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Diagnostic Utility of High-Resolution Ultrasonography in Assessment of Laryngeal Disorders: A Comparative Study

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ABSTRACT

Background: Laryngoscopy is widely used as a diagnostic procedure for the detection of structural and functional laryngeal disorders. Ultrasound is also used as an effective technique for evaluating the head and neck region, including the larynx. **Aim:** The study aimed to investigate the efficiency of high-resolution ultrasonography in the evaluation of laryngeal disorders in comparison with laryngoscopy for better diagnosis, effective treatment, and follow-up. **Patients and methods:** Forty-five patients who suffered from hoarseness of voice were included in our study, and the ultrasound results were compared to indirect laryngoscopy.

Results: Ultrasonography had a sensitivity of 97.3% in the detection of vocal cord lesions and 100% specificity regarding other laryngeal lesions. There was a significant difference ($p < 0.05$) between ultrasonography and indirect laryngoscopy in the detection and characterization of these lesions. A case of vocal cord mass was missed by ultrasonography because of dense thyroid cartilage calcification in an elderly male. Regarding characterization of lesions, ultrasonography was more accurate, as two cystic lesions were misdiagnosed by laryngoscopy as polyps, although they were cysts by ultrasonography. Ultrasonography was better in determining exact size of the lesion, internal vascularity or calcification, laryngeal skeleton assessment, and tumoral invasion to surrounding structures, which could not be detected by laryngoscopy. **Conclusion:** High-resolution ultrasonography had high sensitivity and specificity in the assessment of laryngeal lesions compared to indirect laryngoscopy. High-resolution ultrasonography is superior in the characterization of laryngeal lesions.

Keywords: Ultrasonography, Laryngoscopy, Larynx.

INTRODUCTION

Otolaryngologists evaluate patients with laryngeal lesions using a variety of diagnostic techniques. The imaging technique used for this purpose should ideally be reliable, non-invasive, and well-tolerated. The outcomes must be verifiable, precise, and recordable for later use [(1)]. Laryngeal diseases include structural and functional abnormalities. Structural lesions such as benign vocal cord masses represent about 80% of all lesions. Vocal cord polyps are currently the most common benign vocal cord lesions in clinical practice [(2)].

Laryngeal carcinoma is the second most common head and neck cancer after skin cancer, accounting for 30 to 40% of all head and neck malignancies [(3)]. Mobility disorders of the vocal cords are considered functional abnormalities. True vocal fold immobility (TVFI) is a well-known consequence of head and neck surgery or injury. The gold standard for measuring vocal fold motion is laryngoscopy. Laryngoscopy is a good diagnostic modality; however, it can be painful and not well tolerated by patients [(4)]. Laryngeal diseases can be diagnosed and evaluated using various modalities, including laryngoscopy, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography (US). Laryngoscopy in conjunction with cross-sectional imaging (CT or MRI) is currently the standard procedure for the diagnosis and evaluation of most laryngeal diseases [(5)]. CT or MRI are employed to evaluate the submucosal extension of laryngeal lesions and the tumoral invasion of intra- and extra-laryngeal structures, but laryngoscopy cannot delineate the extra-laryngeal extension and is considered an invasive procedure [(6)].

Ultrasonography offers higher resolution imaging than CT or MRI, as it can identify laryngeal anatomy as well as minor but clinically significant anomalies that are not readily apparent with CT or MRI. It is also considered more useful than CT in the diagnosis of benign lesions like vocal cord nodules, polyps, cysts, and Reinke edema. Moreover, ultrasonography is widely available, inexpensive, non-invasive, radiation-free, and allows real-time imaging for dynamic assessment, especially for vocal cord motility, unlike CT and MRI. Additionally, it is

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safe for use during pregnancy and in infants, where it is frequently used to diagnose stenosis and hemangiomas in the subglottis. It can also be used in conjunction with guided fine-needle aspiration or biopsy [7].

Despite all these advantages, ultrasonography is not frequently used for imaging of laryngeal lesions, as it is thought that adults' calcified thyroid cartilage and the soft-tissue-air interface prevent the visualization of laryngeal structures. However, the majority of laryngeal structures can be evaluated by ultrasonography through certain locations that allow proper transmission of the ultrasound beam [7]. Therefore, this study aimed to assess the diagnostic accuracy of ultrasonography in the assessment of various laryngeal lesions in comparison with laryngoscopy.

PATIENTS AND METHODS

Study design: This comparative study was conducted on 45 patients presented with hoarseness of voice at the Otolaryngology and Diagnostic Radiology Departments, Suez Canal University Hospital, between August 2023 and April 2024.

Inclusion Criteria: Patients **of** both sexes who suffered from hoarseness of voice.

Methods: The procedure was explained to all patients, and informed consent were obtained. Patients were assessed for laryngeal structural and functional disorders using ultrasonography and laryngoscopy. Structural disorders included any abnormal growth or masses of the larynx or vocal cords, while functional disorders included abnormal movement of the vocal cords or paralysis. To verify and compare the accuracy of both techniques, ultrasound and laryngoscopy findings were collected.

The larynx was evaluated using the Hitachi Arietta 65 ultrasound system with a linear probe (2–12 MHz frequency). The laryngeal ultrasound imaging technique required the patient to be in a supine position with shoulder support and neck extension. Both anterior and lateral approaches were used for proper imaging of the larynx. The anterior approach began with hyoid bone recognition, followed by scanning beneath the strap muscles to visualize the thyroid cartilage. Transverse plane scanning was performed for vocal cord imaging. The true vocal folds appeared hypoechoic, while the false cords were hyperechoic. For visualization of the true and false vocal cords and arytenoid cartilage, a linear transducer was positioned on the lateral surface of the larynx using lateral approach. Both vocal cords were evaluated during breath holding, for optimal assessment of vocal cord lesions, and during the Valsalva maneuver to assess function and mobility [8]. Any abnormal growth or masses of the larynx and vocal cords were assessed using both ultrasound and laryngoscope then both results were compared.

Ethical considerations: The study protocol was in accordance with Helsinki and was approved by The Research Ethics Committee of the Faculty of Medicine, Suez Canal University. Informed written consents were obtained from all participants.

Statistical analysis

Data were analyzed using IBM SPSS software version 20.0. Qualitative data were described using numbers and percentages. The Shapiro-Wilk test was used to verify the normality of distribution. Quantitative data were described using range, mean, standard deviation, median and interquartile range (IQR). The significance of the results was judged at the 5% level. The tests used included Chi-square test for categorical variables, Fisher's exact test was used for correction when more than 20% of the cells had an expected count of less than 5.

RESULTS

The study included 45 patients: 57% were males (26 males) and 42.2% were females (19 females). High-resolution laryngeal ultrasonography was performed for all cases, followed by indirect flexible laryngoscopy. The age ranged from 2 to 72 years with mean age of 37.07 ± 14.75 years.

There was a significant difference ($p<0.05$) between laryngoscope and ultrasound in the diagnosis of vocal cord lesions. Out of 45 cases, the number of vocal cord lesions detected by ultrasound was 37, while the number of vocal cord lesions detected by laryngoscope was 38. There were significant differences in the characterization and final diagnosis of both modalities as follows, 14 cysts were detected by US vs 12 cysts detected by laryngoscope, 4 masses detected by US vs 5 masses detected by laryngoscope and 9 polyps by US vs 11 polyps detected by laryngoscope (table 1).

Table (1): Comparison between laryngoscope and ultrasound in the diagnosis of vocal cord lesions (n= 45)

	N	Laryngoscope diagnosis										FET	p
		Cyst (n = 12)		Mass (n = 5)		Nodule (n = 10)		Polyp (n = 11)		No (n = 7)			
		No.	%	No.	%	No.	%	No.	%	No.	%		
US diagnosis													
Cyst	**14**	12	100.0	0	0.0	0	0.0	2	18.2	0	0.0		
Mass	**4** [A]	0	0.0	4	80.0	0	0.0	0	0.0	0	0.0		
Nodule	**10**	0	0.0	0	0.0	10	100.0	0	0.0	0	0.0	89.827*	<0.001*
Polyp	**9**	0	0.0	0	0.0	0	0.0	9	81.8	0	0.0		
No	**8**	0	0.0	1	20.0	0	0.0	0	0.0	7	100.0		

FET: Fisher Exact test, **p:** p value for association between different categories, ***:** Statistically significant at $p \leq 0.05$, **A:** 1 out of 4 masses detected by US and laryngoscope, was invading the thyroid cartilage (this tumoral invasion was detected only by US).

Regarding vocal cord masses, only one vocal cord mass was not detected by US due to heavily calcified thyroid cartilage in 70-year-old male, which prevented the sound beam transmission through this calcified thyroid cartilage. On the other hand, laryngoscope detected this case easily. Therefore, laryngoscope was better than US regarding the detection rate of vocal cord masses. The sensitivity of US was 97.37%, while NPV was 87.5% and diagnostic accuracy was 97.78%. The 4 vocal cord masses were seen by US as hypoechoic thickening of the vocal cord with lost hyperechoic line between thyroarytenoid muscle and vocalis muscle medially together with irregular medial margins. However, US was better than laryngoscope in detecting vascularity within vocal cord masses as well as thyroid lamina invasion, which was seen as loss of hyperechoic line between thyroid lamina and vocal cord. So US was better in detection of vocal cord masses invasion to nearby structures (figure 1). Figure (1) showed right sided vocal cord mass lesion with invasion to right thyroid cartilage detected only by US (seen as lost hyperechoic line between vocal cord and inner perichondrium of thyroid cartilage).

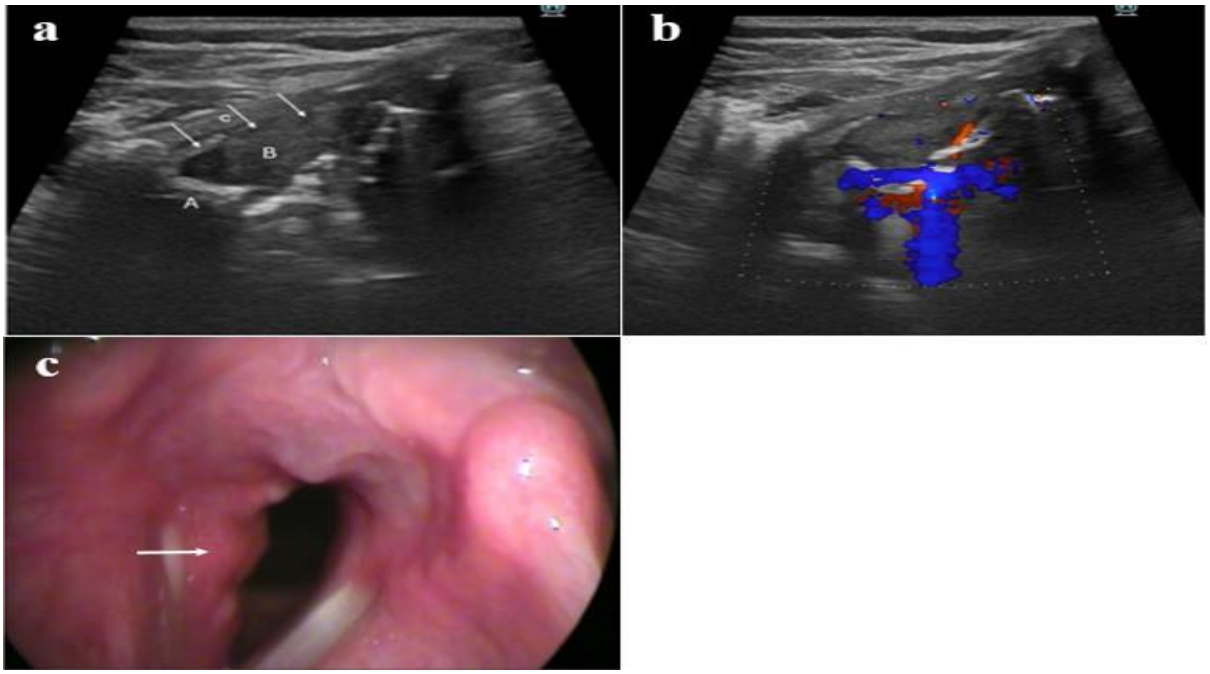

Figure (1): right vocal cord mass lesions with invasion to right thyroid cartilage lamina.

Figure (2) showed equal abilities of laryngoscope and US in detection of laryngeal web, vocal cord palsy and anterior commissure lesions.

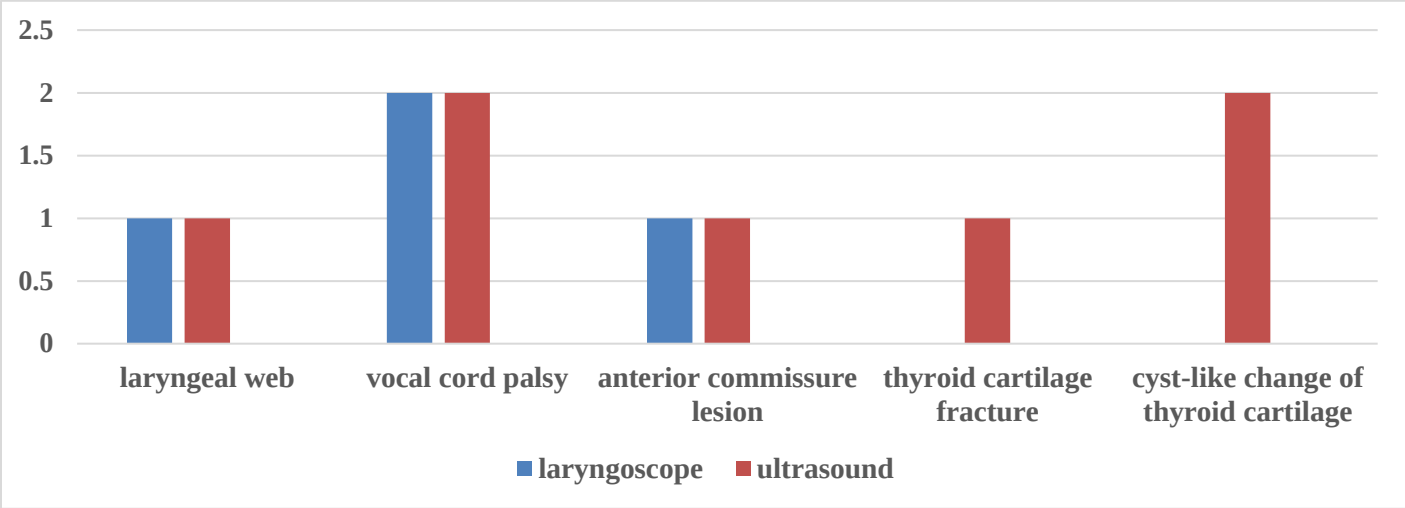

Figure (2): Comparison between laryngoscope and US in the detection of laryngeal disorders.

US was superior to laryngoscope in detection of laryngeal skeleton abnormalities as thyroid cartilage fracture and cyst-like changes of thyroid cartilage. Differences in total number of cysts and polyps detected by US and laryngoscope were attributed to the ability of US in tissue characterization than that of laryngoscope. However, US and laryngoscope had equal abilities in detection of laryngeal web, vocal cord palsy and anterior commissure lesions, yet US was superior to laryngoscope in detection of laryngeal skeleton abnormalities as thyroid cartilage fracture and cyst-like changes of thyroid cartilage (figure 3).

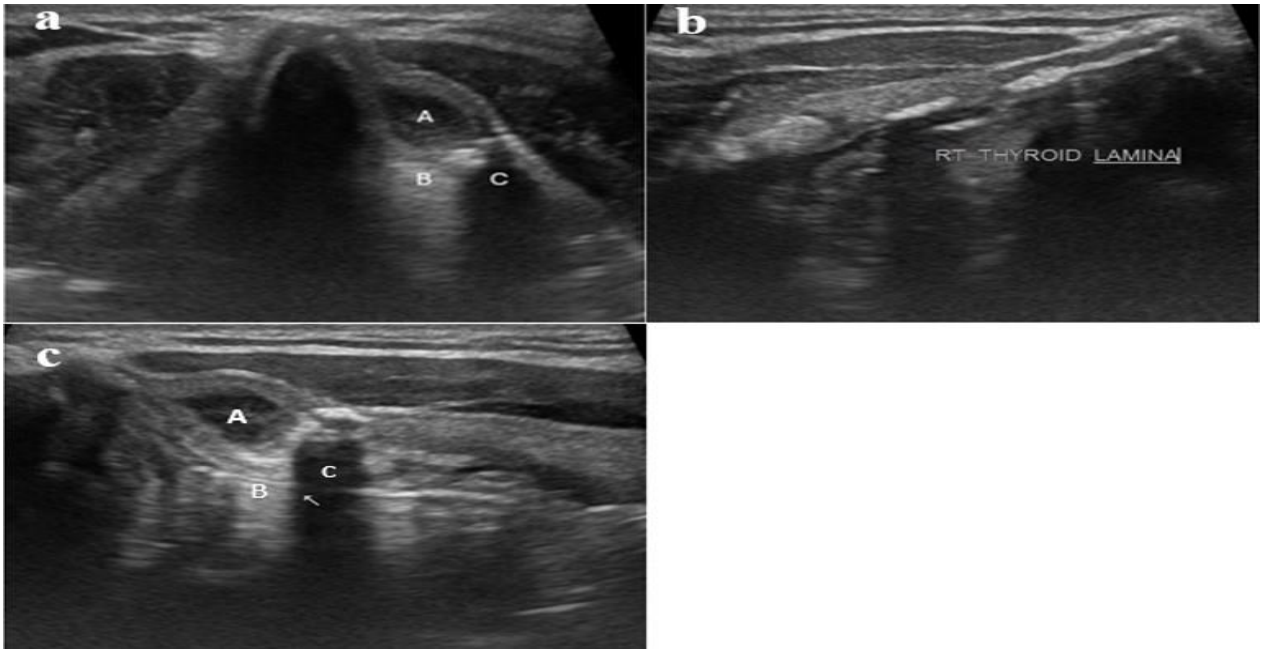

Figure 3: Cyst like change of left thyroid lamina, B-posterior acoustic enhancement, C- calcific focus with posterior shadowing (detected only by US).

Table (2) showed two cases of left-sided vocal cord palsy detected by laryngoscope and US with no significant difference between both modalities in the detection of such cases.

Table (2): Comparison between laryngoscope and US regarding the total number of vocal cord palsy cases.

	laryngoscope vocal cord palsy			
	Yes (n = 2)		No (n = 43)	
	No.	%	No.	%
US vocal cord palsy Yes No	 2 0	 100.0 0.0	 0 43	 0.0 100.0

χ^2**:** Chi square test, **FET:** Fisher Exact test, **p:** p value for association between different categories, ***:** Statistically significant at $p \leq 0.05$.

Regarding detection of vocal cord lesions, the sensitivity of US if compared to laryngoscope was 97.37%, while NPV was 87.5% and diagnostic accuracy was 97.78%. This was attributed to thyroid cartilage calcification which limited diagnostic ability of US leading to underdiagnosis of cases and also attributed to superior ability of US than laryngoscope in the characterization of cystic and solid lesions. So many polyps diagnosed by laryngoscope were actually cysts by US. On the other hand, there was total agreement and equal diagnostic accuracy between US and laryngoscope regarding the detection of laryngeal web, vocal cord palsy and anterior commissure lesions (Table 3).

Table (3): Agreement (Sensitivity, Specificity, and Accuracy) For US

Ultrasound VS laryngoscope	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**	**κ**	**level of agreement**
Vocal cord lesion	97.37	100.0	100.0	87.50	97.78	0.920	Very good
Laryngeal web	100.0	100.0	100.0	100.0	100.0	1.000	Very good
Vocal cord palsy	100.0	100.0	100.0	100.0	100.0	1.000	Very good
Anterior commissure lesion	100.0	100.0	100.0	100.0	100.0	1.000	Very good

PPV: Positive predictive value, **NPV:** Negative predictive value, **κ:** kappa test.

Figure 4: showing left sided vocal cord cyst (displaying posterior acoustic enhancement), which was seen misdiagnosed by laryngoscope as a polyp. Two out of the 11 polyps detected by laryngoscope were actually cysts by US as they had posterior acoustic enhancement by US denoting the cystic nature of these lesions. Accordingly, these two polyps were misdiagnosed by laryngoscope, as they were actually cysts (cystic in nature) by US. In fact, US was superior to laryngoscope in characterization whether the vocal cord lesion is cystic or solid. There was a significant difference ($p<0.05$) between laryngoscope and ultrasound in detection of vocal cord lesions. Regarding the use of ultrasound in diagnosis of vocal cord lesions, the numbers of cases showed cyst, mass, and polyp were 14, 4 and 9 respectively. These numbers were different on using the laryngoscope modality. The number of cases showed no vocal cord lesions was 8 out of 45 cases, while it was 7 in case of using laryngoscope (Figure 4).

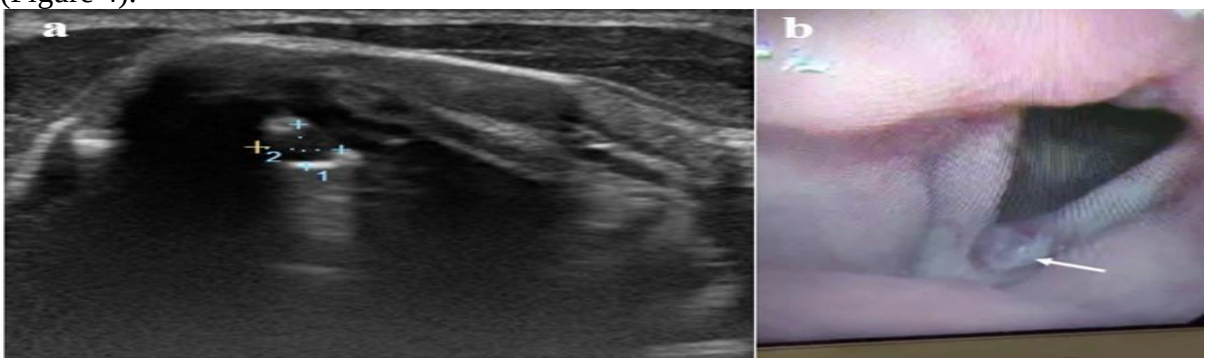

Figure (4): left vocal cord cyst.

DISCUSSION

This study compared high-resolution ultrasonography and indirect flexible laryngoscopy in the detection and characterization of laryngeal lesions. Ultrasonography demonstrated a sensitivity of 97.3% compared to 100% for flexible indirect laryngoscopy. The missed case by ultrasonography was attributed to dense thyroid cartilage calcification in an elderly male, which limited sound beam transmission. Our study results agree with **Gadalla *et al.*** [8] whose study was conducted on 52 cases comparing US with indirect laryngoscopy in detecting the laryngeal lesions. They stated that 6 elderly male patients with laryngeal abnormalities were not detected by US but were detected by indirect laryngoscopy as follows: 1 patient presented with a mass lesion within the supraglottic region, 1 patient had left-sided vocal cord nodule, 2 cases of bilateral vocal cord leucoplakia and 2 patients had right-sided nodulesClick or tap here to enter text. This also agrees with **Wenaas *et al.*** [9] regarding thyroid cartilage calcification, where who performed their study on about 200 cases (half of them were males) with ages ranging between newborn to 50 years of age. They concluded that the thyroid cartilage calcification rate increased with age (more in males). In addition, thyroid cartilage calcification is not very dense until 40 years of age, yielding the ability of US to be used efficiently until this age group. This agrees with the present study as the missed case by US, was a male patient of 70 years old who had dense thyroid cartilage calcification.

This study clarified that there was a significant difference ($p<0.05$) between laryngoscope and ultrasound in the diagnosis and characterization of vocal cord lesions. The total number of detected cysts by the US was 14 while the number of cysts detected by laryngoscope was only 12. On the other hand, the number of polyps detected by US was 9, while the number of polyps detected by laryngoscope was 11. The recorded differences in the total number of cysts and polyps detected by US and laryngoscope could confirm the ability of US in tissue characterization than that of laryngoscope. In fact, 2 out of 11 polyps detected by laryngoscope were cysts by US as they had posterior acoustic enhancement denoting the cystic nature of these lesions. Therefore, US was superior to laryngoscope in tissue characterization, whether the vocal cord lesion is cystic or solid. In addition, US was quite able to assess the turbidity of fluid within cysts (as 4 had turbid fluid component seen by US, while laryngoscope couldn't detect such character). This agrees with **Gadalla *et al.*** [8] who reported that 6 cysts were misdiagnosed by laryngoscope as polyps, while they were detected as cysts by US. This has been proven later by histopathological assessment to be cysts not polyps. This is also consistent with **Gomaa *et al.*** [10].

Our study showed that US was better than laryngoscope in the characterization of lesions. For example, regarding the 4 cases of vocal cord masses (which were seen as hypoechoic thickening of vocal cord associated with lost hyperechoic line between thyroarytenoid and vocalis muscles), 2 cases showed internal vascularity on Doppler interrogation, 1 case showed lost hyperechoic line between thyroid lamina and vocal cord suggesting invasion to thyroid cartilage (table 1 & figure 1) , which couldn't be detected by laryngoscope. This agrees with **Beale *et al.*** [7] who stated that US had high specificity (up to 97.9%) and sensitivity (up to 87.5%) regarding the invasion of the laryngeal tumor to the larynx. In addition, the invasion of the laryngeal tumor to paraglolttic space could be easily detected by US with a sensitivity of 95.5% and specificity of 94.9%.

Regarding the ability of US to detect tumoral invasion to nearby structures (for example laryngeal cartilage), the current study agrees with **Xia *et al.*** [11] who showed that ultrasound could also detect the tumoral invasion to nearby structures as paraglottic space, (the inner perichondrium of the thyroid cartilage remains immobile during respiration, while the paraglottic area exhibits some degree of motion). US could diagnose tumoral involvement of the paraglottic space with a sensitivity of 95.5% and a specificity of 94.9% when complete or partial immobility of this space was observed.

Ultrasonography also proved effective in our study in assessing vocal cord mobility, with 100% sensitivity and specificity compared to laryngoscopy. The negative predictive value of ultrasonography was also 100%, supporting its use as a reliable diagnostic tool for vocal cord mobility assessment. This agrees with **Beale *et al.*** [7] who stated that US had higher negative predictive value ranging between 97% and 99% during the assessment of vocal cord mobility. Our study results are similar to a study done by **Wong *et al.*** [12] who compared laryngeal US and laryngoscopy in an adult

population and discovered that ultrasound had a 93% sensitivity and 98% specificity in identifying impairment of vocal fold mobility [12].

CONCLUSION

High-resolution ultrasonography is a highly sensitive, specific, and accurate modality for the detection of laryngeal abnormalities compared to laryngoscopy. It is non-invasive, widely available, inexpensive, and radiation-free. Ultrasonography is particularly advantageous in determining the exact dimensions of the lesions, characterizing lesions and detecting extension to nearby structures. However, its diagnostic ability was limited by thyroid cartilage calcification, especially in elderly patients.

DECLARATIONS

Informed consent: Obtained from all participants.

Conflict of interest: The authors declared no conflict of interest.

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