Original Article

Utilization of submandibular ultrasound in assessing upper airway changes following the administration of propofol

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Abstract

Background and Aims: Our study aimed to use submandibular ultrasound to measure upper airway parameters before and after induction dose of propofol in order to further understand upper airway changes that occur during induction of anesthesia. Measuring the changes that occur in airway anatomy due to the hypotonic effects of induction agents will allow for a deeper understanding of airway management.

Material and Methods: We enrolled 39 patients between November 2021 and January 2022. Submandibular ultrasound was used to measure tongue thickness, geniohyoid muscle thickness, the distance between the lingual arteries (DLA), lateral pharyngeal wall thickness, and hyomental distance before and after administration of induction doses of the commonly used, sedative-hypnotic agent, propofol.

Results: The mean DLA increased significantly after propofol administration, from 3.62 ± 0.63 cm to 3.79 ± 0.56 cm ($P < 0.001$). The mean tongue thickness was 4.89 ± 0.51 cm and decreased significantly to a mean of 4.62 ± 0.50 cm after propofol administration ($P < 0.001$). The change in DLA measurements after propofol administration decreased significantly as STOP-BANG score increased ($\rho = -0.344$, $P = 0.037$). However, DLA measurements when patients were awake increased significantly with an increase in the STOP-BANG score ($\rho = 0.351$, $P = 0.031$).

Conclusion: These findings suggest that propofol widens and flattens the tongue, which are changes that may contribute to difficult airway management. Given the quick and non-invasive nature of ultrasound, further studies should evaluate the role of submandibular ultrasound for understanding the upper airway and airway management in various populations.

Keywords: Airway management, airway obstruction, anesthesia, propofol, ultrasonography

Introduction

Ultrasound assessment of airway characteristics has been proposed as a novel method to predict difficult airway management.[1,2] Airway characteristics are typically assessed preoperatively, prior to induction of anesthesia. Two studies found that ultrasound oral cavity measurements change with sedative agents, such as zolpidem and propofol, in patients with obstructive sleep apnea (OSA), likely due to the medications' relaxation effects.[3,4] However, it is still unclear how changes in the oral cavity might contribute to difficult airway management. Our hypothesis was that propofol administration would result in anatomical airway changes that could be assessed with submandibular ultrasonography. The objective of this study was to observe changes in airway measurements prior to and following propofol administration.

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Material and Methods

This observational study took place over two months from November 2021 to January 2022 at an academic tertiary care center. Our initial goal was to have 45 patients in a two-month study period. We recruited 45 patients; two patients refused to participate. In total, we enrolled 43 patients, and four patients were excluded because we were not able to get the data intraoperatively. We analyzed anatomy in 39 patients. All patients were ASA 1 to 3 scheduled for non-emergent surgery.

Adult patients who were scheduled for elective surgery requiring general anesthesia were eligible for the study. The inclusion criteria were the following: 1) adult population (age of 18 years old or over), and 2) elective surgical patients undergoing general anesthesia. Exclusion criteria were the following: 1) patients with a history of difficult intubation, 2) patients undergoing procedures that did not require general anesthesia, 3) patients that were unable to consent, or 4) pediatric population (age of under 18 years old). The study was approved by the Institutional Review Board (NCR: 203147) in March 2021.

We filled the STOP-BANG questionnaire responses[5] and collected patient demographic data (age, sex, height (cm), weight (kg), and BMI), neck circumference, OSA diagnosis, and continuous positive airway pressure (CPAP) use. Ultrasound images were taken in two states: while the patient was awake and after propofol-induced anesthesia. Ultrasound was used to take measurements of the upper airway while the patient was awake in the preoperative area. These measurements were later repeated in the operating room after propofol infusion was administered by the attending anesthesiologist. After propofol was administered, the patient received supplemental oxygen via the nasal cannula. We used ultrasound to complete the five measurements prior to administration of neuromuscular blockade. The airway was not manipulated during sonographic measurements, and all five images were stored on the ultrasound hardware for complete analysis and measurements following the surgical case. The time required to capture the five anatomic images with ultrasound was less than 30 seconds, thereby ensuring maximal patient safety. Difficulty of mask ventilation was then assessed by the attending anesthesiologist and graded according to the mask ventilation (MV) scale.

Ultrasound images and measurements were performed by two anesthesiology team members with extensive experience in ultrasonography of the head and neck. The ultrasonographic assessment was comprised of five anatomic measurements, including: the distance between lingual arteries (DLA), lateral pharyngeal wall (LPW), tongue thickness (TT), geniohyoid muscle thickness (GMT), and hyomental distance (HMD) [Figure 1]. The SonoSite X-porte Ultrasound System (FujiFilm, Philips Healthcare, Bothell, WA) equipped with a 3–8 MHz curvilinear probe was used for all measurements. In the preoperative and operative arena, the patient was placed in supine position. To measure the lateral pharyngeal wall (LPW), the transducer was placed in the coronal orientation on the lateral neck, below the mastoid process. The LPW was measured as the distance between the inferior border of the internal carotid artery and the lateral wall of the pharynx. We used a submandibular approach, with the transducer placed in the sagittal midline position of the submental area to measure the TT, GMT, and HMD. To measure the DLA, the transducer was placed in the transverse midpoint between the inferior border of the mandible and the hyoid bone.[6]

Statistics

Descriptive analysis was performed for number and percentage for categorical variables, and mean, and standard deviation for numeric variables. Relationships between various variables were examined using Spearman's correlation. Within group comparisons between awake and propofol infusion were analyzed using the Wilcoxon matched pairs test. Greater than two group comparisons were analyzed using the Kruskal–Wallis test. The level of statistical significance was set at $P < 0.05$. Statistical analysis was performed using Statistical Package for the Social Sciences version 28.0 (SPSS, Inc, Chicago, Illinois).

Results

From November 2021 to January 2022, we enrolled a total of 39 patients in this study with a mean age of

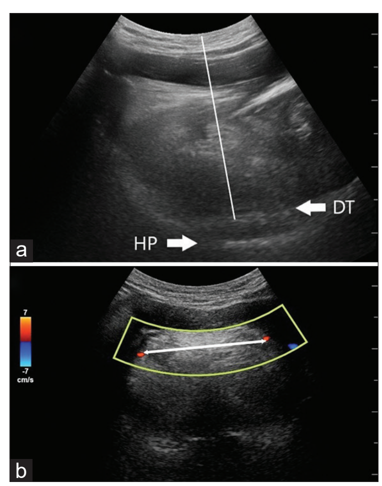

Figure 1: Airway anatomy measurements using submandibular ultrasound. (a) Sagittal scan showing the dorsal surface of the tongue (DT), hard palate (HP), and tongue thickness (white line). (b) Distance between the lingual arteries (white line) using a transverse scan with colorimetric flow

52.7 ± 17.7 years [Table 1]. They had a mean BMI of 33.5 ± 8.4 kg/m², ranging 20.5–56.8 kg/m², and a mean neck circumference of 40.9 ± 4.8 cm. Five patients had a known history of OSA. Eighteen patients had a STOP-BANG score of 0–2, 15 patients scored 3–4, and 9 patients had a score of 5 or greater.

Among 38 patients, mean tongue thickness was 4.89 ± 0.51 cm, which decreased to a mean of 4.62 ± 0.50 cm after propofol administration [Table 2]. The distance between lateral arteries of the tongue was a mean of 3.62 ± 0.63 cm, which increased to a mean of 3.79 ± 0.56 cm after propofol. Tongue thickness and DLA were found to be significantly different after patients were sedated with propofol compared to when they were awake ($P < 0.001$). Geniohyoid muscle thickness, lateral pharyngeal wall, and hyomental distance were not statistically different before and after propofol. The change in DLA measurements after propofol administration decreased significantly as STOP-BANG score increased (Pearson correlation $\rho = -0.344$, $P = 0.037$). However, DLA measurements taken while the patients were awake increased significantly with an increase in STOP-BANG score ($\rho = 0.351$, $P = 0.031$).

Table 1: Patient demographics

	n (%)
Age (years, *n*=29)*	
Mean±SD	52.7±17.7
Range	24-82
Sex (*n*=39)*	
Male	10 (25.6)
Female	19 (48.7)
BMI (kg/m², *n*=39)	
Mean±SD	33.5±8.4
Range	20.5-56.8
Neck circumference (cm, *n*=39)	
Mean±SD	40.9±4.8
Range	32.0-54.0
History of OSA (*n*=39)	5 (12.8)
Modified Mallampati score (*n*=37)	
1	10 (27.0)
2	13 (35.1)
3	11 (29.7)
4	3 (8.1)
STOP-BANG score (*n*=38)	
0-2	18 (42.1)
3-4	15 (36.9)
≥5	8 (21.0)

**Age and sex were not recorded for 10 patients. Abbreviations: OSA, Obstructive sleep apnea; BMI, Body mass index; SD, Standard deviation.*

Table 2: Airway measurements before and after propofol administration.

Anatomy (*n*)	Awake, Mean±SD (cm)	Propofol, Mean±SD (cm)	Difference,* Mean±SD (cm)	*P*†
TT (38)	4.89±0.51	4.62±0.50	−0.2297±0.22629	<0.001
GMT (35)	1.75±0.42	1.73±0.35	0.0203±0.18922	0.20
DLA (38)	3.62±0.63	3.79±0.56	0.1818±0.34616	<0.001
LPW (39)	3.14±0.54	3.22±0.56	0.0828±0.44382	0.26
HMD (35)	4.52±0.64	4.39±0.71	−0.0874±0.35292	0.22

** Difference between measurements taken before vs after propofol infusion.*
† Significant difference at <0.05, using Wilcoxon matched pairs test.
Abbreviations: TT, Tongue thickness; GMT, Geniohyoid muscle thickness; DLA, Distance between lingual arteries; LPW, Lateral pharyngeal wall; HMD, Hyomental distance; SD, Standard deviation

Discussion

Difficult laryngoscopy poses a challenge in airway management because of an increased risk of resultant morbidity and mortality. Some patients have airway characteristics that increase the difficulty of intubation and mask ventilation. Administration of hypnotics during induction can produce upper airway collapse, further complicating mask ventilation and laryngoscopy.[7] Our results suggest that induction doses of propofol, a commonly used induction agent, results in changes to the tongue morphology including increased DLA and decrease in the thickness of the tongue.

Two previous studies have examined the effects of sedative medications on ultrasound airway measurements, specifically in patients with OSA.[3,4] Conflicting results were found based on the medication, route of administration, and dosage of medications. One study used propofol infusion, the same drug that we administered; however, our findings were following induction levels of propofol. The other study measured tongue thickness following administration of oral sleeping aid, zolpidem. Interestingly, we found that the tongue thickness decreased and distance between lateral arteries increased after patients were administered propofol, similar to the results of the Abuan study. Furthermore, although our population was not limited to OSA patients, we did find a correlation between DLA and the STOP-BANG score, similar to the findings of Abuan *et al.*,[3]. that found a correlation between DLA and apnea–hypopnea index (AHI).

Our results differ from the findings of Huang *et al.*,[4] who found that OSA patients receiving a propofol infusion (target-controlled infusion) had an increase in TT. There are several reasons that might account for this discrepancy. For one, the differences may be due to the method or location of measuring the tongue. For example, tongue thickness may have been measured at a point more or less posteriorly, which could affect results, given that the tongue may move posteriorly after administration of a sedative-hypnotic. Moreover, Huang *et al.*,[4] did not identify the dosage of propofol infusion, other than stating that the measurements were made at a bispectral index (BIS) of 50–70, while general anesthesia was often administered to achieve a BIS of 40-60 for many surgeries.[8] We did not use BIS as a depth of anesthesia guide because it has been found to be unreliable.[9] Therefore, we do not routinely use this monitor in clinical practice and did not record this data in our study. We gave an induction dosing of propofol (2–3 mg/kg) which likely produced deeper sedation than that achieved by Huang *et al*.[4]

Furthermore, there may be other factors that were not accounted for in these studies that alter the tone, morphology or location of the tongue during sedation. Patient demographics or airway characteristics, level of sedation and pharmacology of the sedative administered, all could impact the degree and severity in oral cavity changes. The increasing popularity and benefits of portable ultrasound will hopefully allow for further studies and exploration of these changes in a more broad and systematic approach.

These changes in the oral cavity after anesthesia may reflect one aspect of a difficult airway, and may be found in a subset of patients preoperatively. For example, patients with OSA have flatter tongues without anesthesia administration.[10,11] As another example, patients with Ehlers–Danlos syndrome who have abnormal collagen or floppy tissue may experience upper airway collapse more frequently.[12] This upper airway collapse may contribute similarly to a difficult intubation as a larger tongue does, by obstructing the upper airway.[12,13]

Submandibular ultrasound should be explored to elucidate its role in understanding upper airway anatomy and its changes in drug-induced sleep for various populations.

This study has several limitations. First, ultrasound measurements can vary due to inter-operator variability. However, refining the method of ultrasound use and measurements in future studies can eliminate this variability. Second, our study was performed at a single, urban academic center, and thus, our findings may not be generalizable to other populations. Even so, we still see significant changes in tongue thickness and DLA after propofol administration.

In conclusion, upper airway measurements change following induction doses of propofol. The tongue's thickness decreases and the distance between the lingual arteries increases, as measured by submandibular ultrasound. Given the quick and non-invasive nature of ultrasound, further studies should utilize this modality for understanding the upper airway alterations with anesthetic medications and airway management.

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Conflicts of interest

There are no conflicts of interest.

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