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Role of Gray Scale and Color Doppler Ultrasound in Diagnosis of Parotid and Submandibular Gland Diseases

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ABSTRACT

Background: Ultrasonography is considered as the primary imaging technique used for identification, diagnosis, treatment, and follow-up of lesions affecting the major salivary gland. Both grey scale and color Doppler ultrasound maneuvers are frequently used for assessment of various salivary gland infirmities. As well, it is used for classification of the major salivary gland pathologies. This study aimed to assess the validity of ultrasound in the diagnosis and prediction of the parotid and submandibular gland lesions.

Patients and Methods: Sixty-nine cases with salivary gland masses were investigated via using grey scale, color Doppler and spectral Doppler. Grey scale was used for the morphological features of each tumor; color Doppler for the blood vessel distribution and frequency; and spectral Doppler for determination of the peak systolic velocity, resistive index and pulsatility index. Postoperative through histopathological examination was carried out for all cases after excision of mass.

Results: According to the histopathological examination, 28 of 69 (40.6%) lesions were identified as benign, 13 of 69 (18.8%) as malignant, and 28 of 69 (40.6%) as inflammatory. Color Doppler revealed that malignant lesions had significantly higher grade of vascularity and a mixed “scattered” pattern of distribution. Using spectral Doppler, malignant masses had significantly higher Doppler ultrasound wave forms. Grey scale sonar showed that the rate of ill-defined borders, heterogeneous structure, and irregular shape was significantly higher in Malignant than benign tumors.

Conclusions: Adding Doppler ultrasound (color and pulse wave) may grant better diagnosis for malignant salivary gland tumors.

Keywords: Salivary gland, Malignant, Doppler, Grey scale, Color, Spectral.

INTRODUCTION

Salivary glands (SGs) are susceptible for affliction by group of diseases either systemic, inflammatory, obstructive or malignancy **[1]**. Most of SG tumors are benign with variable degree of liability for recurrence and/or malignant transformation **[2]**. Hence, prompt and proper diagnosis is crucial for disease management. Clinical examination alone won't give the proper salivary gland disease diagnosis. Therefore, imaging techniques are fundamental for accurate diagnosis and classification **[3]**.

The role of ultrasonography (USG) in the diagnosis and treatment of SG lesions is crucial and central. The final diagnosis may be suggested by the USG examination alone, or significant differential diagnostic information may be provided **[4]**. It can differentiate between intraglandular from extra-glandular lesions in 98% of cases i.e., it can discriminate salivary gland lesions as focal or diffuse. Lesion edge outline may differentiate focal lesions into malignant and benign. High resolution transducers USG is better than Computerized Tomography (CT) or Magnetic Resonant Imaging (MRI) in detection of lesions with irregular borders **[5]**.

The findings of the Color Doppler are frequently used for classification and characterization of lesions i.e., diagnosis of pleomorphic adenoma. Doppler findings of intralesional vascularity, type and grade of vascularity, and Doppler ultrasound wave forms (pulse wave velocity (PSV), resistive index (RI) and pulsatile index (PI)) are important for identification of malignant lesions **[6]**.

Moreover, it was approved that the method of choice for obtaining biopsy for histopathological examination is the USG guided Fine Needle Aspiration Cytology (FNAC). This adds extra-advantage for the use of USG in discrimination between benign and malignant lesions **[3]**. Plain X-ray, sialography, CT, MRI and PET-CT are other imaging modalities used for diagnosis and characterization of salivary gland diseases **[7]**.

Although USG is a good tool for diagnosis, sometimes full visualization of lesion might be impossible and this is because of the lesion position, its extension into the deep gland tissue or behind the bone of the mandible. Thus, further imaging with CT or MRI is necessary **[4]**.

The current study aimed to assess the validity of USG (grey-scale and Doppler) in the diagnosis and prediction of SG lesions.

PATIENTS AND METHODS

The present study adopted an observational design and was conducted at the Radiology Department, Assiut University, Egypt in the period from the 1st of January 2019 to the 1st of February 2021. Institutional Ethical Committee permission was taken before starting the study (**IRB: 17100612**) Trial registration was prospectively undertaken in clinical trial.gov (**NCT03746730**) .The study was carried out in accordance with the Helsinki Declaration guidelines.

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Before enrollment, the study's objectives, methods were described to the patients, and their written informed consent was obtained. All participants in the study had the right to withdraw their consent at any time.

Sample size calculation was carried out using G*Power 3 software [8]. A minimum calculated sample of 69 patients with SG tumor was needed to detect a diagnostic yield (sensitivity and specificity) of USG of 80% and 93% in prediction of malignant lesions, respectively against the FNAC diagnosis, with an error probability of 0.05 and 80% power on a one-tailed test.

A total of 69 patients were recruited from the Otorhinolaryngology and Surgery Department's outpatient and inpatient units for this study (37 male and 32 female). USG was used to assess patients who had neck pain, edema, or any other complaint involving the main salivary glands. Patients with surgical conditions underwent GSU and CDS study, FNAC and excisional biopsy. Those with inflammatory conditions, imaging and clinical follow up after medical treatment was considered to get to the final diagnosis. The study included patients with major salivary glands lesions. Patients with extra salivary glands lesions and those lost to follow-up imaging were excluded from the study.

Technique:

USG was used to assess patients with neck pain, swelling, or any other complaints involving the major SGs. In patients with significant SGs lesions, a detailed examination using GSS, CDS, PDS, and PWD was conducted. All patients were subjected to Logic P6 colour Doppler machine with 7.5-10 MHz linear transducer. Patients were placed in supine position with a pillow under their lower neck and shoulders, and their necks were hyperextended. The patient's head was tilted in the other direction and examination of submandibular and parotid glands on both was carried out. In both longitudinal and transverse planes, USG of the parotid gland was carried out. The transducer was positioned so that it was inferior to the ear lobe and perpendicular to the transverse scan. The transducer was positioned anteriorly and perpendicular to the long axis of the ear to provide a longitudinal scan. In transverse plane, the submandibular gland was checked. Localizing lesions and tracing vasculature are made easier with oblique and coronal modifications. To evaluate the lymph nodes and look for concurrent or linked lesions, the rest of the neck was examined.

GSS assessment of SG lesions included assessment of asymmetry (as there is possibility of bilateral affection e.g., mumps, Warthin's tumour), echogenicity of the lesion vs. glandular parenchyma (hypoechoic or hyperechoic), homogeneity of the lesion vs. the surrounding parenchyma (homogenous or heterogeneous), border (well defined or ill defined) and shape (regular, lobulated, irregular), regional lymph node affection (benign featuring or not).

Lesion and gland vascularity was investigated using colour Doppler, power Doppler and pulse wave Doppler. When Power Doppler Sonography (PDS) was utilized, the Pulsed Repetition Frequency (PRF) was set at 700 Hz for small vessels recognition and the Doppler setting was optimised at high sensitivity, low wall filter, and medium persistence. Colour gain was increased until noise or artefacts started to show. It was then gradually diminished until it disappeared. Intra-tumour vascularity seen on colour Doppler sonograms was subjectively graded on a four-step analogue scale of 0 to 3+ [4]: from no colour signal (0) to large feeder vessels and a high number of colour signals (+3).

Peripheral (basket-like), hilar (branching), or mixed patterns of vascular distribution were seen in the lesion. Spectral Doppler was utilised to assess the vascular resistance (RI and PI) of lesions, and the most prominent feeding vessel was commonly chosen for the assessment. Angle adjustment was used at 60 or less when measuring Peak Systolic Velocity (PSV).

Final USG conclusion was made based on SG lesion's Doppler findings along with its grey-scale characters. Criteria of benign lesions based on the USG finding as homogenous or heterogeneous echo-pattern of the lesion were well-defined margins, benign featuring lymph node affection, low grade vascularity (0/1+), PSV, RI and PI of (<25 cm/sec <0.8 and PI <1.8, respectively). On the other hand, malignant criteria included: lesion with a heterogeneous echo pattern, ill-defined margins, malignant featuring lymph node affection, extension into nearby structures, high grade vascularity (2+/3+), PSV, RI and PI of (>25 cm/sec, >0.8, and >1.8, respectively). FNAC or surgical biopsy provided the definitive final diagnosis. The final diagnosis was correlated with the lesion's grey scale and Doppler evaluations. The study's findings were analysed and compared with previous research.

Ethical consent:

An approval of the study was obtained from Assiut University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

SPSS v.22 (IBM-SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Data was expressed as mean ± standard deviation (SD), median, range, frequencies, and percentages as appropriate. Normality of continuous variables was examined using Shapiro-Wilk test. Independent sample t-test/Mann Whitney U test was used for comparison of means/medians as appropriate. Chi-square/ Fisher's Exact test was calculated for assessing the difference in frequency between categorical variables as appropriate. For comparison of PSV, RI, PI and GSS categories in benign and malignant tumors differentiation was done by using Open Epi software (Open Epi version 2.3.1 from Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA 30322, USA. A p-value of $\leq$0.05 level was considered significant.

RESULTS

The present study included 69 patients, with a median age of 33 ranged from one to 70 years. Out of 69 studied cases; 37 (54%) were males and 32 (46%) were females. The common presenting complaint was swelling (97%). Most of them presented with painless swelling 47 (68%), and 14 (20%) presented with painful swelling. Seven cases (10%) with acute infection (abscess formation) had fever in addition to painful swelling.

Other symptoms included: neck mass, dental pain while eating. The most frequently affected gland was the parotid gland (n=50) representing about two-thirds of the sample followed by submandibular gland that was affected in 19 (27.5%) cases. Further, most cases (87%) had unilateral lesion (n=60), and only 9 cases (13%) had bilateral lesions. Moreover, about 60% (n=41) of cases had neoplastic lesions (41% benign and 19% malignant) and 41% have inflammatory lesions. The majority (94%) of cases (16/17) of pleomorphic adenomas occurred in parotid gland **(Table 1)**.

Table (1): Demographic data of the studied participants (n=69).

Variable	Number	Percentages
Age (years)		
• Mean ±SD	35.86 ± 18.78	
• Median (range)	36 (1 – 70)	
Sex, n (%)		
• Male	37	(53.6)
• Female	32	(46.4)
Clinical presentation, n (%)		
• Painless swelling	47	(68.1)
• Painful swelling	14	(20.3)
• Painful swelling + Fever	7	(10.1)
• Asymptomatic	1	(1.4)
Site of lesion, n (%)		
• Parotid	50	(72.5)
• Submandibular	19	(27.5)
Lesion laterality, n (%)		
• Unilateral	60	(87.0)
• Bilateral	9	(13.0)
Diagnosis, n (%)		
• Benign	28	(40.6)
• Malignant	13	(18.8)
• Inflammatory	28	(40.6)

Quantitative data are presented in the form of mean ± SD and median (range), qualitative data are presented in the form of number (%).

Figure (1) depicted the sonographic characters of parotid gland benign masses and **Figure (2)** represented those of the malignant masses.

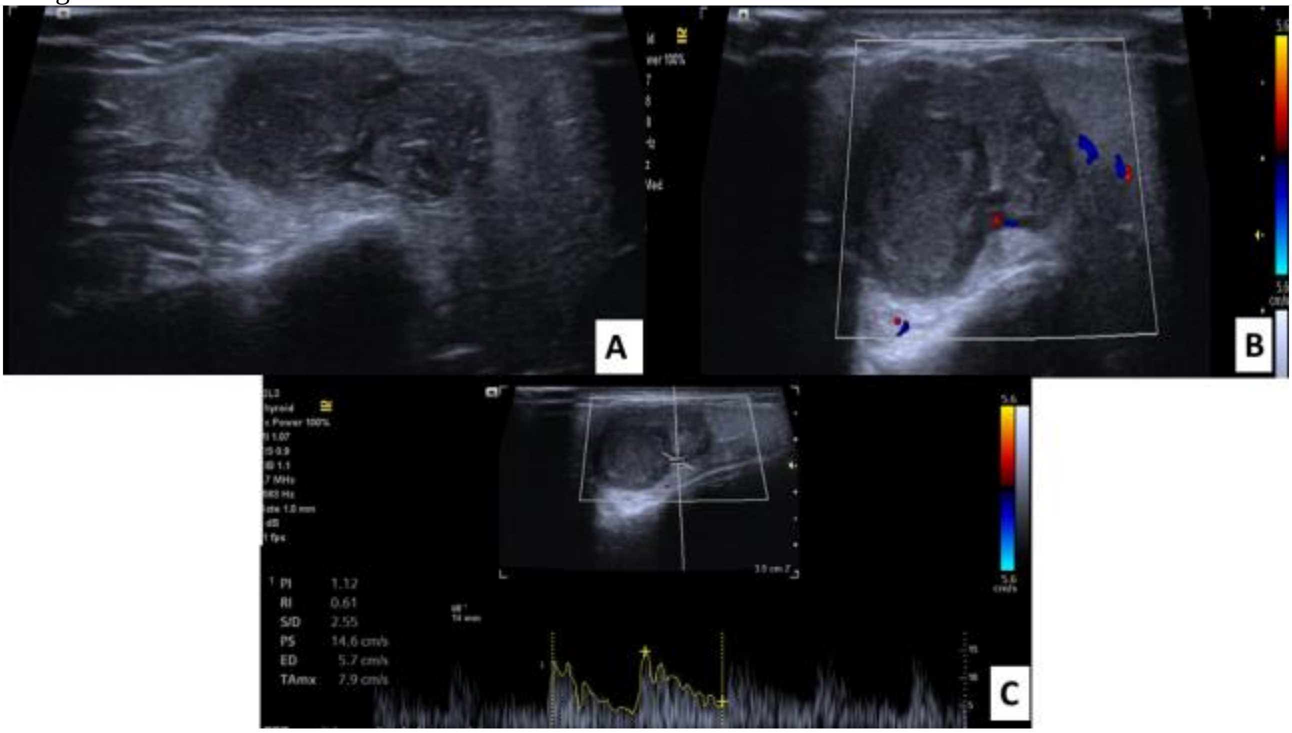

Figure (1): Female patient 19 years old presented with left parotid painless swelling of 2-year duration. Findings on ultrasound (A) An ovoid well defined hypoechoic homogenous mass lesion in superficial lobe of left parotid gland with posterior acoustic enhancement and benign featuring upper deep cervical lymphadenopathy of oval shaped with preserved fatty hilum (B) Grade I peripheral arterial flow is noted, (C) Pulse wave Doppler findings {PSV: 14.6 cm/s (<25cm/s), RI: 0.61 (<0.8), and PI: 1.12 (<1.8)}. GSS and CDS suggesting pleomorphic adenoma. Histopathological examination revealed the lesion to be pleomorphic adenoma

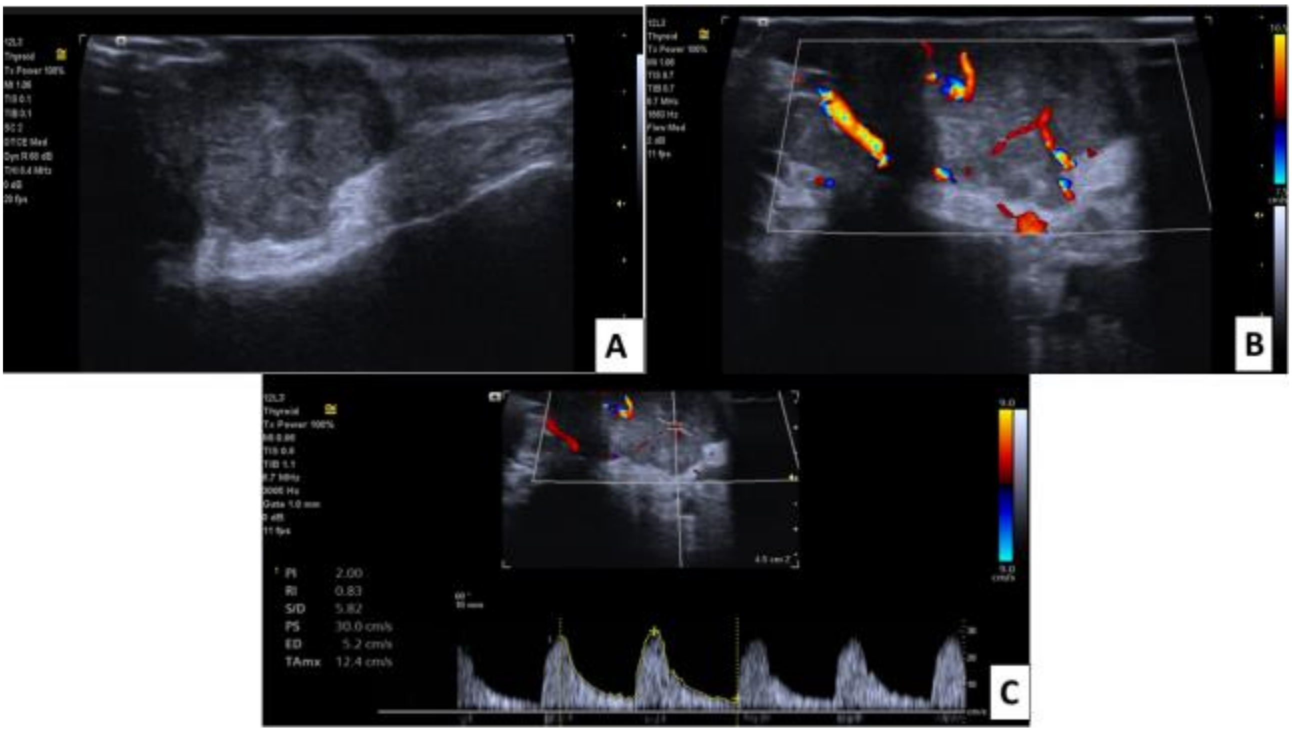

Figure (2): Male patient 52 years old presented by painless swelling of right parotid gland of 3-months duration. Findings on ultrasound (A) Hypoechoic inhomogeneous solid mass lesion with ill-defined border seen at superficial part of right parotid gland, (B) Grade II vascularity of mixed pattern, (C) Pulse wave Doppler findings {PSV: 30 cm/s (>25 cm/s), RI: 0.83 (>0.8), and PI: 2.00 (>1.8)}. GSS and CDS suggesting malignant featuring mass lesion. Histopathological examination revealed the lesion to be intermediate grade mucoepidermoid carcinoma tumor.

The findings of Doppler revealed that the criteria of benign SG lesions were predominantly low-grade vascularity, the only benign tumor with Grade 3+ vascularity was infantile hemangioma. Malignant tumors showed high-grade vascularity except MALT lymphoma. Most inflammatory lesions revealed predominantly low-grade vascularity except the acute Sialadenitis revealed grade 2 vascularity.

About three-quarter of cases of pleomorphic adenoma had predominantly peripheral pattern of vascularity and all cases with Warthin's tumors (n=7) had hilar flow with Infantile hemangioma cases showed mixed pattern of vascularity.

In malignant tumors, about 77% showed mixed pattern of vascularity, mucoepidermoid carcinoma showed predominantly mixed pattern of vascularity (83%), adenoid cystic carcinoma and squamous cell carcinoma showed mixed pattern of vascularity. Patients with MALT Lymphoma showed peripheral pattern of vascularity, cases with metastasis showed hilar pattern and other cases show mixed pattern of vascularity **(Table 2)**.

Table (2): Grade and pattern of vascularity of salivary gland lesions.

Histopathological Diagnosis	Grade of lesion Vascularity					Pattern of Vascularity			
	N	0	+1	+2	+ 3	N	Peripheral	Hilar	Mixed
Benign lesions									
Pleomorphic Adenoma	17	1	13	3	0	16	12	3	1
Warthins Tumor	7	0	6	1	0	7	0	7	0
Lipoma	1	1	0	0	0	0	0	0	0
Infantile hemangioma	1	0	0	0	1	1	0	0	1
Congenital cystic lymphangioma	1	1	0	0	0	0	0	0	0
Simple cyst	1	1	0	0	0	0	0	0	0
Malignant lesions									
Mucoepidermoid carcinoma	6	0	1	2	3	6	1	0	5
Adenoid cystic carcinoma	2	0	0	1	1	2	0	0	2
Squmous cell carcinoma	2	0	0	1	1	2	0	0	2
MALT Lymphoma	1	0	1	0	0	1	1	0	0
Metastasis	2	0	1	1	0	2	0	1	1
Inflammatory lesions									
Acute Sialodenitis	21	0	9	12	0				
Chronic Sialodenitis	3	0	2	1	0				
Sjogren's syndrome	1	0	1	0	0				
Sialolithiasis	2	0	2	0	0				
Sialadenosis	1	0	1	0	0				

Qualitative data are presented as number.

Table 3 showed that the mean age of patients with malignant SG lesions was higher than those with benign lesions (53.2 ± 10.9 vs. 36.4 ± 15.4, P=0.001). Also, malignant lesions were significantly more prevalent among males (P=0.021). Regarding the site of lesion, it was found that most parotid gland lesions were benign 96% vs. 69% malignant (P=0.028). Color and power Doppler findings were that benign lesions were predominantly low-grade vascularity while malignant lesions were predominantly higher-grade vascularity (P=0.001). As well, 50% of benign lesions showed peripheral vascularity and 77% of malignant lesions showed mixed pattern vascularity (P<0.001).

The results of B-mode GSS showed that all tumors either benign or malignant were visualized as hypoechoic masses. When comparing malignancies against benign lesions, there was higher incidence of ill-defined borders (69% versus 4%, P<0.001), inhomogeneous echo structure (69% versus 21%, P=0.005) and irregular shape (69% versus 4%, P<0.001). Additionally, according to SPD, malignant tumors recorded significantly higher mean PSV, RI and PI compared to benign ones (P<0.05) (**Table 3)**.

Table (3): Demographic, clinical, Pulse wave Doppler, and grey scale sonography findings in Benign vs. Malignant tumors.

Variable name	Benign (n=28)		Malignant (n=13)		P value
Age					**0.001***
• Mean ± SD	36.43±15.39		53.23±10.91		
• Median (range)	34 (3 – 63)		55 (34 – 70)		
Sex					**0.021***
• Male	13	(46.4)	11	(84.6)	
• Female	15	(53.6)	2	(15.4)	
Symptoms					-----
• Painless swelling	28	(100.0)	13	(100.0)	
Site					**0.028***
• Parotid	27	(96.4)	9	(69.2)	
• Submandibular	1	(3.6)	4	(30.8)	
Doppler findings					
Grade					**0.001***
• A vascular	4	(14.3)	0	(0.0)	
• Grade 1	19	(67.9)	3	(23.1)	
• Grade 2	4	(14.3)	5	(38.5)	
• Grade 3	1	(3.6)	5	(38.5)	
Pattern of vascularity					**0.001***
• Peripheral	12	(50.0)	2	(15.4)	
• Hilar	10	(41.7)	1	(7.7)	
• Mixed "scattered"	2	(8.3)	10	(76.9)	
Grey scale sonography					
Border					**0.001***
• Ill defined	1	(3.6)	9	(69.2)	
• Well defined	27	(96.4)	4	(30.8)	
Homogeneity					**0.005***
• Homogeneous	22	(78.6)	4	(30.8)	
• Inhomogeneous	6	(21.4)	9	(69.2)	
Shape					**0.001***
• Regular	17	(60.7)	3	(23.1)	
• Irregular	1	(3.6)	9	(69.2)	
• Lobulated	10	(35.7)	1	(7.7)	
PSV (cm/s)					**0.001***
• Mean ± SD	19.81±11.92		31.82±8.60		
• Median (range)	19.5 (5.3 – 48)		31 (15 – 50)		
RI					**0.001***
• Mean ± SD	0.70±0.11		0.85±0.09		
• Median (range)	0.74 (0.43 – 0.90)		0.84 (0.70 – 1.10)		
PI					**0.001***
• Mean ± SD	1.32±0.35		1.91±0.23		
• Median (range)	1.3 (0.6 – 2.0)		1.9 (1.4 – 2.3)		

PSV: Peak Systolic Velocity; RI: Resistive Index; PI: Pulsatility Index. Quantitative data are presented in the form of mean ± SD and median (range), qualitative data are presented in the form of number (%). *Significance defined by $p \leq 0.05$.

For Doppler indices, 12 out of 13 patients with malignant tumors (92.3%) were correctly diagnosed by PSA and RI while 11/13 (84.6%) were correctly diagnosed by PI. Conjointly, RI has higher sensitivity and specificity in prediction of malignant tumors with higher accuracy (89%) over the other two indices. For GSS categories, nine out of 13 patients with malignancy (69%) were correctly diagnosed by GSS. Of the three categories, GSS border and shape have higher specificity in differentiating malignant from benign tumors with higher accuracy (88%) over the GSS Homogeneity. The combination of the three categories yielded higher validity measures (69% sensitivity of, 100% specificity and the 90.2% accuracy **(Table 4)**.

Table (4): Validity of PSV, RI, PI and GSS categories for SG Malignant tumors Prediction.

Doppler Index	Sensitivity	Specificity	PPV	NPV	Accuracy
• PSV >25 cm/sec	92.3%	83.3%	75.0%	95.2%	86.5%
• RI >0.8	92.3%	87.5%	80.0%	95.5%	89.2%
• PI>1.8	84.6%	87.5%	78.6%	91.3%	86.5%
GSS					
• Border	69.2%	96.4%	90.0%	87.1%	87.8%
• Homogeneity	69.2%	78.6%	60.0%	84.6%	75.6%
• Shape	69.2%	96.4%	90.0%	87.1%	87.8%
• Combination	69.2%	100.0%	100.0%	87.5%	90.2%

PSV: Peak Systolic Velocity; RI: Resistive Index; PI: Pulsatility Index; PPV: positive predictive variable; NPV, negative predictive variable.

DISCUSSION

Diagnosis and characterization of SG tumors depend mainly on imaging investigation. USG is considered as the best imaging tool for provisional examination of SG masses. It had several advantages; being simple to perform, uses non-ionizing radiation, being non-invasive and easily available. Unlikely, some recognize sonography as the ideal imaging modality for baseline assessment of SG lesions[9]. The aim of the present study was to assess the validity of ultrasound in the diagnosis and prediction of the parotid and submandibular gland lesions in patients presented with neck swelling, any major SG symptom.

The mean age of our studied participants was 35.9 (SD 18.8) years. Similar finding reported by **Zaleska-Dorobisz *et al.*** [10]**, meanwhile Dumitriu *et al.*** [11]**, El-Khateeb *et al.*** [12] **and DiBBaD *et al.*** [4] reported older age. This difference could be attributed to the difference in the age range included in these studies. In this study, slight male predominance was observed among the studied case as it was found that 58% were males. This was in accordance with previous studies[12, 13]. Conversely; **Zaleska-Dorobisz *et al.*** [10] **and DiBBaD *et al.*** [4] reported female predominance in SG lesions.

Malignant SG lesions were significantly higher among older aged, male patients and those with the parotid gland swelling ($P<0.05$, for all). Insignificant difference was reported regarding the presenting symptoms as all studied patients suffered from painless swelling. This finding was supported by **Guzzo *et al.*** [13] who stated that the incidence of malignant SG tumors was higher among older aged patients, and in males than in females. Controversially, **El-Khateeb *et al.*** [12] could not find no any significant difference in age between benign and malignant tumors. Parotid was the most affected gland (72.5%) among the studied cases. Similar results were reported in previous studies [4, 11, 13, 14]. It was noted that several disorders could affect the major SG including infective, inflammatory, systemic, obstructive, neoplastic and non-neoplastic infirmities [1]. In the present study, out of 69 studied cases, 59.4% had neoplastic lesions (41% have benign and 19% have malignant lesions) and 41% have inflammatory lesions. 94% of pleomorphic adenomas occurred in parotid gland. Similarly; **Dibbad *et al.*** [4] found that 66% of studied cases suffered from neoplastic lesions and 83% of pleomorphic adenomas occurred in the parotid.

CDS is an established tool for tumor differentiation. It was established that Doppler imaging can provide detailed data about the vascularity of the SG, which is very useful for differential diagnostic[15]. Blood vessel perfusion of the tumor plays major role in its growth and malignant tumors have more ability to induce angiogenesis [16], so higher vascularity degree is expected with malignant tumors. This was confirmed in the current study. Only one benign lesion “infantile hemangioma” presented with Grade 3+ vascularization. Also, most inflammatory lesions revealed predominantly low-grade vascularity except the acute Sialadenitis that revealed higher vascularity.

This was consistent with **Martinoli *et al.*** [6] **and Wei *et al.*** [17] as both reported that on Color Doppler examination, malignant tumors showed hypervascularity while lower vascularity grade was displayed by benign tumors. Also, **Gritzmann *et al.*** [18] reported reduced vascularization as among the established ultrasound criteria for SG benign tumors. The current finding was in agreement with several previous studies [1,4,12]. On the other hand, **Dumitriu *et al.*** [11] reported that about 61% of benign and 56% of malignant tumors were poorly vascularized, this finding could be explained by the fact that malignant tumors included in this study were very early stage, thus explain the poor vascularization in these tumors.

Using CDS, our study affirmed that pleomorphic adenoma, which represented the most common benign SG tumors, showed predominantly peripheral pattern of vascularity (75%), but Warthin’s tumors had hilar type of flow. Additionally, infantile hemangioma showed mixed pattern of vascularity. In malignant tumors, 77% showed mixed pattern of vascularity, mucoepidermoid carcinoma showed predominantly mixed pattern of vascularity (83%), adenoid cystic carcinoma and squamous cell carcinoma show mixed pattern of vascularity.

On summation, in benign masses, peripheral vascularization predominated, while scattered type predominated in malignant tumors. This was in accordance with previous studies of **Martinoli *et al.*** [6] **and Wei *et al.*** [17] who reported that on Color Doppler imaging, malignancies showed multiple/irregular internal vessels. Also, **El-Khateeb *et al.*** [12] showed that malignant tumors had scattered vascularity. In addition **Dibbad *et al.*** [4] reported that peripheral vascularity predominated in the pleomorphic adenoma (71%), hilar flow in Warthin's tumors and mixed vascularity in malignant tumors (67%).

Furthermore, in line with this study, recent study of **Nagendra and Phatak** [19] found that on Color Doppler the pleomorphic adenoma typically takes up peripheral flow around the nodule termed as "basket like flow pattern" due to subtle vascular pattern around the mass. The same author reported that Warthin's tumor characteristically appears as oval shaped with well-defined borders containing cystic areas and good vascularization on color Doppler. Our finding was in opposition to **Bradley *et al.*** [20] **and Dumitriu *et al.*** [11] who reported that malignant lesions had non-specific vascularization pattern.

Regarding Doppler wave parameters (PSV, RI and PI), significant difference was documented between benign and malignant SG lesions. In other words, malignant lesions had higher flow velocities and vascular resistance; by using 25 cm/s-1 as a threshold of PSV, 0.8 as a threshold of RI and 1.8 as a threshold of PI for prediction of malignant tumors. Using this criterion, sensitivity was as follows: PSV=92%, RI=92% and PI=85%) and specificity was as follows: PSV=83%, RI=88% and PI=88% for malignant tumor detection. This was confirmed in several previous studies.[4, 6,12,20-22] There is an ongoing debate in the literatures [4, 6, 12, 20-22], about the optimal cutoff of PSV for malignant diagnosis. **Martinoli *et al.*** [6] reported PSV > 60 cm s-1 as cutoff for malignant prediction. Lower PSV threshold was recorded by other researchers i.e., PSV of 25 cm s-1 was set as cutoff by **Schick *et al.*** [22] **and Dibbad *et al.*** [4]**,** PSV of 29 cm s-1 was set as cutoff by **Mazaher *et al.***[23] and PSV of 44 cm s-1 was set as cutoff for malignant prediction by **El-Khateeb *et al.*** [12]**.**

By using B-mode GSS; the current study revealed that malignant tumors were more likely to have ill-defined, inhomogeneous echo structure and with irregular shape than benign SG tumors (P<0.05). Validity measures for the border, homogeneity, and shape of lesion for malignant diagnosis was as follows: sensitivity of 69%, specificity of 96% and accuracy of 88% for tumor border/shape; likewise, sensitivity of 69%, specificity of 79% and accuracy of 76% for tumor homogeneity. Using combination of the three GSS categories improved the predictive power for malignant lesions (sensitivity of 69%, specificity of 100% and accuracy of 90%.

In agreement with this study **El-Khateeb *et al.*** [12] observed that on using GSS; ill-defined borders and lymph node involvement predominated in malignant, but malignant and benign lesions were comparable regarding echogenicity, homogeneity or sonographic shape. It was found that tumor border had good predictive power (sensitivity of 88%, specificity of 82% and accuracy of 84%), contrarily, homogeneity had poor predictive indices (sensitivity of 50%, specificity of 57% and accuracy of 55%), and tumor shape had fair validity measures (sensitivity of 63%, specificity of 57% and accuracy of 59%). Combination of the three categories together has a sensitivity of 88%, specificity of 34% and the accuracy of 59% for malignant prediction. It could be reported that GSS items combined or single (except for lesion border) cannot be used as a reliable tool to discriminate benign from malignant. Besides, the current finding was similar to what was documented by **Shimizu *et al.*** [24] **and Mazaher *et al.*** [23] as they reported a sensitivity of 71.2% and 77.8% for tumor border for differentiation of benign from malignant SG lesions,

In accordance with the current results, **Dumitriu *et al.*** [11] **and Schick *et al.*** [22] hypothesized that homogeneity is a weak discriminant between malignant and benign tumors, and **Schmelzeisen *et al.*** [25] reported that the echogenicity add no value in differentiation between benign and malignant neoplasms as both had reduced echogenicity than surrounding tissues. In addition **Bradley *et al.*** [20] concluded that GSS morphological criteria were matched in benign and malignant SG pathology.

For the diagnostic accuracy of the sonographic assessment aspects, it was found that RI > 0.8 cm/sec was the most accurate indices, followed by PSV>25 cm/sec, and PI > 1.8 cm/sec, the combination of lesion borders, shape, and homogeneity has similar accuracy in differentiating malignant from benign tumors. Also, the vascularity grade and distribution also play important role in this differentiation. In agreement, **Dumitriu *et al.*** [11] declared that doppler wave items (PSV, RI and PI) had higher predictive power for malignant tumors than CDS.

As well, **Schick *et al.*** [22] reported that for parotid tumor vascularization both CDS and SPD of PSV were better predictors than RI and PI, while PSV was assigned by **Schmelzeisen *et al.***[25] as the best SPD single malignant lesion predictor. Despite this clear evidence, tumor border, shape, homogeneity, and lymph node involvement will remain to be assessed firstly by most sonographers then vascularity assessment will precede using CDS for definite diagnosis.

Being numerical is the main drawback for the SPD (PSV, RI and PI) indices as is difficult for any physician to memorize the authentic threshold value for them (not to mention for every organ). A possible solution would be the incorporation of these measures into software of new USG. Future research is needed for the determination and confirmation of the predictive power and validity of contrast-enhanced Doppler USG in malignant SG tumors prediction.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this study (USG had good validity in infective, inflammatory, and neoplastic SG lesions diagnosis and lesion morphology is also good predictor for malignant lesions), it is recommended to use USG as an initial modality for the evaluation of different SG lesions. Color and PWD added value in malignant tumors diagnosis. PSV >25 cm/sec, RI value > 0.8, PI value > 1.8, ill-defined borders, inhomogeneous, irregular shape, Grade 2 or 3 vascularity and mixed pattern of blood vessels distribution should be used as alarming signs for malignant early diagnosis.

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