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ORIGINAL RESEARCH

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Investigative Otolaryngology

Proposal for standardized ultrasound analysis of the salivary glands: Part 1 submandibular gland

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Abstract

Objectives: The Salivary Gland Committee of the American Academy of Otolaryngology-Head and Neck Surgery seeks to standardize terminology and technique for ultrasonography used in the evaluation and treatment of salivary gland disorders.

Methods: Development of expert opinion obtained through interaction with international practitioners representing multiple specialties. This committee work includes a comprehensive literature review with presentation of case examples to propose a standardized protocol for the language used in ultrasound salivary gland assessment.

Results: A multiple segment proposal is initiated with this focus on the submandibular gland. We provide a concise rationale for recommended descriptive language highlighted by a more extensive supplement that includes an extensive literature review with additional case examples.

Conclusion: Recommendations are provided to improve consistency both in performing and reporting submandibular gland ultrasound.

KEYWORDS
anatomic subsites, color doppler, salivary glands, shear wave elastography, submandibular, ultrasound

For affiliations refer to page 9

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1 | INTRODUCTION

Point-of-care ultrasound (POCUS) analysis was described by Moore and Copel in 2011 as an evaluation performed and interpreted immediately at the bedside by the clinician.[1] Advances in technology have made ultrasound "*user-friendly for all practitioners*" with a recent report addressing POCUS by Liao et al supporting it as "*essential for clinical practice as well as for training in the field of otolaryngology and head and neck surgery*."[2]

This AAO-HNS Salivary Gland Committee sponsored proposal to standardize technique and nomenclature initially arose from POCUS as practiced in Otolaryngology. However, the recommendations are designed to be broadly applicable to clarify established protocols in other settings including the consultative comprehensive technician-performed examinations done in Radiology departments. Multidisciplinary specialists were called on to refine these recommendations to cross boundaries between specialties and support broad acceptance.

This work identifies assessment techniques and defines subsites to improve consistency in performing and reporting ultrasound evaluations. This approach to standardization focuses on static images but is also applicable to terminology used in review of video clips as has been advocated to improve interrater reliability.[3] The technique of ultrasound video-imaging review has also been supported by the OMERACT (Outcome Measures for Rheumatoid Arthritis Clinical Trials) group. OMERACT has published a semi-quantitative approach to provide a global assessment of salivary gland (primarily parotid) abnormalities associated with Sjogren's disease through a review of video-imaging to characterize the degree of pathology seen throughout the gland.[4–6] An updated report by Tang et al supported the value of applying this OMERACT scoring system to the analysis of static images of the salivary glands.[7] However, their report offered only a broad review of "*typical static grayscale images*" in their report without identifying which subsites within the glands were analyzed.

Radiomics is defined as a method to extract information from medical images beyond that provided by visual inspection and has received intense scrutiny with MRI and CT imaging. Ultrasound radiomics is a developing field with acknowledged limitations due to inconsistency in image acquisition and difficulties in calibrating quantitative methods.[8] Subjective grading of salivary ultrasound images through semi-quantitative classification schemes has been supplemented by quantitative assessment employing shear wave elastography to refine analysis.[4,6,9–11] Assessment by many different methods of ultrasound analysis generally lack consistency in identifying specific anatomic regions (subsites) within the salivary glands and rarely report differences between regions in the same gland.[12,13]

Shear wave elastography is a quantitative ultrasound method used to determine the velocity of tissue displacement resulting from a secondary "push pulse" produced by the ultrasound probe. The speed of tissue displacement (shear wave) correlates with the tissue stiffness or fibrosis from the selected "regions of interest" evaluated.[14] Standardization to identify specific subsites within the salivary glands is needed to provide consistency for many reasons, including the value in the identification of "regions of interest" needed for shear wave measurements.[15–18]

This report addresses the standardization of salivary gland ultrasound nomenclature and measurement technique with an additional focus on the reporting to include specific subsites within the gland. Recommendations are designed to provide logical terminology and consistency in salivary gland imaging intended for clinical and research applications within the evolving field of ultrasound radiomics.[19]

The following recommendations derive both from expert opinion of the contributing authors and an extensive literature review that is detailed in the accompanying supplement along with representative case examples.

2 | RECOMMENDATIONS

2.1 | Submandibular gland anatomy and subsites

We propose that the submandibular gland is comprised a superficial lobe and a deep lobe. The deep lobe also includes an anterior projection termed the uncinate process partially surrounding Wharton's duct. The traditional use of the term 'lobe' is clearly defined when applied to the lung to identify segments determined by bronchial branching.[20] The pulmonary lobes are also identifiable through the classic definition that "a lobe is part of an organ defined by a fissure seen at the surface of the organ".[21]

The superficial 'lobe' of the submandibular gland is more accurately termed the superficial 'aspect' or 'portion'. Discrimination from the deep 'aspect' of the gland is determined by its relationship to an external structure (the mylohyoid muscle) and not an internal organization or an identifiable fissure. Similarly, the liver has been broadly classified as having the right and left lobes that do not correspond to the more critical subdivision into multiple sectors or segments discriminated by blood supply and biliary flow.[22] We acknowledge the more accurate division of the submandibular gland into two "aspects"—the superficial and deep portions. However, due to established conventions, the more widely used terminology employing the term 'lobes' is also reasonable.

Also considered within the anatomic unit of the submandibular gland are the surrounding capsule as well as internal vasculature where surrounded by gland parenchyma (Table 1).[23] The capsule of the submandibular gland has been identified as a continuation of the investing layer of the deep cervical fascia.[24] As

TABLE 1 Proposed terminology to define subsites and regions within the submandibular gland.

Ultrasound Anatomic Definitions		
	Entire Submandibular Gland	Includes uncinate process, Warton's duct, gland capsule and blood vessels within the gland parenchyma
	Lobes (Aspects)	
Superficial lobe (aspect)	Superficial to mylohyoid including the aspect of gland posterior to the mylohyoid	Includes branches of facial artery and vein encompassed by parenchyma
Deep lobe (aspect)	Deep to mylohyoid includes uncinate process as well as a portion of gland deep to the line of mylohyoid along the full extent of the gland	Includes branches of the facial artery and vein encompassed by parenchyma
	Subunits	
Uncinate process	Anterior extension of the deep lobe of the submandibular gland between the mylohyoid and hyoglossus muscles and below intraoral mucosa	
Posterior and Superior vascularized gland	Includes branches of the facial blood vessels (artery and vein) within the profile of the gland parenchyma	
Gland capsule (border)	Capsule is anatomically thinner on deep aspect of gland	Ultrasound appearance of capsule (border) is diminished by processes including obesity, sialosis, irradiation and autoimmune sialadenitis

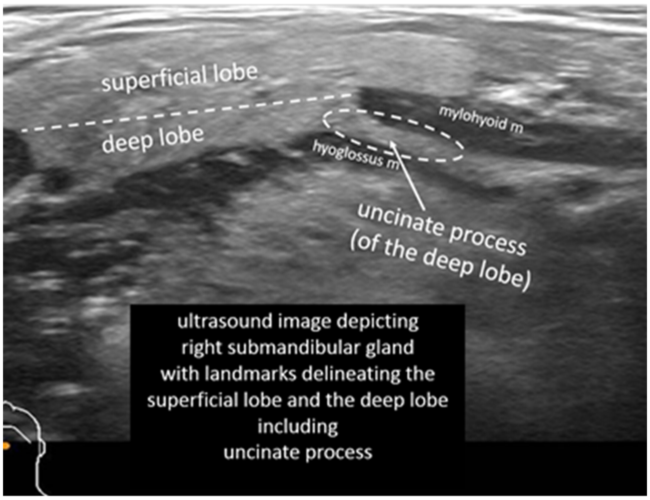


FIGURE 1 Ultrasound (14–5 MHz linear probe transverse) identifying superficial and deep lobes and the uncinate process of the left submandibular gland (with approval from Hoffman HT (ed) Iowa Head and Neck Protocols <Submandibular Gland Anatomy: The Uncinate Process of the Deep Lobe|Iowa Head and Neck Protocols (uiowa.edu) > accessed April 2, 2023.

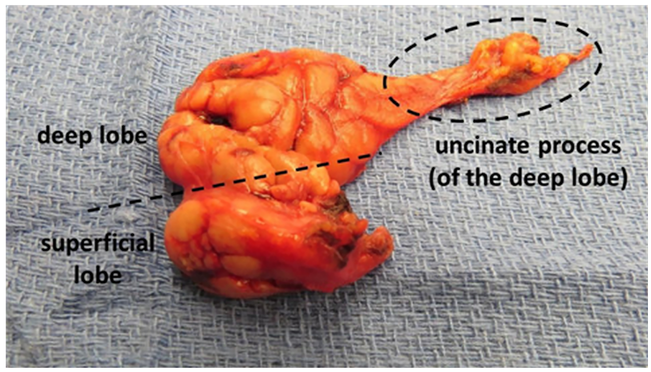


FIGURE 2 Specimen of a submandibular gland resection extended to include the uncinate process and duct after previous total sublingual gland resection for ranula. The pathological review showed no remaining sublingual tissue. (with approval from Hoffman HT (ed) Iowa Head and Neck Protocols <Submandibular Gland Anatomy: The Uncinate Process of the Deep Lobe|Iowa Head and Neck Protocols (uiowa.edu) ≥accessed April 2, 2023.

per O'Daniel, this fascia is thicker anteriorly (superficial aspect) and thinner posteriorly (deep aspect).[25] A normal capsule to the submandibular gland will be identified with a hyperechoic appearance. The loss of definition to the gland border is considered a sufficiently abnormal finding that its absence is used in ultrasound grading scales to support the diagnosis of Sjogren's syndrome.[10,13,26] Obesity, diabetes and sialosis have also been identified to be associated with an invisible deep (posterior) border.[3,27]

The superficial lobe is distinguished from the deep lobe (including the uncinate process) by a line running parallel to the transverse axis of the gland as determined by the posterior margin of the mylohyoid muscle (Figure 1).

The deep lobe includes the uncinate process, which is defined as the anterior extension of the submandibular gland between the mylohyoid and hyoglossus muscles (Figure 2).

This uncinate process of the submandibular gland includes parenchymal tissue surrounding Wharton's duct and may be difficult to discriminate on ultrasound examination from sublingual gland tissue. Leppi performed elegant cadaveric dissections to discriminate the uncinate process from the sublingual gland and identified "variable groupings" of submandibular tissue above the mylohyoid muscle (Figure 3).[28] Although he termed these anterior extensions of the submandibular gland as either "accessory glands" or "secondary glands," we feel the term "uncinate process" of the submandibular gland most effectively describes this extension.

The anatomy of the floor of the mouth is complicated by the variable relationships not only between the sublingual gland and Wharton's duct but also by variety in the extent of the uncinate process (Figure 4).

Anatomic variation to the posterior and superior aspects of the submandibular gland may create difficulty in measuring the extent of parenchyma due to variability in the vascular structures in this region. Ultrasound with color doppler is useful not only in discriminating between blood vessels and non-vascular ductal elements but may direct more accurate size measurement of the submandibular gland by identifying where blood vessels are surrounded by gland parenchyma (Figure 5).[3,29]

Although the arterial blood supply to the submandibular gland may also arise from the lingual, deep lingual, and external carotid arteries, the dominant blood supply is from the facial artery (including the submental branch of the facial artery). Li et al identified that the facial artery runs along a "*groove*" within the submandibular gland and can be surrounded by the cortex of the gland.[29,30]

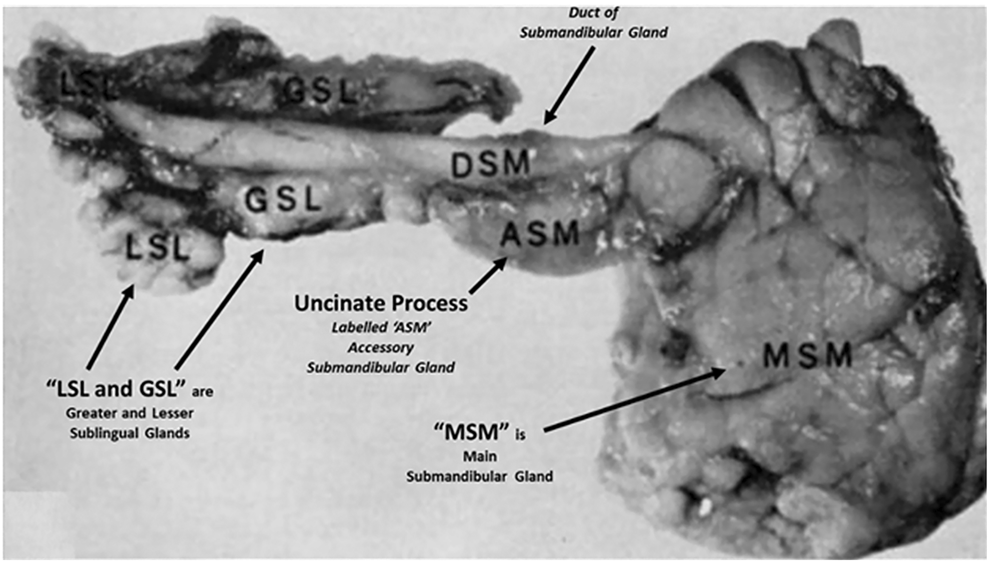


FIGURE 3 Medial (deep) view of right submandibular complex with relabeling of the submandibular duct (DSM) associated with the uncinated process (ASM, "accessory submandibular gland") in relation to sublingual glands (GSL, "greater sublingual gland," LSL, "lesser sublingual gland") (with permission Leppi 1967).

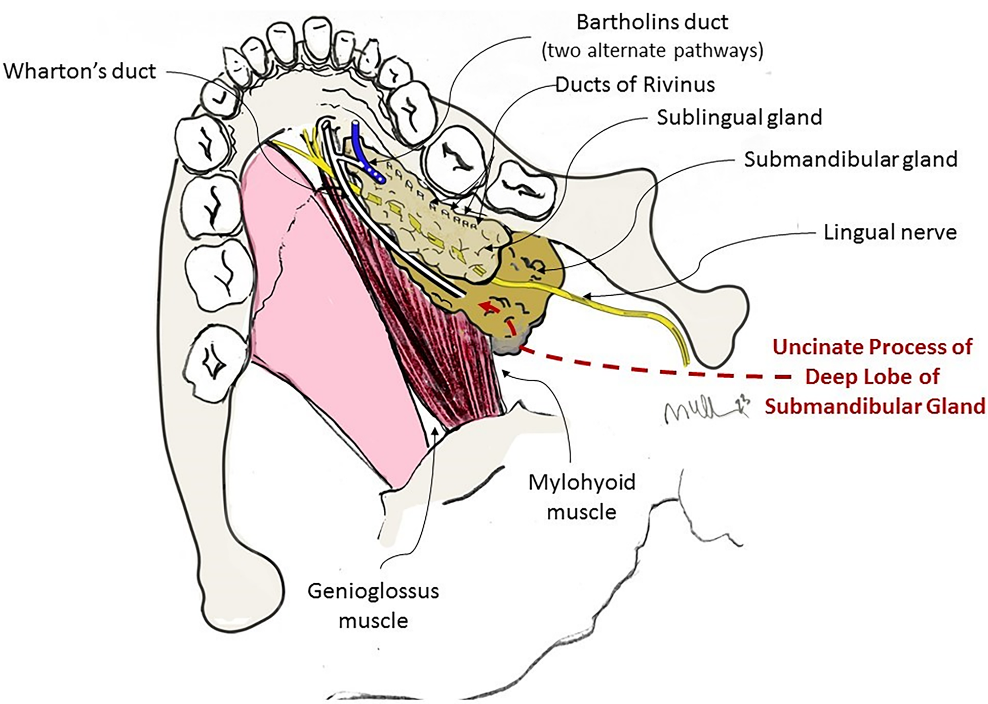


FIGURE 4 Diagram of the floor of mouth highlighting the variable drainage from the sublingual gland (Bartholin's duct and Ducts of Rivinus) in demonstrating the relationships to the uncinate process of the deep lobe of the submandibular gland. (with approval from Hoffman HT (ed) Iowa Head and Neck Protocols <Submandibular Gland Anatomy: The Uncinate Process of the Deep Lobe|Iowa Head and Neck Protocols (uiowa.edu) > accessed June 18, 2023).

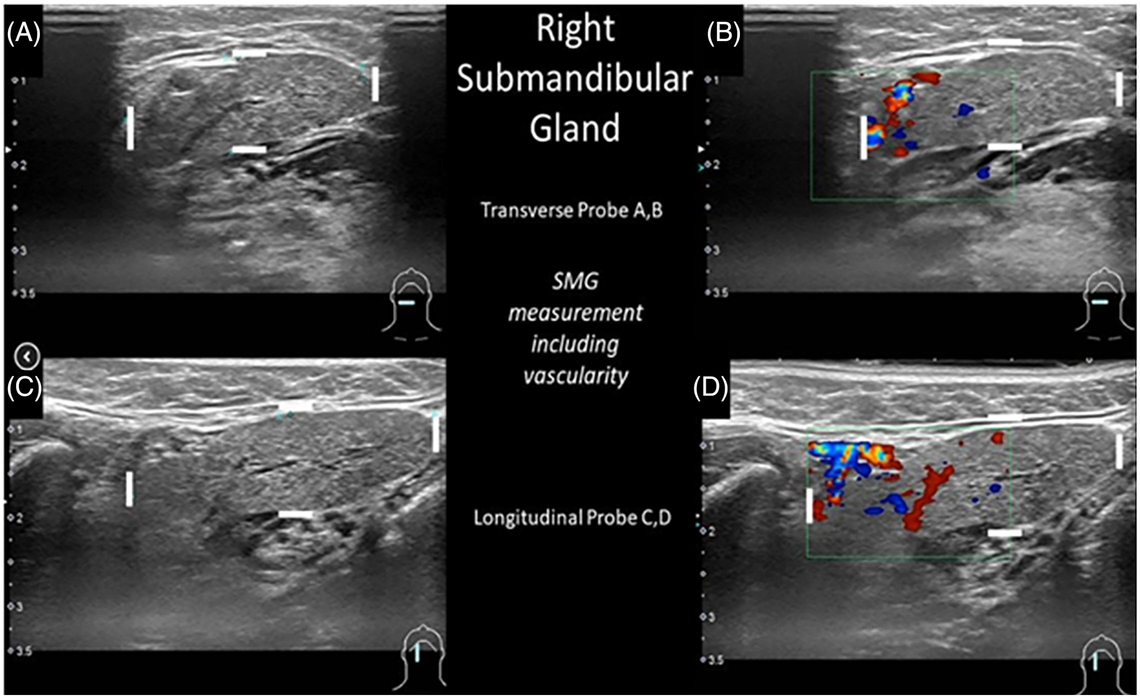
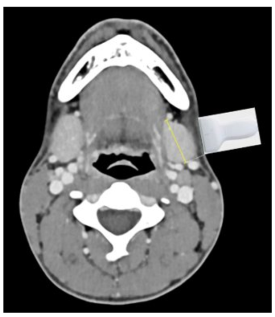
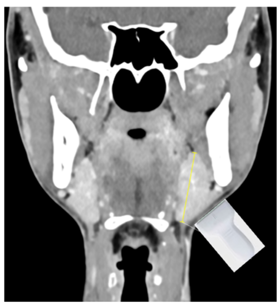
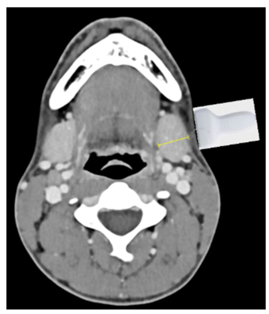


FIGURE 5 Ultrasound of right submandibular gland assessed with 5–14 MHz linear probe in transverse (3A, B) and longitudinal (3C, D) orientations identifying measurement of the size of the gland to include the blood vessels imaged with color doppler. (with approval from Hoffman HT (ed) Iowa Head and Neck Protocols <Submandibular Gland Anatomy: Vascular Supply—Ultrasound Imaging with Color Doppler https://medicine.uiowa.edu/iowaprotocols/submandibular-gland-anatomy-vascular-supply-ultrasoundimaging-color-doppler> accessed June 18, 2023).

TABLE 2 Terms addressing probe orientation in reporting SMG ultrasound measurement.

Analysis should be done in 2 planes—anatomic limitations may require oblique planes.			
AAO-HNS Salivary Gland Committee Recommendation 2023 dimensions recorded are widest for each orientation the uncinate process is not included in reporting dimensions. (images courtesy of Francisco Donato)	**Length (L)** Anterior to posterior **Transverse Probe**  Axial CT with diagram showing **Length** measurement with transverse probe position	**Height (H)** Inferior to superior **Longitudinal Probe**  Coronal CT with diagram showing **Height** measurement with longitudinal probe position	**Depth (D)** Lateral to medial. **Transverse Probe** **Width (W)** is also a commonly used term but not as precise **Depth (D)**  Axial CT with diagram showing **Depth** measurement with transverse probe position

2.2 | Salivary ultrasound assessment techniques

2.2.1 | Equipment

As is recommended by the American Institute of Ultrasound in Medicine (AIUM) for "extracranial head and neck ultrasound evaluations", we support use of a linear transducer for salivary gland evaluation.[31] The AIUM recommends a mean frequency of 10 to 14 MHz probe and notes that a greater depth of penetration may warrant use of lower frequencies.

2.2.2 | Technique

The American Institute of Ultrasound in Medicine (AIUM) has published practice parameters for the documentation of an ultrasound examination.[31] These generalized guidelines emphasize that "*accurate and complete documentation and communication are essential for high-quality patient care*." Recording of anatomic measurements is recommended when appropriate. A separate publication from the AIUM addressing head and neck ultrasound offers more specific recommendations to identify that reporting of "*focal abnormalities within the salivary glands should include the size in 3 dimensions*".[14]

We propose terminology to standardize the assessment and reporting of ultrasound probe positioning and assessment (Table 2) highlighted by representative ultrasound images (Figures 6 and 7). Ultrasound assessment of submandibular size usually does not include consideration of the anterior extension of Wharton's duct with surrounding tissue. The anterior extension of Wharton's duct can occasionally be difficult to image due to shielding from the bone of the mandible despite the use of sonopalpation.[32]

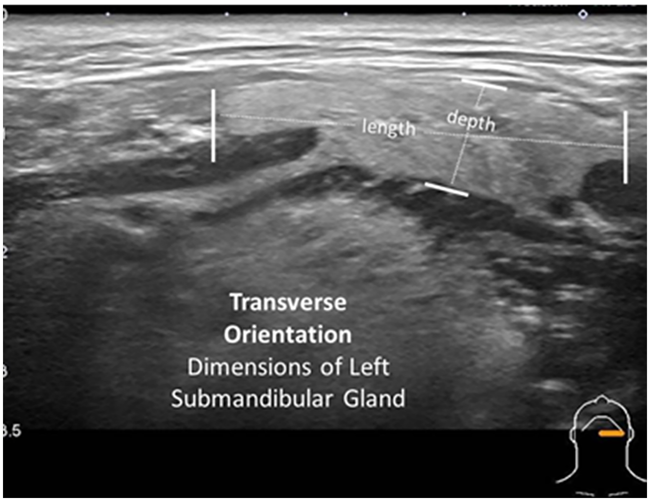


FIGURE 6 Transverse orientation (with slight obliquity) of the 14–5 MHz linear ultrasound probe identifies measurement of the length and depth of the left submandibular gland.

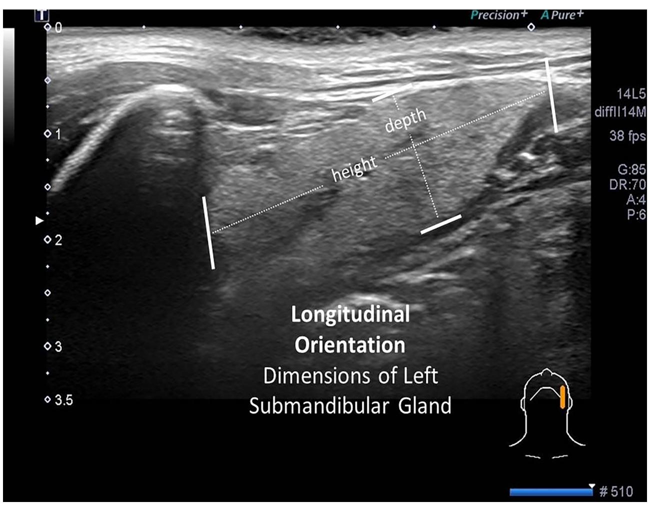


FIGURE 7 Longitudinal orientation of the 14–5 MHz linear ultrasound probe (with slight obliquity) identifies the height and depth of the left submandibular gland.

Although the terms "transverse" and "longitudinal" may be used without modifiers, some degree of obliquity relative to the central axis is usually introduced to permit examination with the probe parallel (transverse) and perpendicular (longitudinal) to the body of the mandible usually initiated perpendicular to the skin surface (Figure 8).

Additional imaging with the probe position altered from this initial orientation is generally required to identify ductal and hilar stones.[33] Angling the transversely positioned probe in a rostral direction (under the mandible) is often needed and may be supplemented by intraoral digital depression of the floor of the mouth to deliver structures into the field of view by the process termed "sono-palpation."

The terminology addressing probe orientation is confusing and differs based on whether the long axis of the patient or the long axis of the structure studied is emphasized.[34] The term "transverse" is recommended to describe imaging with the probe positioned parallel to the body of the mandible—similar to "axial" or "cross-sectional"—in a plane that is perpendicular to the long axis of the patient.[35–37] Differences persist in the literature regarding terminology to description the image of the gland as identified by this transverse probe placement. The word "longitudinal" is used by some to describe the perspective of the anterior-to-posterior dimension of the submandibular gland despite imaging with transverse probe placement. Our recommendations are to employ the terms "length" and "depth" when relating the perspective of the gland determined by the transverse placement of the probe.

We recommend reserving the term "longitudinal" to describe probe positioning along the long axis of the patient which is perpendicular to the body of the mandible as is used to assess the "height" of the gland.[38] A consensus statement from the orthopedic literature identified the correlate of the ultrasound term "longitudinal" to be equivalent to CT/MRI terminology of "coronal" or "sagittal".[39] These investigators acknowledged difficulty in finding a consensus in the terminology used to discuss the axes of an isolated structure described out of the context of its relationship to the patient.[39]

We propose terminology (Table 3) to identify regions within the gland as determined by transverse probe orientation include: "**midportion (or middle)**", "**anterior**", "**posterior**", "**superficial**", and "**deep**" also depicted in ultrasound examples (Figure 9). Longitudinal orientation of the probe defines "**superior**" and "**inferior**" in addition to "**middle (midportion)**", "**superficial**" and **"deep"** (Figure 10). As is consistent with measurement of thyroid nodules, we recommend that the dimension of "depth" is reported from measurement employing the transverse but not the longitudinal probe orientation.

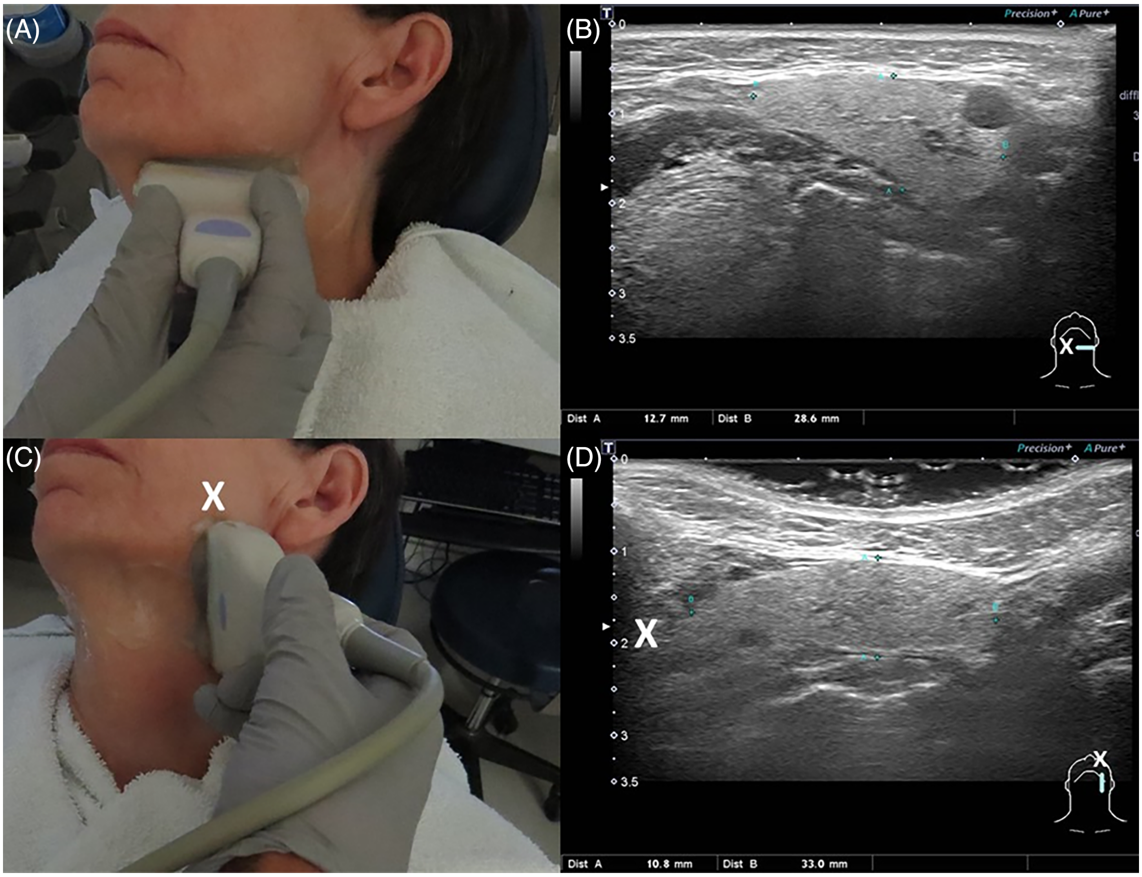


FIGURE 8 The linear 6.5 cm × 0.75 cm 14–5 megahertz (MHz) probe (Canon Aplio 500 ultrasound unit) is positioned slightly oblique in transverse (parallel to body of mandible A and B) and longitudinal (perpendicular to body of mandible C and D) orientations to image the left submandibular gland. Note the change in orientation delineated by "**X**" showing the anatomically superior aspect of the gland (C) on longitudinal view is portrayed on the left side of the image (D) (with approval from Hoffman HT (ed) Iowa Head and Neck Protocols < Salivary ultrasound standardized diagnostic approach and report https://medicine.uiowa.edu/iowaprotocols/salivary-ultrasound-standardized-diagnostic-approach-and https://medicine.uiowa.edu/iowaprotocols/salivary-ultrasound-standardized-diagnostic-approach-and-reportreport> accessed June 18 2023).

TABLE 3 Ultrasound Descriptors of Locations within Submandibular Gland.

Ultrasound Probe Orientation	Ultrasound Description of Locations within Submandibular Gland
Transverse	**Anterior/Posterior** ***[Length]***
Longitudinal	**Superior/Inferior** ***[Height]***
Transverse or Longitudinal	**Midportion** (Middle) ***Superficial/Deep** ***[*Depth]*** *Reporting of "**Depth**" (the superficial to deep measurement) is limited to transverse probe orientation.

Additional descriptive terminology identifying subsites within the submandibular gland and ductal system have been proposed by Goncalves et al to define stone location along the course of the submandibular duct as determined by the anatomic landmarks of the mylohyoid muscle and sublingual gland (Table 4).[40] These investigators also proposed a similar system for parotid gland stone location to employ the masseter muscle as the dominant landmark when employing ultrasound to assess the ductal system.

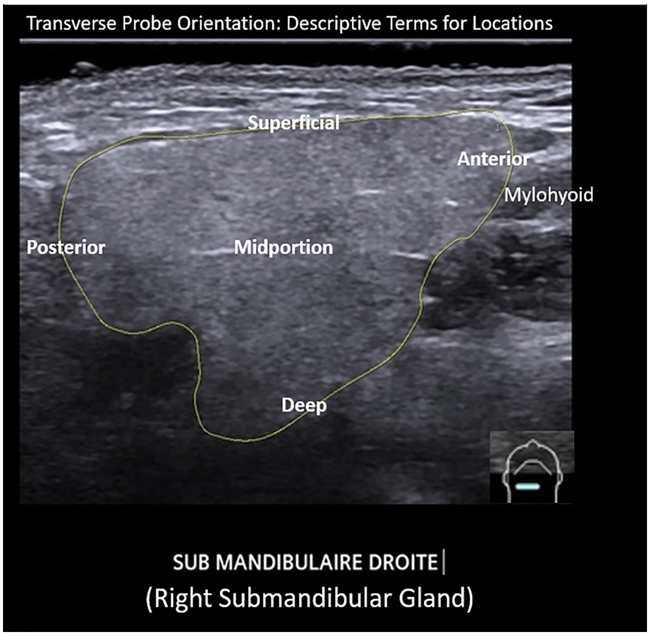


FIGURE 9 Ultrasound image employing transverse orientation of the probe identifies regions within the outlined right submandibular gland that are labeled with descriptive terms (image courtesy of Dr. Philippe Katz; relabeled).

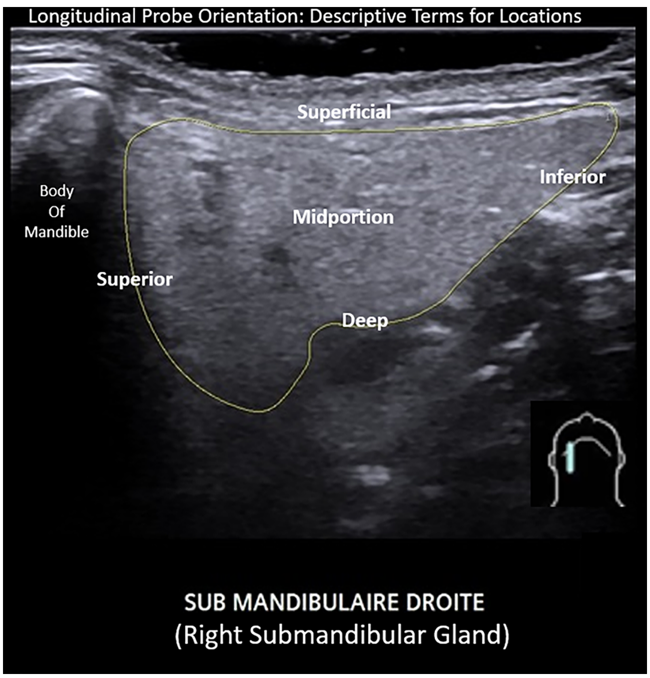


FIGURE 10 Ultrasound image employing longitudinal orientation of the probe identifies regions within the outlined right submandibular gland that are labeled with descriptive terms (image courtesy of Dr. Philippe Katz; relabeled).

TABLE 4 Classification system defining stone location in the gland or ductal system.

Submandibular sonographic terminology and landmarks for sialolithiasis	
Intraparenchymal stone	Proximally located in parenchyma
Proximal/Hilar Stone	1 cm proximal to 1 cm distal to the edge of the mylohyoid muscle
Middle third of duct	1 cm distal to the edge of the mylohyoid muscle to the sublingual gland
Distal ductal system (including papillary region)	Adjacent the sublingual gland extending to the papilla

Note: (Adapted with approval from Hoffman HT. Iowa head and neck protocols as further adapted from Goncalves et al 2017 https://medicine.uiowa.edu/iowaprotocols/salivary-ultrasound. Accessed May 24, 2023).

3 | CONCLUSION

Details of salivary gland anatomy have been determined through cadaveric dissection, review of static imaging (CT/MRI), and analysis of surgical specimens.[41–47] Dynamic ultrasound imaging offers an alternate perspective with advantages and limitations that warrant consistency in assessment and reporting.[48]

The value in assessing salivary gland dimensions to help determine the impact of treatment is emphasized in the EULAR Sjogren's Syndrome Disease Activity Index (ESSDAI) as reported in 2010.[49] This index provides a score to quantify disease activity and includes salivary gland size as one of several domains evaluated. Ultrasound—in the absence of overlying barriers such as facial hair or soft tissue changes (including obesity)—can image the full extent of the submandibular gland parenchyma to assess size.[27] Our effort to standardize nomenclature and assessment techniques will hopefully improve upon the vague approaches previously in common use as described by Badarinza wherein the salivary gland size is "*frequently approximated according to intuition and bilateral comparison*".[50]

Shear wave elastography has become standard in the assessment of liver fibrosis to revolutionize the diagnostic approach to cirrhosis and has markedly diminished the need for liver biopsy.[51] Similar application of elastography to salivary gland assessment for both neoplastic and non-neoplastic processes warrants identification of specific sites within the gland in acknowledging that the gland is often affected in a non-uniform fashion.

Consensus regarding the naming of subsites within the submandibular gland is needed to improve communication about abnormalities detected and to direct the use of more sophisticated assessment schemes such as shear wave analysis targeted to specific regions. Consistency in this terminology should lead to improved reproducibility of findings. Our work to standardize the naming of sites within the submandibular gland is augmented through an ongoing process to address the parotid, sublingual, and minor salivary glands.

The AAO-HNS Salivary Gland Committee in collaboration with international experts proposes this standardized approach to submandibular gland ultrasound analysis focused on technique and nomenclature.

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CONFLICT OF INTEREST STATEMENT

Hoffman H: Henry T. Hoffman: (a) COOK Medical: Research consultant. (b) UpToDate author. Ryan W: scientific advisory boards for Olympus and Rakuten Medical and consultant for C2DX. Donato F: TriSalus advisory board member. No conflicts of interest related to this publication. Bertelli A: Speaker and travel grants for Merck. Anderson C: former compensated now uncompensated since 2013 consultant for Galera Therapeutics since 2013: research funding from Soligenix; research funding from Galera Therapeutics.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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