item, as well as some of the technical conditions of the examination.

It is suggested that future research addresses criterion validity, piloting the protocol in a healthy population. Additionally, further studies should be carried out to obtain standard and normative values. Experts have recognized the need to establish such values to serve as references for diagnosing swallowing disorders (Allen et al., 2021).

Determining normative values will make it possible to identify patient populations that would benefit most from US swallowing assessment. Future studies are being considered that will collect measurements from specific pathologies to obtain sensitivity and specificity values related to the use of the PEVD-US.

Finally, the US technique is a safe, quick, and cost-effective examination that provides both quantitative and qualitative information on the anatomical and physiological aspects of the swallowing process. However, it requires training and a standardized protocol to facilitate result interpretation.

ACKNOWLEDGMENTS

Acknowledgments are extended to the Medical Technology program and the Health Center of Universidad San Sebastián in Providencia, as well as to its non-medical professionals who facilitated our work. We also thank the experts who participated in the study, whom we cannot mention explicitly due to data and background privacy concerns.

REFERENCES

Ahn, S. Y., Cho, K. H., Beom, J., Park, D. J., Jee, S., & Nam, J. H. (2015). Reliability of ultrasound evaluation of hyoid-larynx approximation with positional change. *Ultrasound in Medicine & Biology*, *41*(5), 1221–1225. https://doi.org/10.1016/j.ultrasmedbio.2014.12.010

Allen, J. E., Clunie, G. M., & Winiker, K. (2021). Ultrasound: An emerging modality for the dysphagia assessment toolkit? *Current Opinion in Otolaryngology & Head and Neck Surgery*, *29*(3), 213. https://doi.org/10.1097/MOO.0000000000000708

Canata, C. M., Ramírez, A. R. A., Melgarejo, G., Cáceres, R., & Tornaco, R. (2021). Caracterización de estructuras anatómicas de la laringe por ultrasonografía. *International Journal of Medical and Surgical Sciences*, *8*(2), Article 2. https://doi.org/10.32457/ijmss.v8i2.1472

Chen, S.-Y., Wei, K.-C., Cheng, S.-H., Wang, T.-G., & Hsiao, M.-Y. (2023). The Hyoid Bone Kinematics in Dysphagic Stroke Patients: Instantaneous Velocity, Acceleration and Temporal Sequence Matters. *Dysphagia*, *38*(6), 1598–1608. https://doi.org/10.1007/s00455-023-10587-w

Gambardella, C., Offi, C., Romano, R. M., De Palma, M., Ruggiero, R., Candela, G., Puziello, A., Docimo, L., Grasso, M., & Docimo, G. (2020). Transcutaneous laryngeal ultrasonography: A reliable, non-invasive and inexpensive preoperative method in the evaluation of vocal cords motility—a prospective multicentric analysis on a large series and a literature review. *Updates in Surgery*, *72*(3), 885–892. https://doi.org/10.1007/s13304-020-00728-3

Hsiao, M.-Y., Chang, Y.-C., Chen, W.-S., Chang, H.-Y., & Wang, T.-G. (2012). Application of Ultrasonography in Assessing Oropharyngeal Dysphagia in Stroke Patients. *Ultrasound in Medicine and Biology*, *38*(9), 1522–1528. https://doi.org/10.1016/j.ultrasmedbio.2012.04.017

Huang, Y.-L., Hsieh, S.-F., Chang, Y.-C., Chen, H.-C., & Wang, T.-G. (2009). Ultrasonographic Evaluation of Hyoid–Larynx Approximation in Dysphagic Stroke Patients. *Ultrasound in Medicine and Biology*, *35*(7), 1103–1108. https://doi.org/10.1016/j.ultrasmedbio.2009.02.006

IBM Corp. (2015). *IBM SPSS Statistics for Windows* (Versión 23, Vol. 28) [Software]. IBM Corp. https://hadoop.apache.org

Jadcherla, S. R., Gupta, A., Stoner, E., Coley, B. D., Wiet, G. J., & Shaker, R. (2006). Correlation of Glottal Closure Using Concurrent Ultrasonography and Nasolaryngoscopy in Children: A Novel Approach to Evaluate Glottal Status. *Dysphagia*, *21*(1), 75–81. https://doi.org/10.1007/s00455-005-9002-7

Kim, J.-H., & Kim, M.-S. (2012). Lateral Pharyngeal Wall Motion Analysis Using Ultrasonography in Stroke Patients with Dysphagia. *Ultrasound in Medicine and Biology*, *38*(12), 2058–2064. https://doi.org/10.1016/j.ultrasmedbio.2012.07.028

Kuhl, V., Eicke, B. M., Dieterich, M., & Urban, P. P. (2003). Sonographic analysis of laryngeal elevation during swallowing. *Journal of Neurology*, *250*(3), 333–337. https://doi.org/10.1007/s00415-003-1007-2

Lawshe, C. H. (1975). A Quantitative Approach to Content Validity. *Personnel Psychology*, *28*(4), 563–575. https://doi.org/10.1111/j.1744-6570.1975.tb01393.x

Lee, Y. S., Lee, K. E., Kang, Y., Yi, T. I., & Kim, J. S. (2016). Usefulness of Submental Ultrasonographic Evaluation for Dysphagia Patients. *Annals of Rehabilitation Medicine*, *40*(2), 197–205. https://doi.org/10.5535/arm.2016.40.2.197

Maeda, K., Nagasaka, M., Nagano, A., Nagami, S., Hashimoto, K., Kamiya, M., Masuda, Y., Ozaki, K., & Kawamura, K. (2023). Ultrasonography for Eating and Swallowing Assessment: A Narrative Review of Integrated Insights for Noninvasive Clinical Practice. *Nutrients*, *15*(16), Article 16. https://doi.org/10.3390/nu15163560

Manabe, N., Haruma, K., Nakato, R., Kusunoki, H., Kamada, T., & Hata, J. (2018). New ultrasonographic screening method for oropharyngeal dysphagia: Tissue Doppler imaging. *American Journal of Physiology-Gastrointestinal and Liver Physiology*, *314*(1), G32–G38. https://doi.org/10.1152/ajpgi.00019.2017

Morinière, S., Hammoudi, K., Marmouset, F., Bakhos, D., Beutter, P., & Patat, F. (2013). Ultrasound analysis of the upper esophageal sphincter during swallowing in the healthy subject. *European Annals of Otorhinolaryngology, Head and Neck Diseases*, *130*(6), 321–325. https://doi.org/10.1016/j.anorl.2012.01.008

Nakamori, M., Hosomi, N., Takaki, S., Oda, M., Hiraoka, A., Yoshikawa, M., Matsushima, H., Ochi, K., Tsuga, K., Maruyama, H., Izumi, Y., & Matsumoto, M. (2016). Tongue thickness evaluation using ultrasonography can predict swallowing function in amyotrophic lateral sclerosis patients. *Clinical Neurophysiology*, *127*(2), 1669–1674. https://doi.org/10.1016/j.clinph.2015.07.032

Ogawa, N., Mori, T., Fujishima, I., Wakabayashi, H., Itoda, M., Kunieda, K., Shigematsu, T., Nishioka, S., Tohara, H., Yamada, M., & Ogawa, S. (2018). Ultrasonography to Measure Swallowing Muscle Mass and Quality in Older Patients With Sarcopenic Dysphagia. *Journal of the American Medical Directors Association*, *19*(6), 516–522. https://doi.org/10.1016/j.jamda.2017.11.007

Picelli, A., Modenese, A., Poletto, E., Businaro, V., Varalta, V., Gandolfi, M., Bonetti, B., & Smania, N. (2021). May ultrasonography be considered a useful tool for bedside screening of dysphagia in patients with acute stroke? A cohort study. *Minerva Medica*, *112*(3), 354–358. https://doi.org/10.23736/S0026-4806.20.06571-4

Potente, P., Buoite Stella, A., Vidotto, M., Passerini, M., Furlanis, G., Naccarato, M., & Manganotti, P. (2023). Application of Ultrasonography in Neurogenic Dysphagia: A Systematic Review. *Dysphagia*, *38*(1), 65–75. https://doi.org/10.1007/s00455-022-10459-9

Sanz Paris, A., Calmarza Chueca, F., Sanz Arqué, A., & González Fernández, M. (2022). Situación actual y visión de futuro de la utilidad de la ecografía en el estudio de la disfagia orofaríngea. *Nutrición Clínica en Medicina*, *16*(2), 105–118.

Señoret R., F., Cabrera Sch., M. C., Aranda G., F., & Gutiérrez V., C. (2022). Ultrasonido como complemento en el manejo de la vía aérea. *Revista Chilena de Anestesia*, *51*(2), 203–212. https://doi.org/10.25237/revchilanestv5108021500

Sepúlveda, J., Rojas, R., & Casanova, M. (2019). Ultrasonido para la evaluación de la deglución: Una revisión narrativa. *Revista Chilena de Fonoaudiología*, *18*, 1–22. https://doi.org/10.5354/0719-4692.2019.55327

Sepúlveda, P., Lecaros, M., Sandoval, D., & Gallardo, A. (2023). Utility of ultrasonography in the evaluation of thyroid-hyoid approximation in Sistrunk surgery: A case report. *Revista Chilena de Medicina Intensiva*, *38*(1), 25–29.

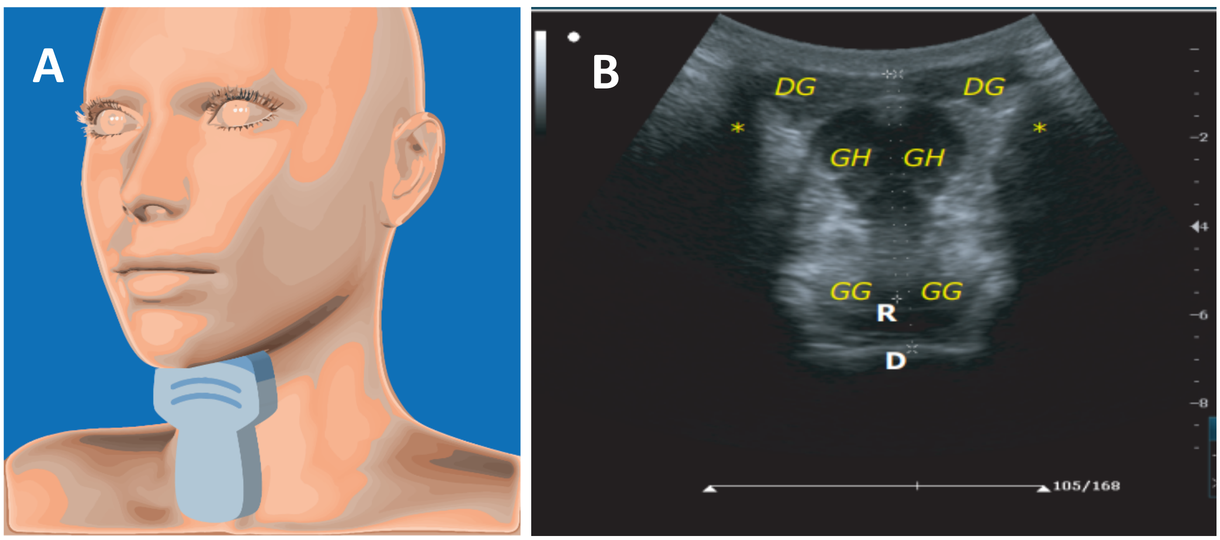
Söder, N., & Miller, N. (2002). Using Ultrasound to Investigate Intrapersonal Variability in Durational Aspects of Tongue Movement During Swallowing. *Dysphagia*, *17*(4), 288–297. https://doi.org/10.1007/s00455-002-0071-6

APPENDIX 1. Items included in the PEVD-US with transducer type, location, and image characteristics in B-mode.

Item and Type of Analysis	Transducer and Location.	Characteristics of the Image in B Mode
Tongue (Thickness) / Quantitative Analysis	A convex transducer in the transverse axis is used to obtain an image of the coronal plane of the oral cavity, at the midpoint between the mandibular bone and the hyoid bone. The insonation should be directed perpendicularly to the Frankfurt plane (a virtual horizontal plane that is transverse to the skull, passing through the upper margin of the external auditory meatus and the lower edge of the orbital cavity).	On each side of the image, acoustic shadows formed by the body of the jaw are visible. In this position, in the short axis view, the suprahyoid muscles are clearly defined with a hypoechoic signal at the floor of the oral cavity. Superficially, the anterior bellies of the left and right digastric muscles are observed. Deeper, the geniohyoid and genioglossus muscles are visible. The symmetry, presence of involuntary movements, and atrophy are qualitatively analyzed. The muscle thickness at rest can be quantified using a caliper (Appendix 2).
Tongue (Mobility) / Qualitative and Quantitative Analysis	A convex transducer, in the longitudinal (anteroposterior) axis, placed along the midline of the submental triangle is used to obtain an image in the sagittal plane of the oral cavity.	On each side of the image, two acoustic shadows are observed. To the left of the monitor, the shadow corresponds to the jaw bone, and on the right, it corresponds to the hyoid bone. The lingual surface appears hyperechoic, and at the base, a hypoechoic anteroposterior signal corresponds to the geniohyoid muscle. In this plane, the analysis of mobility is performed according to the swallowing phase and at rest/swallowing, including the contraction distances of various muscle groups (appendix 3).
Hyoid (Displacement) / Quantitative Analysis	A convex transducer, in the longitudinal (anteroposterior) axis, placed along the midline of the submental triangle, is used to obtain a sagittal plane image of the oral cavity.	On each side of the image, two acoustic shadows are observed. To the left of the monitor, the shadow corresponds to the mandibular bone, and on the right, the hyoid bone can be observed. The bony structures appear hyperechoic. The distance between the two structures is measured at rest and during swallowing (appendix 4).
Hyoid-Thyroid (Approximation) / Quantitative Analysis	A convex or linear transducer, depending on the clinician's preference, in the longitudinal (anteroposterior) axis, placed along the midline of the upper portion of the muscular triangle, is used to obtain a sagittal plane image of the supraglottic structures.	On each side of the image, two hyperechoic structures are observed. To the left of the monitor, the structure corresponds to the hyoid bone, and on the right is the thyroid cartilage. The distance between the two structures is measured at rest and during swallowing. It is also possible to describe the presence of compensatory movements or multiple swallows (appendix 5).
Vocal Folds / Qualitative Analysis	A linear transducer, insonating over the thyroid cartilage in the transverse plane (anteroposterior axis) and parallel to the Frankfurt plane.	The vocal folds (VFs) have the shape of an inverted V structure with a hypoechoic or isoechoic signal and are mobile during phonation and respiratory mechanics (moving away from and towards the medial axis, which appears anechoic). The anterior vertex is inserted into the thyroid cartilage, highlighted with a hyperechoic signal. The thyroid cartilage itself also has an inverted V shape, and in some cases, it appears more like a horseshoe. In both hemilarynges, between the thyroid cartilage and the vocal cords, there is an isoechoic signal corresponding to the ventricular bands. In some cases, two mobile hyperechoic signals corresponding to the arytenoid cartilages are observed in a posterior segment of the plane. The mobility and symmetry of the structures described can be analyzed (appendix 6).
UES / Qualitative Analysis	A linear transducer in the anteroposterior axis, insonating in the transverse plane at the lower edge of the cricoid cartilage (or up to 1 cm below this position, with a slight cephalic	The reference in this image is a circular anechoic structure on the right side of the screen, corresponding to the left common carotid artery. Above this artery and towards the cervical surface, several hypoechoic structures are observed, corresponding to the omohyoid, sternohyoid, sternothyroid, and sternocleidomastoid muscles. In the medial area of

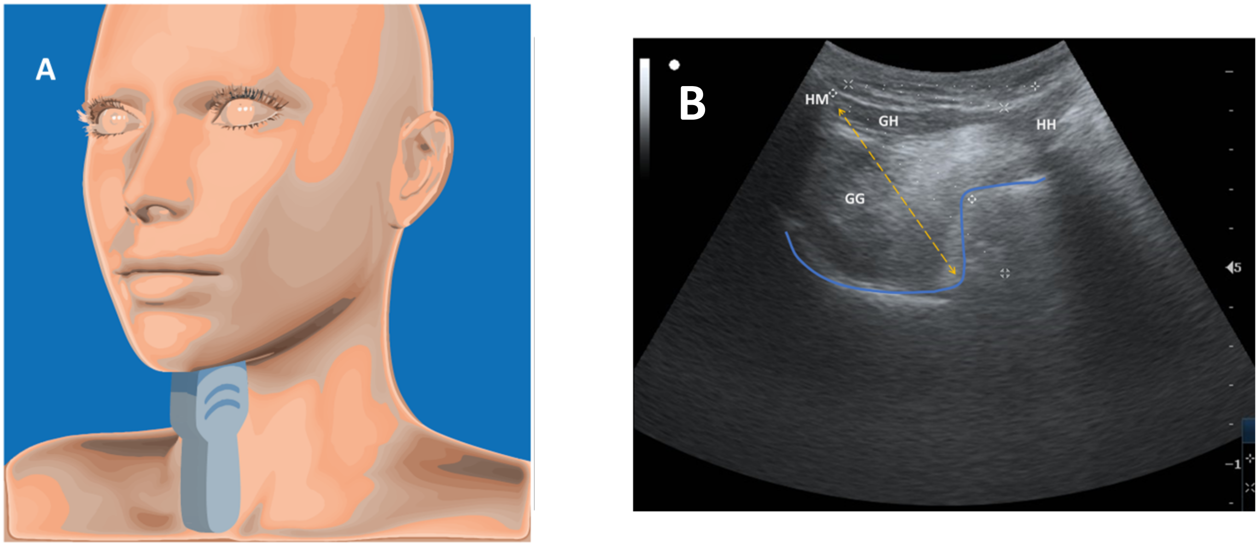
	direction), parallel to the Frankfurt plane, from the left side of the neck.	the image, there is a homogeneous isoechoic structure corresponding to the left lobe of the thyroid gland, which continues towards the left side of the image with the isthmus. Below the isthmus, a hyperechoic horseshoe-shaped structure is observed, corresponding to the cricoid cartilage. The structure behind the cricoid cartilage corresponds to the tracheal space. Towards the posterior border of the cricoid cartilage and behind the left lobe of the thyroid gland, a hypoechoic ring-shaped structure is observed. This structure corresponds to the upper esophageal sphincter (UES). It is possible to analyze its morphology, qualitative mobility during swallowing, and measurements of its opening (appendix 7).

APPENDIX 2. Body of the tongue.



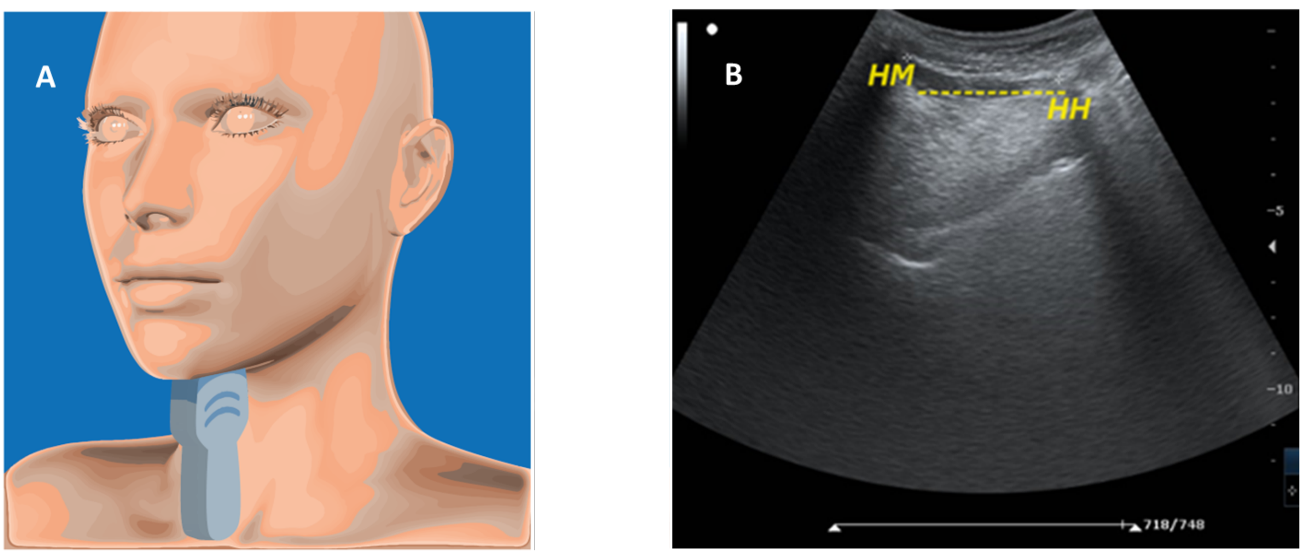
A: Convex transducer in the transverse plane, at the midpoint between the chin and hyoid bone, insonating in a direction perpendicular to the Frankfurt plane. **B:** Lingual mass (Transverse plane) DG: Digastric muscle; GH: Geniohyoid muscle; GG: Genioglossus muscle; *: Jaw bone shadow; R: Tongue position at rest; D: Tongue position during swallowing.

APPENDIX 3. Lingual Mobility.



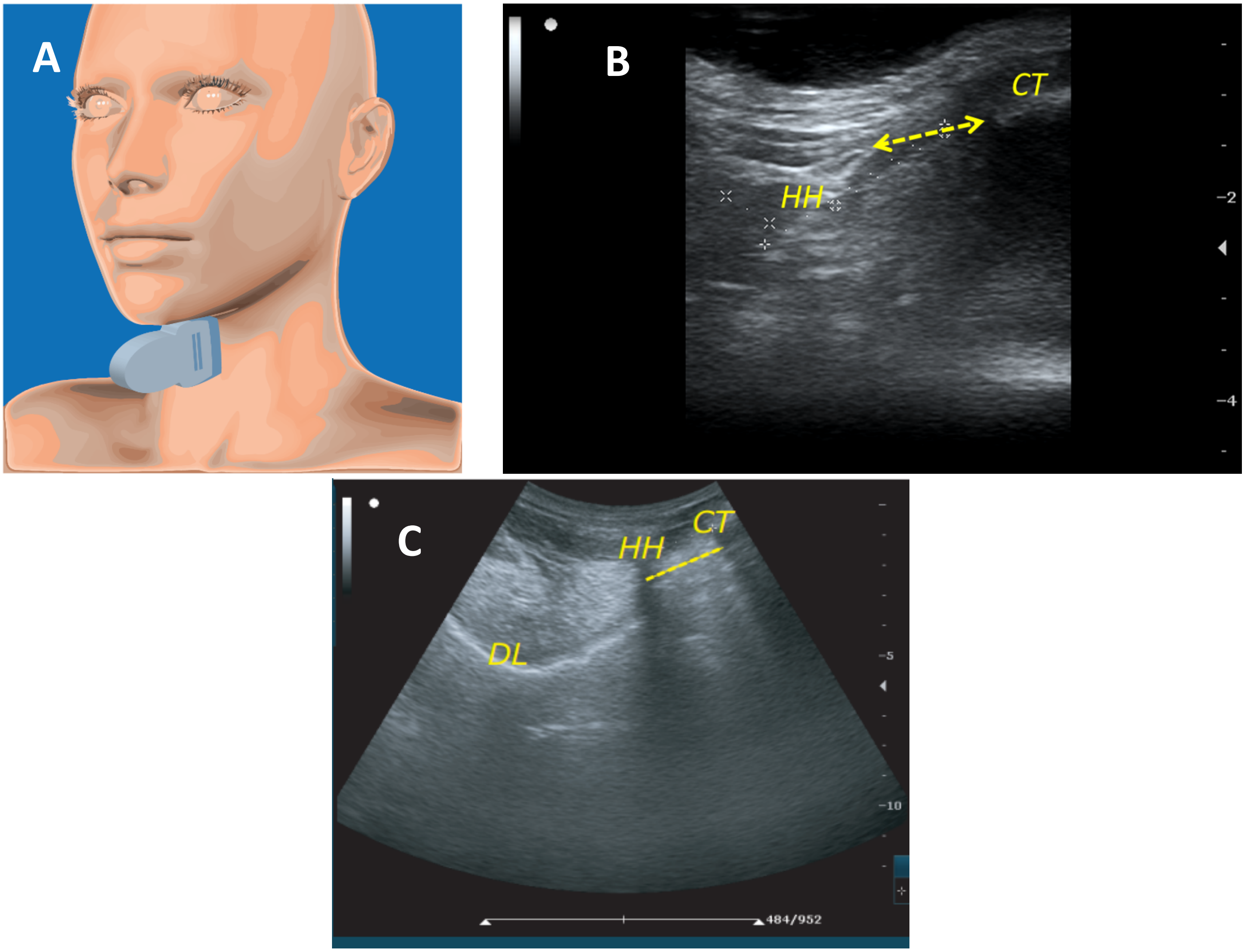
A: Convex transducer, longitudinal, along the midline of the submental triangle. **B:** The lingual mobility during the phases of swallowing can be described in terms of anteroposterior and cephalocaudal displacements relative to fixed structures such as the jaw (HM), as the lingual border exhibits a hyperechoic signal. HH: Hyoid bone; HM: Jaw bone shadow; GH: Geniohyoid muscle; GG: Genioglossus muscle.

APPENDIX 4. Hyoid bone displacement.



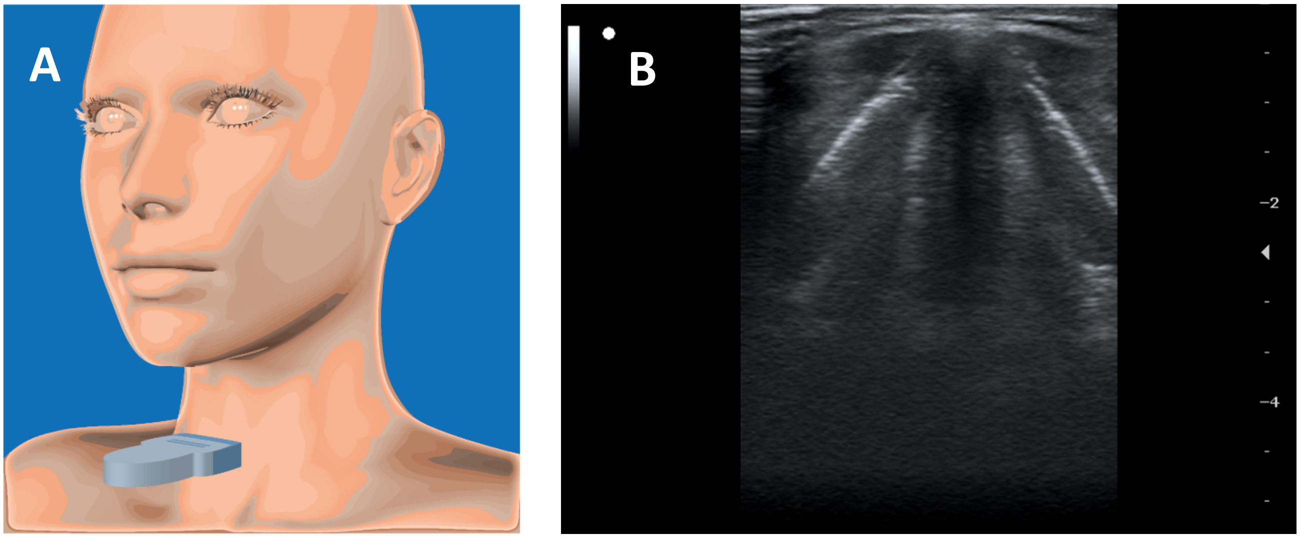
A: Convex transducer, longitudinal, along the midline of the submental triangle. **B:** Hyoid displacement (Longitudinal plane) HH: Hyoid bone; HM: Mandibular bone shadow; ---- Displacement axis of the hyoid bone during swallowing.

APPENDIX 5. Hyoid-Thyroid Approximation.



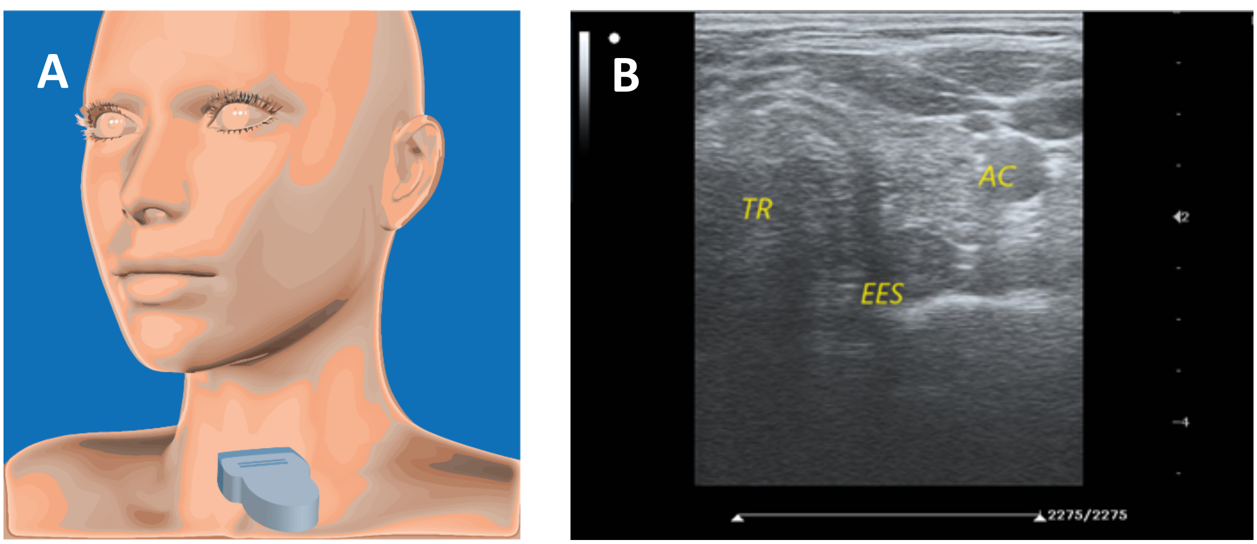
A: Longitudinal plane transducer along the midline of the muscular triangle, over the thyrohyoid space. **B:** Linear transducer: HH: Hyoid bone; CT: Thyroid cartilage; ---- Thyrohyoid displacement axis at rest. **C:** Convex transducer: HH: Hyoid bone; CT: Thyroid cartilage; DL: Lingual dorsum ---- Thyrohyoid displacement axis at rest.

APPENDIX 6. Vocal Folds.



A: Linear transducer, insonating in the muscle triangle over the thyroid cartilage transversely and parallel to the Frankfurt plane. **B:** Vocal folds (Transverse plane) CT: Thyroid cartilage visualized as a hyperechoic inverted V; CCVV: Vocal folds (observed with an anechoic central area corresponding to the glottic space, with the vocal folds appearing as two hypoechoic vertical lines with an anterior vertex); BV: Ventricular band (isoechoic signal parallel to the vocal cords, denoting the ventricular bands).

APPENDIX 7. Upper Esophageal Sphincter.



A: Linear transducer, insonating at the lower edge of the cricoid cartilage (or up to 1 cm below this position) transversely and slightly diagonally to the Frankfurt plane, from the left side of the neck. **B:** AC: Left common carotid artery. In the medial zone of the image, there is an isoechoic structure corresponding to the left lobe of the thyroid gland (GT), which continues towards the left side of the image with the isthmus of the gland. Below the isthmus, a hyperechoic horseshoe-shaped structure is observed, corresponding to the cricoid cartilage (CC). The hypoechoic and anechoic structure behind the mentioned cartilage corresponds to the tracheal space (TR). Towards the posterior edge of the cricoid cartilage and behind the left lobe of the thyroid gland, a ring-shaped structure is observed. This structure corresponds to the upper esophageal sphincter (UES).