Original Article

A feasibility study to assess vallecula and pyriform sinus using protocol-based ultrasonic evaluation of floor of mouth and upper airway

ABSTRACT

Purpose: The current study aimed to systematically evaluate the sonoanatomy of floor of the mouth and upper airway using protocol-based ultrasonography (USG); and to assess the feasibility of imaging the valleculae and pyriform fossae.

Materials and Methods: An institutional prospective observational study was planned on fifty volunteers of all ages and both sexes, attending outpatient department for nonairway-related diseases. Protocol for ultrasonographic systemic evaluation was designed before starting the trial. All the patients were positioned supine with neck extended (sniffing position), seven steps of ultrasonographic protocol were followed and visualization of structures denoted in each step was documented. Furthermore, time taken to complete each scan was noted.

Results: The USG was completed, and checklist successfully followed in all cases. Floor of mouth structures was easy to evaluate and visualized with ease in all the cases. Epiglottis was visualized in 100% cases in transverse plane. Valleculae and pyriform fossae were identified in 82% and 90% of the cases, respectively, and they appeared either as paired air-filled round structures or air-lined linear structures. Complete visualization of vocal cords was seen in 78% females and 63% males. The average time taken to complete the protocol-based study was 10.4 ± 1.4 min.

Conclusions: Application of protocol-based USG for upper airway can allow the examination of structures from tongue to thyroid cartilage in a thorough, convenient, and timely manner. The air filled/lined structures such as valleculae, pyriform fossae, and vocal cords can be visualized in majority of the cases.

Key words: Airway; epiglottis; larynx; protocol; pyriform fossae; thyroid cartilage; ultrasound; valleculae; vestibular ligaments; vocal cords

Introduction

Airway evaluation is a vital element in various diagnostic and periprocedural scenarios. The research in the previous decade has shifted the focus on an indispensable imaging tool for airway evaluation, the ultrasonography (USG). The promoting factors include ease of availability, noninvasiveness, and its dynamic capability.

The normal sonographic appearance of various anatomical structures has been described in relation to difficult airway,

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assessment of airway diameters, nerve blockade, and otolaryngeal applications.[1-7] Furthermore, observational researches have proved landmark demonstrating ultrasonographic appearances of all structures relevant to airway examination in adults and fetus, respectively.[8,9] Apart from this, the clinical applications of sonoimaging in airway assessment and management have also been reviewed in detail.[10] These articles suggest USG may be a cornerstone to airway-related issues in forthcoming time.

Considering the wide span of sonographic uses for this anatomical region, there is a requirement of step-by-step approach describing the sonographic views and structures displayed in each view. This may avoid errors related to missing any structure during evaluation, provide uniformity in scanning, and simplify USG examination for new users, especially anesthesiologists in a timely manner.

The vallecula and pyriform sinus are air-filled spaces posing a challenge to scan them in normal undisturbed anatomy. However, any turbulence of air (snoring/obstructive sleep apnea [OSA]), fluid-filling cavity (cyst), or pathology mass may be detected with ease appearing as loss of air filling. There is a description of congenital vallecular cyst and pyriform sinus fistula being imaged with a multitude of modalities including USG.[11-15] In an educational exhibit on high-resolution ultrasound of larynx, Martinez *et al*. have described the normal appearance of pyriform sinus along with its computed tomography (CT) correlation. To the best of our knowledge, no study in literature has yet conducted an observational study on sonographic appearance of valleculae and pyriform fossae in normal adult patients, which are of paramount importance both to otolaryngologists and anesthesiologists.[16-18]

We, therefore, planned a study to provide a user-friendly methodology of USG relevant to upper airway assessment and related pathologies with the following objectives.

- To create an ultrasonographic protocol for systematic evaluation of the floor of mouth and upper airway
- To evaluate the various structures of oral cavity and upper airway including valleculae and pyriform using USG in normal adult patients.

We assume that all the structures enumerated in the protocol can be visualized in all the participants with ease.

Materials and Methods

A prospective observational study was planned and conducted over 1 year at a single rural tertiary teaching institute after Ethical Committee and Institutional Review Board approval. A convenience sample of fifty volunteers of both sexes, who came to the Department of Radio-diagnosis for nonairway-related USG was enrolled for the study. There were 22 males (mean age ± standard deviation [SD]; 41 ± 12.9 years) and 28 females (mean age ± SD; 37.2 ± 12.7 years).

Patients with known airway-related diseases and those who refused to participate were excluded from the study. The study and procedure were explained in local language, and written informed consent was taken.

Systematic ultrasonographic evaluation was carried out by linear (L12–3 MHz) and curved (C5-2 MHz) transducers on Phillips HD 11 XE ultrasound unit in oblique, axial, sagittal, and coronal planes. The systematic approach to scanning of airway was followed in seven steps as proposed for the study [Table 1]. All the structures were primary scanned using linear probe; curvilinear probe was also used whenever depth impeded scanning. Salivary glands and thyroid glands evaluation was excluded from the protocol and study.

The volunteer was comfortably positioned supine with neck flexed and head extended (sniffing position). The USG examination was performed by a single experienced radiologist (KS).

The evaluation started with the identification of hyoid bone using axial and sagittal views (step 1), followed by three suprahyoid steps (2–4) and three infrahyoid steps (5–7) as shown in Table 1.

In the suprahyoid area, floor of the mouth (step 2) was subdivided into anterior (2a) and posterior (2b) floor of the mouth: assessed using oblique coronal views with linear probe. The tongue (step 3), visualized using sagittal/parasagittal, was divided by a line drawn perpendicular to the terminal echogenicity of hard palate into anterior and posterior halves for facilitating reporting of the scan. The valleculae (step 4) were scanned in oblique axial views.

The infrahyoid steps included superior laryngopharynx (step 5) to scan the epiglottis, preepiglottic space, and vestibular ligaments using oblique axial views. The anteroposterior dimensions of epiglottis were also measured in the protocol. The larynx (step 6) was scanned in axial view to document the thyroid cartilage, false and true vocal cords. The hypopharynx (step 7) was scanned using oblique axial view to scan the pyriform fossa.

The success in visualizing all these structures ultrasonographically was documented in each participant. The anatomical orientation of each structure visualized in the sonographic images thus obtained was compared with normal

Table 1: Protocol for sonographic evaluation of floor of mouth and upper airway

Steps	Anatomical space		Anatomical structures	View	Type of transducer
1	Hyoid region		Hyoid Bone	Axial & Sagittal	Linear
2 (a)	Supra-hyoid	Floor of mouth-Anterior	Anterior digastric, Myelohyoid, Genioglossus, Geniohyoid	Oblique Coronal	Linear
2 (b)		Floor of mouth Posterior	Myelohyoid, Hyoglossus, Lingual artery and Submandibular gland duct	Oblique Coronal	Linear
3		Tongue	Tongue	Sagittal and parasagittal	Convex
4		Suprahyoid Oropharynx	Valleculae	Oblique axial	Linear
5	Infrahyoid	Superior laryngopharynx	Epiglottis, Pre-Epiglottic space and Vestibular ligaments	Oblique Axial	Linear
6		Larynx	False and true vocal cords Thyroid cartilage	Axial	Linear
7		Hypopharynx	Pyriform fossa	Axial and oblique parasagittal	Linear

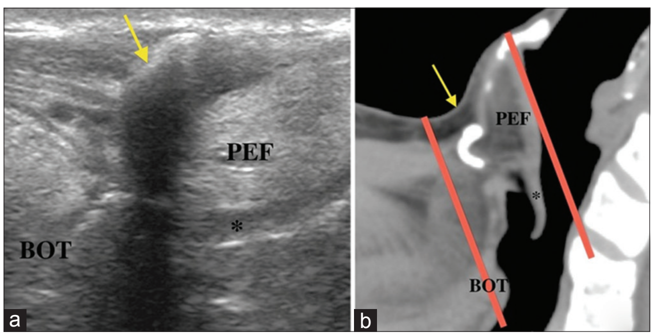

Figure 1: (a) Midsagittal section in the region of hyoid bone using linear transducer, demonstrating sonographic echogenic signature of the body of hyoid bone with posterior acoustic shadowing. (b) Corresponding computed tomographic section (red lines – representing limit of ultrasound scan extent) BOT: Base of tongue; PEF: Preepiglottic fat; asterisk, Epiglottis; Yellow arrow, body of hyoid bone

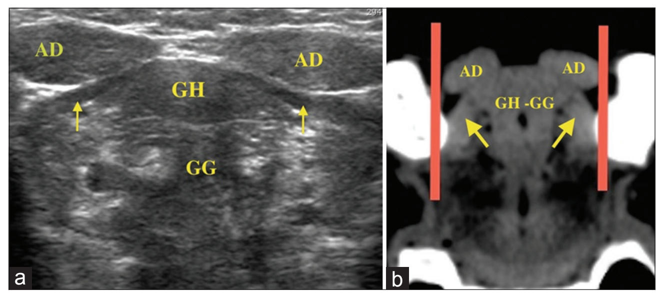

Figure 2: (a) Coronal section in submental location using linear transducer, demonstrating sonoanatomy of step 2a structures (anterior floor of mouth). (b) Corresponding computed tomographic section (red lines – representing limit of ultrasound scan extent) AD: Anterior digastric muscle; GH: Geniohyoid muscle; GG: Genioglossus muscle; Yellow arrows, Mylohyoid Muscle

CT neck images unrelated to any of the study volunteers at the level corresponding to seven steps denoted in the protocol.

Furthermore, time taken to complete the scan (from putting the probe to completion including storing of images) was also recorded in all the cases using a clock timer calibrated to seconds by an observer blinded to the trial. At the end of the study, sonographic results and time taken to complete the scan were complied.

Results

The ultrasound examination of all fifty volunteers was performed and completed successfully using linear and curvilinear probes. The USG examination was followed step by step as denoted in the protocol.

The hyoid bone, tongue, and structures of floor of mouth were visualized in all cases [Figures 1-4]. Thyroid cartilage was well visualized in transverse view as inverted V-shaped hypoechoic structure with reasonably good sound penetration. The valleculae could be visualized in 82% (41 of 50) in oblique axial plane using linear transducer as paired air-filled round structures [Figure 5] We could visualize epiglottis in transverse plane using linear probe just below the hyoid in all cases with a mean anteroposterior thickness of 2.67 mm [Figure 6]. Complete visualization of vocal cords was seen in 22 out of 28 females (78%) and 14 out of 22 males (63%) [Figure 7]. The pyriform fossae were also visible in 90% of the cases as air-lined linear structures using oblique axial and parasagittal views with linear probe [Figure 8]. The average time taken to complete the protocol-based ultrasound scan was 10.4 ± 1.4 min.

Discussion

USG of upper airway is a challenging task due to the presence of air, bone, ossified cartilages, and bumpy terrain.[6,8] The structures desired in the study could be

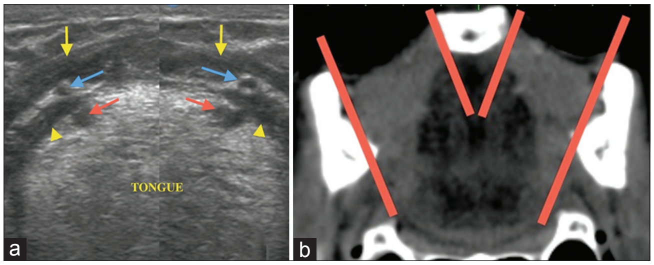

Figure 3: (a) Split/dual coronal Sections in submental location using linear transducer, demonstrating sonoanatomy of step 2b structures of either side (posterior floor of mouth). (b) Corresponding computed tomographic section (red lines – representing limit of ultrasound scan extent on either side) yellow arrows, mylohyoid muscle; yellow arrowhead, hyoglossus muscle; blue arrow, submandibular gland duct; red arrow, lingual artery

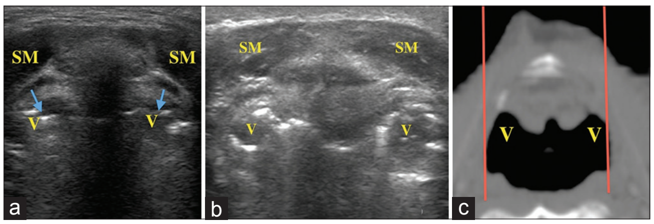

Figure 5: (a and b) Oblique axial view, just above the level of hyoid with cephalad angulation of linear transducer demonstrating sonoanatomy of valleculae on either side. Two different patterns were appreciated. (a) Linear hyperechoic air mucosal interface on either side of midline and (b) Air-filled rounded paired structures on either side of midline. (c) Corresponding oblique axial computed tomographic section (red lines – representing limit of ultrasound scan extent) V, valleculae; blue arrows, hyperechoic air mucosal interface of anterior wall of valleculae; SM: suprahyoid muscles

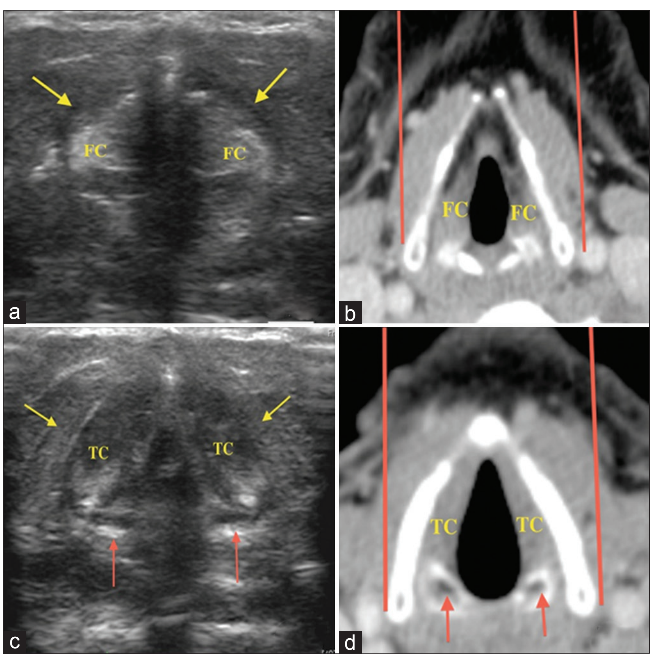

Figure 7: (a) Axial section at the level of larynx (step 6), i.e., false vocal cords, using linear transducer. (b) Corresponding computed tomographic section of (a) (red lines – representing the limit of ultrasound scan extent). (c) Axial section at the level of larynx demonstrating sonoanatomy of step 7 structures. (d) Corresponding computed tomographic section of (c) (red lines – representing limit of ultrasound scan extent) FC: False vocal cords; TC: True vocal cords; Yellow arrows, Thyroid cartilage; Red arrows, Arytenoid cartilages

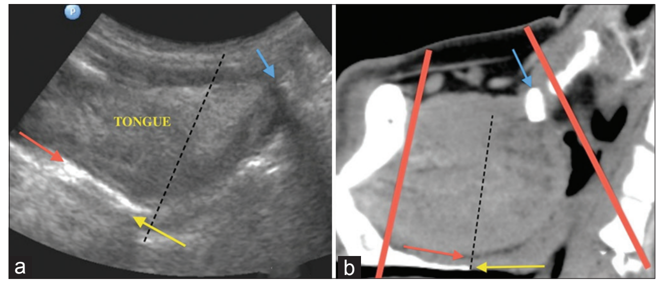

Figure 4: (a) Midsagittal section (step 3). Two parallel echogenic lines are seen at dorsum of tongue, inner representing the air-mucosal interface tongue and outer representing hard palate with posterior acoustic shadowing. Dotted black dividing tongue into anterior and posterior halves. (b) Corresponding computed tomographic section (red lines – representing limit of ultrasound scan extent); blue arrow, body of hyoid; red arrow, inner echogenic line; yellow arrow, outer echogenic line; dotted black line, imaginary line perpendicular to the axis of palate

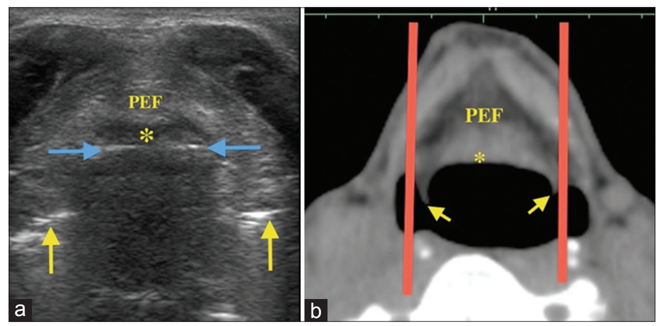

Figure 6: (a) Oblique axial section just below the level of hyoid bone demonstrating the sonoanatomy of step 5 structures, using linear transducer. (b) corresponding computed tomographic section (red lines – representing the limit of ultrasound scan extent) PEF: preepiglottic fat; asterisk, hypoechoic epiglottis; Blue Arrows, Hyperechoic Air-mucosal interface of posterior surface of epiglottis; Yellow arrows, Hyperechoic Air-mucosal interface of vestibular ligaments

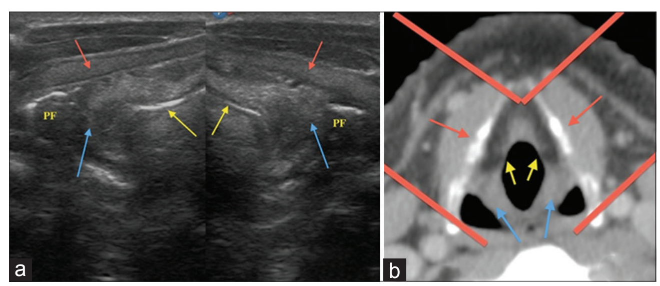

Figure 8: (a) Split/dual axial sections overlying thyroid cartilage using a linear transducer, demonstrating sonoanatomy of step 7 structures of either side (hypopharynx). (b) Corresponding computed tomographic section (red lines – representing the limit of ultrasound scan extent on either side) PF: Pyriform fossae; Red arrows, Thyroid cartilage; Blue arrows, Aryepiglottic folds; Yellow arrows, air-mucosal interface of larynx

assessed systematically in a timely manner, barring few cases, wherein valleculae, pyriform sinus, and/or vocal cords were not appreciated. We have deliberately excluded the sonography of salivary glands and thyroid gland since their dedicated evaluation is extensively studied in the past and it requires a separate study on its own.

The study protocol uses oblique axial and oblique coronal orientation of the probe in addition to the transverse, sagittal, and parasagittal placement described in previous studies.[6,8,19,20] The advantage of using these views was a better acoustic window. Further, literature recommends scanning of floor of mouth and tongue using a curvilinear probe.[6,21-23] Although this decision may be at the discretion of the user, in our experience, we found linear transducer in two oblique coronal views (anterior and posterior; Figures 2 and 3 respectively) friendly for scanning the floor of the mouth which is relatively superficial. Moreover, posterior floor can allow the assessment of submandibular duct and lingual vessels.

The tongue and related structures were analyzed using curved transducer in sagittal view.[8,21] By convention, clinically, sulcus terminalis or the circumvallate papillae are used to divide the tongue into anterior and posterior halves. To facilitate reporting, an imaginary line perpendicular to the junction of hard and soft palate may be used to sonographically divide anteroposterior halves of tongue.

The epiglottis can be evaluated at infravallecular level since above this level, its free edge is suspended in air.[24,25] Our epiglottic measurement is in consensus with the Werner *et al*. who revealed an anteroposterior thickness of 2.39 ± 0.15 mm just distal to hyoid bone using linear probe in 100 participants.[24] Apart from epiglottis and preepiglottic fat, vestibular ligaments are also seen in transverse view, lying lateral and posterior to epiglottis and showing similar hyperechoic margin due to air-mucosal interface.[25]

Calcification or ossification of the thyroid causes poor penetration of ultrasound and resulting in suboptimal visualization of vocal cords.[15,26] In our study, optimal visualization of vocal cords was seen in 78% females and 63% males; this may be attributed to the fact that males show early and more complete calcification of thyroid cartilage and also the mean age of males were more in our study.

There is a previous educational exhibit of utility of high-resolution sonography in assessing a series of cases with normal anatomy as well as functional and structural changes in larynx, and its correlation with other cross-sectional imaging modalities.[7] In our study, anatomy of each structure of all the seven steps visualized sonographically has been related to computerized tomography images (figures) to serve the purpose of demonstrating orientation and path of ultrasonic beam as well as structures encountered superficial to deep.

The valleculae could not be visualized on sonography in some of the cases, due to air filling in the otherwise empty spaces. Small mucosal lesions can be easily missed; however, large lesions cause obvious abnormality in the form of loss of air, displacements, and architectural distortion. Linear transducer placed just above the hyoid bone and angled cranially in oblique axial orientation has been used to evaluate both valleculae in our study. For the pyriform sinus, axial plane shows air-filled round hyperechoic area or hyperechoic air mucosal interface, lateral to the air-mucosal interface of the laryngeal inlet. The anterior wall of pyriform sinuses can be appreciated, with obscuration of posterior wall. The sonographic appearance is quite similar to valleculae. In our study, apart from axial view, oblique parasagittal plane has been used with the transducer placed over the thyroid lamina in long axis, parallel to the airway. Hsiao *et al*. have mentioned that valleculae and pyriform sinuses could not be assessed sonographically, while studying the role of ultrasound in oropharyngeal dysphagia.[27] However, since our assessment was based on normal airway anatomy, we could visualize bilateral valleculae in 82% and pyriform fossae in 90% of the cases. The dynamic maneuvers have been used to differentiate the movement of air in the pyriform fossae than from movement of air in the larynx, by asking the patient to swallow or to say "ee" while doing sonography. In our experience, pyriform fossa may also be seen expanding due to turbulence of air during snoring, which may be more relevant in OSA patients.

The average time taken to complete this protocol-guided USG was around 10 min. The protocol of describing all these structures in seven views can simplify the scanning, also eliminating the chance of missing any element in routine preoperative scanning or emergency scenarios. Further, following the protocol initially may look cumbersome and lengthy, but with practice may prove systematic and time saving, especially for physicians inexperienced in sonology. The anesthesiologists and otolaryngologists require close acquaintance with sonoanatomy of these structures before customizing their own protocols for specific requirements.

Conclusions

A step-by-step approach to USG from tongue to thyroid cartilage may provide a roadmap for detailed evaluation of structures pertinent to the floor of mouth and upper airway in a timely manner. The valleculae and pyriform fossae could also be visualized as air-filled paired echogenic spaces.

Scope of research

The factors (weight, height, sex, body mass index, neck circumference, Mallampati score, and thyromental distance) unfavorable for imaging various structures such as vocal cords, valleculae, epiglottis, and pyriform sinus using USG may be investigated and explored for association with anatomical structure visualization failure.

Further, research may be conducted to investigate USG to be a baseline screening tool for otolaryngeal masses before the patients are subjected to radiation or other expensive imaging techniques.

Limitations

- The current study has evaluated normal participants by a single observer. The reader should be cautioned that the results using the described standardized imaging technique may not be achieved by less experienced/skilled sonographers
- The whole extent of certain structures such as epiglottis could not be evaluated: incomplete evaluation of valleculae and pyriform could reduce the sensitivity of diagnosing small lesions
- With the current technology, it is not possible to evaluate the posterior pharyngeal wall and posterior commissure
- Ossified cartilages commonly seen in the elderly patients offer acoustic hindrance to visualization of structures beneath them.

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Conflicts of interest

There are no conflicts of interest.

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