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31.1 Background

Thyroidectomy is one of the most commonly performed surgical procedures worldwide and because vocal cord paresis or palsy (VCP) is an important outcome measure of the procedure itself, surgeons should have the knowledge of a patient's vocal cord (VC) function before and after the procedure [1, 2]. However, the gold standard examination for VC function, namely the flexible nasopharyngeal laryngoscopy (FLS) or better still video-laryngo-stroboscopy, is only available in some general or endocrine surgical practices and therefore, if a patient requires a formal VC examination, further consultation to an otolaryngologist is necessary. This not only increases cost but also causes inconvenience and disrupts patient flow [3]. In addition, many patients find FLS to be uncomfortable and

unpleasant leading to poor patient compliance and cooperation [4].

Transcutaneous laryngeal ultrasound (TLUSG), on the other hand, is a less-invasive and more convenient method of assessing the VCs. With increasing number of surgical practices now equipped with an ultrasound (USG) machine, TLUSG has become more applicable for surgeons and could potentially reduce many additional consultations and FLS [3, 5]. Furthermore, learning the skills of TLUSG is not difficult and it is clear that even individuals who do not routinely perform USG could quickly overcome the learning curve and become competent [6]. A recent study involving three high-volume independent endocrine surgeons reported that by adopting TLUSG in their clinical practice, 107 additional consultations and FLS were prevented over 1 year period and there was a net saving of USD \$7918 to \$21,507 [5]. Although TLUSG is never meant to be a replacement or an alternative to FLS because it does not allow a full visualization of the larynx, it is highly accurate in determining the VC function before and after thyroidectomy [7, 8]. In fact, instead of thinking of it as a replacement, a more pragmatic approach would be to use TLUSG as a screening tool for FLS. One study has shown that if TLUSG is used as a screening tool for FLS, the total number of routine FLS could potentially be reduced by up to 86% without having to miss a clinically significant VCP [7].

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It is worth pointing out that TLUSG is not a particularly novel technique. In fact, the earliest reports could be traced back in the 1980s [9, 10]. However, since most of the earlier reports were published in the radiology literature, surgeons were simply either unaware of this technique or did not recognize its clinical importance to thyroid surgery. One of the earlier reports by surgeons was published by an Australian group in 2001 [11]. In that study, TLUSG only correctly identified the side of the lesion in four of six VCPs and therefore, the overall sensitivity was only 67%. As a result, the authors concluded that TLUSG was not a reliable alternative to FLS in the assessment of VC function after thyroid or parathyroid surgery [11]. However, perhaps with advances in the quality of USG as well as improving skills over time, recent studies reported better success with some even reporting a sensitivity of up to 100% [7, 8, 12–14]. In a large prospective assessor-blind evaluation of TLUSG, one group reported a VC visualization rate of 94.5% with an overall sensitivity of detecting a VCP of 93.3% [7]. Therefore, the chance of missing an actual VCP when one could clearly see movement in both VCs on TLUSG is very low [7].

31.2 How Does TLUSG Work?

TLUSG essentially relies on the propagation of USG waves from the anterior neck skin to VCs via the ventral part of the thyroid cartilage and then back again. Although the laryngeal box has air in and around it, the movement of the VCs and the arytenoids are still visible and imageable on TLUSG. This is believed to be due to the fact that the thyroid cartilage can act as an acoustic window for USG waves to propagate. On actual imaging, the true VCs usually appear hypoechoic while the false VCs appear hyperechoic. This is because the former are made of muscles while the latter comprise fibro-fatty tissues. In addition to these two landmarks, the other landmark is the arytenoids. Because the arytenoids are made of hyaline cartilage and elastic cartilage, they normally would appear almost echoless with a hyperechoic rim at the posterior end of the VCs. Figure 31.1 shows the true and false VCs.

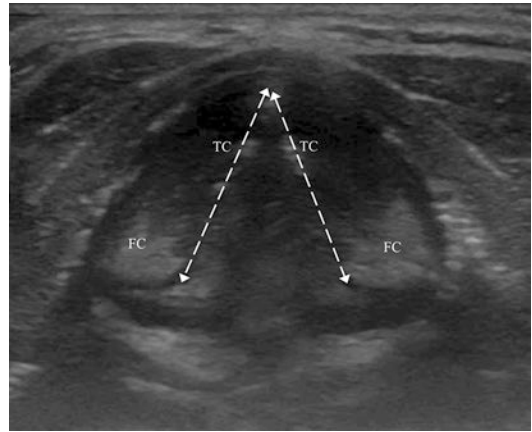


Fig. 31.1 This is an image depicting the true (TC) and false (FC) vocal cords on transcutaneous laryngeal ultrasound using the ventral approach

31.3 Steps and Tips in Carrying Out a TLUSG of the VCs

Similar to performing an USG for the thyroid or parathyroid gland, it is recommended that the patient should be placed in a supine position with the neck slightly extended and arms resting on the side. After applying ample amount of gel over the thyroid cartilage area, a linear transducer is placed transversely in the middle of the thyroid cartilage. It is important that the transducer is placed gently on the cartilage rather than pressing too forcefully onto the cartilage. The reason for using ample amount of gel is maximize the physical contact while avoiding air between the linear probe and the concavity of the cartilage. This is particularly crucial in male patients because the thyroid cartilage is usually more angulated in the middle than female patients and so there is less direct contact between the probe and cartilage. In terms of selecting the most appropriate USG probe for TLUSG, we believe the lower the frequency (i.e., 5–10 MHz) the better because the lower frequency helps with the tissue penetration and as mentioned earlier, the quality of the images depends on how well the USG waves could propagate through the thyroid cartilage. After placing the probe transversely on the body of the cartilage, the region is scanned cranio-caudally along the sagittal plane until either the true or false VCs are clearly visualized.

In the transverse plane, the false VCs are located immediately above the true VCs while the arytenoids are usually in the same transverse plane as the false VCs. To enhance visualization, it is recommended to turn up the gain or gray-scale during examination until the false VCs become hyperechoic. Based on the experience of previous authors, probably among the three moving landmarks on TLUSG (namely, false VCs, true VCs and arytenoids), the most easily visible landmark (at least initially) is the false VCs [15]. This is supported by a study that showed the rate of visualization of false VCs is almost three times higher than that of true VCs (92.7% vs. 36.7%, $p < 0.05$) and is also slightly higher than that of the arytenoids (89.8%) [16]. Once one or more landmarks are visualized on TLUSG, there are two types of VC movement that one should observe to determine if the function of the VCs has been compromised. First is passive (where a patient is breathing normally) and the other is active (where a patient is instructed to either phonate or perform a Valsalva maneuver). To date, there is no consensus on which type of VC movement or active maneuver provides the most reliable assessment. However, given that passive movement is technically the easiest to do, most clinicians prefer passive movement alone to determine if a patient has a unilateral VCP or not. For a patient without VCP, during passive movement, one could observe spontaneous, subtle symmetrical movement of both VCs with each cord moving in a rhythmic matter along with respiration while for a patient with an unilateral VCP, this passive movement either becomes asymmetrical or completely absent on the affected side. However, it should be noted that there is a small percentage of patients who do not have spontaneous passive movement in their VCs and so, it is not unreasonable to combine the finding of passive movement with at least one other active maneuver to confirm the motility in both VCs. In terms of active maneuvers, the recommended technique is the Valsalva maneuver because it is the technically easiest to learn [5, 17]. During Valsalva maneuver, if the patient has normal VCs, one could see both VCs adducting symmetrically to the midline (see Video 31.1).

On the other hand, when a patient suffers from a unilateral VCP, one would see either reduced (Video 31.2) or completely absent movement (Video 31.3) on the affected side (i.e., asymmetrical movement). Other maneuvers such as active phonation at times may induce movement in other laryngeal muscles and therefore not prefer. The other trick one could also try to induce voluntary movement of VCs is to ask the patient to swallow his or her own saliva for a few times.

31.4 Factors Leading to Non-visualization of VCs

Since visualization of the VCs really depends on whether the USG waves could travel from the skin to the VCs and the landmarks via the thyroid cartilage, the presence of ossification in the thyroid cartilage is the major reason for unclear VC visualization. There is little controversy that patients with ossified thyroid cartilage are not good candidates for TLUSG. Ossification itself blocks the propagation of USG waves onto the VCs and therefore, on imaging, one could see that there is a large acoustic shadow over the VCs and arytenoids making evaluation of VCs impossible (Fig. 31.2). Nevertheless, there are patient factors that could help to predict the presence of ossification. First is age. It has been well demonstrated that the extent of ossification gradually increases with age. This is compatible with our and others' experience that it is much easier to image VCs in young patients [12–15]. In fact, a previous study found that almost 100% of patients aged <30 years old had clear VC visualization while this rate dropped to <90% in patients aged >70 years old [15]. A recent anatomical study of 200 healthy individuals of all ages have shown that this ossification process begins at the age of 18–20 years in the posterior part of the thyroid cartilage regardless of sex and over time, the ossification process slowly moves in an anteromedial direction until the entire cartilage has been completely replaced by bone (i.e., ossified) [18]. In this study, the authors found that the thyroid cartilage is not consistently denser (as measured by Hounsfield units) on CT scan until

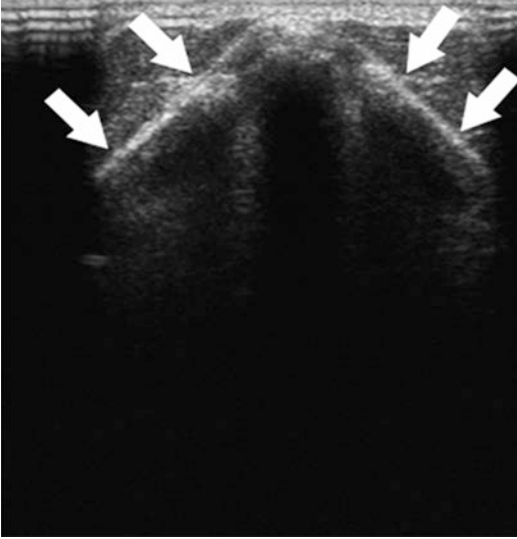


Fig. 31.2 This is an image depicting the presence of ossification at both lamina of the thyroid cartilage. Please also note the large post-acoustic shadow posterior to the cartilage

after the age 40 [18]. Consistent with this, some studies have reported that the entire cartilage only becomes replaced by bone by age of 65 [19]. Fortunately, this process appears to be less complete in females and therefore, some females may still have a small non-ossified ventral window in their thyroid cartilage making TLUSG possible [20]. Partly because of this difference in ossification between the two sexes, male patients generally have significantly lower rate of VC visualization than female patients. By adjusting for other significant clinical variables, one study found male patients to be 13 times more likely to have non-visualized VCs than females [15]. The other reason for this gender difference might be due to the thickness of the thyroid cartilage as males tend to have thicker and larger thyroid cartilage than females leading to poorer propagation of USG waves.

In addition to age and sex, patient height and the placement of neck incision in relation to the cricoid cartilage have also been found to be independent factors for non-visualization of VCs in postoperative TLUSG. For patient height, it was shown that even after adjusting for sex and age, those who were taller were significantly less

likely to have non-visualized VCs on TLUSG than those who were shorter in height. Using a median cutoff of 158 cm, the non-visualization rate for patients taller than 158 cm was significantly higher than those shorter than 158 cm (9.0% vs. 1.0%, $p < 0.001$). Similarly, using a median distance of 60 mm from skin incision to the cricoid cartilage, those with distance less than 60 mm were significantly more likely to have non-visualized VCs than those with distance ≥ 60 mm (6.9% vs. 3.9%, $p = 0.050$) [15]. The reason why the distance between wound and cricoid cartilage is an independent factor for non-visualization is probably related to the presence of subplatysmal swelling or edema after thyroidectomy. Therefore, it may still be possible to visualize the VCs in patients with short distance between wound and cricoid cartilage provided that a longer waiting period is allowed for the resolution of swelling and edema.

31.5 Ventral vs. Lateral Approach

To date, two general approaches for TLUSG had been described in the literature and they were the ventral and lateral approaches. For the ventral approach, the USG probe is placed transversely in front of the middle of the thyroid cartilage. The advantages with this approach are the symmetrical view and the better appreciation of the three landmarks in the larynx as this is the same view as in FLS. The symmetrical view is important in TLUSG particularly when one relies on seeing symmetrical passive movement as a criterion to rule out unilateral VCP. However, the ventral approach may not always be possible because male patients sometimes have very prominent and angular cartilage making a full contact between the probe and cartilage almost impossible. More recently, another group of investigators suggested the lateral approach could be one way to overcome this drawback for male patients [8]. Using the lateral approach, the authors were able to achieve 100% visualization rate and a sensitivity and specificity of 100% and 98.7%, respectively, in male patients. Unlike the ventral approach, the lateral approach

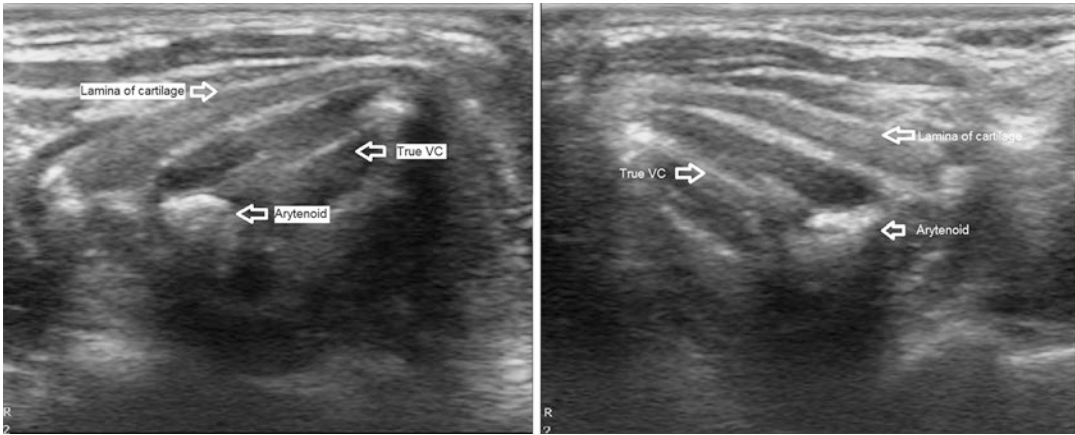


Fig. 31.3 These are two images showing the right and left true vocal cords and arytenoids via the lateral approach

involves placing the USG probe on the lateral surface of the thyroid lamina (Fig. 31.3). The authors believed the lateral approach could significantly improve the efficacy of TLUSG in male patients and postulated that placing the probe on the lateral surface of the larynx improves not only the physical contact but also shorten the distance between the probe and the laryngeal landmarks [8]. However, it is worth pointing out that in their comparison, the actual visualization rate of both the true VCs and arytenoids in the lateral approach tended to be lower than those in the ventral approach. Furthermore, based on anatomical studies, the ossification process actually starts posteriorly and moves slowly in the anteromedial direction and so the chance of encountering ossification using the lateral approach might actually be higher than the ventral approach. Nevertheless, more studies are needed to confirm their findings.

31.6 Conclusions

TLUSG is a noninvasive and convenient method of evaluating the motility of VCs before and after thyroidectomy. In our opinion, provided appropriate training has been given, the skills of TLUSG could be quickly learned even by individuals who do not routinely perform USG in their clinical

practice. Ossification of thyroid cartilage remains the main reason for clear VC visualization. Given the association between age, sex, and presence of ossification, TLUSG is most applicable in young, female patients. Ventral approach remains the preferred approach over the lateral approach in the assessment of VC function.

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