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Original Research Article

Diagnostic Accuracy of Doppler Ultrasound in Detecting Parotid Tumors

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Abstract: *Parotid tumors constitute the majority of salivary gland neoplasms and exhibit a wide histopathological spectrum, from benign pleomorphic adenomas to malignant mucoepidermoid carcinomas. Accurate preoperative diagnosis is critical for guiding management; however, limited access to advanced imaging techniques like CT and MRI in resource-constrained environments presents a challenge. Doppler ultrasound provides a non-invasive, cost-effective alternative for initial tumor evaluation.* ***Objective****: To assess the diagnostic accuracy of Doppler ultrasound in detecting parotid tumors, using histopathology as the gold standard.* ***Methods****: A prospective, cross-sectional study was conducted at the Burn Center, Hayatabad Medical Complex, Peshawar, from January 1 to June 30, 2024. A total of 124 patients presenting with clinically or radiologically suspected parotid tumors were enrolled. All patients underwent Doppler ultrasound using a high-resolution Mindray® system, with evaluation of parameters including lesion shape, margins, echogenicity, vascularity, resistive index (RI), and peak systolic velocity (PSV). Final diagnoses were established through histopathological examination. The diagnostic performance of Doppler ultrasound was assessed using 2×2 contingency tables to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy.* ***Results****: The mean age of participants was 42 ± 15.2 years, with a mean disease duration of 7.0 ± 3.5 months. Doppler ultrasound identified parotid tumors in 79 patients (63.7%), while histopathology confirmed 80 cases (64.5%). The sensitivity of Doppler ultrasound was 86.3%, specificity 77.3%, PPV 87.3%, NPV 75.6%, and diagnostic accuracy 83.1%.* ***Conclusion****: Doppler ultrasound demonstrates high diagnostic accuracy and serves as a valuable, non-invasive imaging modality for evaluating parotid tumors. It is especially beneficial in low-resource settings where access to advanced imaging is limited, supporting its role in early diagnosis and clinical decision-making.*

Keywords: Parotid Tumors, Doppler Ultrasound, Diagnostic Accuracy, Histopathology

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Introduction

Parotid tumors, arising from the largest salivary glands located anteroinferior to the ears, constitute approximately 70-80% of all salivary gland neoplasms (1). The global incidence of parotid tumors is estimated to be 0.4-13.5 cases per 100,000 individuals annually, with a slight male predominance and peak occurrence between the fourth and sixth decades of life (2,3). Histologically, around 80% of these tumors are benign, the most common being pleomorphic adenomas and Warthin tumors, while malignancies such as mucoepidermoid carcinoma and adenoid cystic carcinoma account for the remaining 20% (4,5). Clinically, these tumors often present as painless, slow-growing masses, although malignant variants may exhibit rapid growth, facial nerve involvement, or lymphadenopathy (6). Accurate diagnosis is essential to distinguish between benign and malignant lesions, as misdiagnosis can lead to inappropriate management strategies, including unnecessary surgery or delayed oncologic care. Despite advances in imaging, the preoperative differentiation of parotid tumors remains challenging, especially in resource-limited tertiary care centers, where diagnostic delays can compromise patient outcomes (7).

Doppler ultrasound is a non-invasive, real-time imaging modality that combines traditional ultrasonography with the assessment of blood flow through the use of the Doppler effect. It employs high-frequency sound waves via linear-array transducers, typically 7.5-15 MHz, to visualize vascular patterns within superficial structures such as the parotid glands (8,9). During the procedure, grayscale imaging identifies the mass, followed by color and spectral Doppler to evaluate internal vascularity, resistive indices, and flow patterns (10). This technique offers numerous advantages, including affordability, portability, lack of ionizing radiation, and high resolution for superficial lesions, making it especially valuable in initial assessments and follow-ups (11). However, Doppler ultrasound is inherently operator-dependent, with diagnostic performance varying by experience and equipment quality. Additionally, its sensitivity may be limited in detecting deeper or isoechoic lesions (12). Nevertheless, in training institutions and low-resource settings where MRI or CT may not be readily accessible, Doppler ultrasound remains a viable and frequently used alternative for evaluating parotid masses (13).

Recent studies have highlighted the diagnostic potential of Doppler ultrasound in distinguishing between benign and malignant parotid tumors. A study by Zulfiqar Z. et al. in 2021 reported a sensitivity of 100%, specificity of 68%, and overall accuracy of 80% when using color and pulsed Doppler in the evaluation of parotid gland tumors. (14) Similarly, a study by Stoia S. et al. in 2023 compared the Ultrasound, MRI, and Fine-Needle Aspiration Biopsy (FNAB) in the preoperative evaluation of parotid gland tumors and found that diagnostic accuracy doppler ultrasound reached up to 82%, with sensitivity 75%, specificity 87%, positive predictive values of 75% and negative predictive values of 87% (15). These figures underscore the reliability of Doppler ultrasound as a front-line tool in parotid tumor evaluation. Furthermore, patient-reported outcome measures (PROMs) from both studies indicated high satisfaction due to the non-invasive nature, minimal discomfort, and short duration of the scan, factors that can influence diagnostic compliance and follow-up adherence (14,15).

Given the diagnostic complexity and high clinical burden of parotid tumors, especially in tertiary care hospitals like Hayatabad Medical Complex (HMC), Peshawar, there remains a pressing need to evaluate cost-effective and accessible diagnostic tools such as Doppler ultrasound. Although existing literature supports its use, there is a paucity of localized data assessing its safety, efficacy, and diagnostic accuracy in the regional context of Khyber Pakhtunkhwa. This study aims to bridge that gap by examining Doppler ultrasound's performance in detecting parotid tumors, thereby aiding clinicians in making informed, timely decisions. Enhanced diagnostic capability can reduce reliance on more invasive procedures, minimize surgical morbidity, and facilitate better preoperative planning. Ultimately, this research could contribute to improving diagnostic protocols and patient quality of life in resource-constrained healthcare environments.

Methodology

This prospective, cross-sectional study was conducted at the Burn Center Hayatabad Medical Complex (HMC), Peshawar, from 01-Jan-2024 to 30-Jun-2024, after obtaining approval from the Ethical Review Committee. The objective was to assess the diagnostic accuracy of Doppler ultrasound in detecting parotic tumors, using histopathological findings as the gold standard.

A sample size of 124 participants was calculated using the WHO formula. Sample size estimation was based on previously reported sensitivity of 100% and specificity of 68%, and overall diagnostic accuracy of 80% using color and pulsed Doppler ultrasound, with a 95% confidence interval and 10% margin of error (14). Patients of either gender, aged 18 years and above, presenting with clinically or radiologically suspected parotid gland tumors were included. The inclusion criteria required the presence of a palpable or radiologically detectable mass in the parotid region. Exclusion criteria included patients with contraindications to biopsy, active infection over the region, bleeding disorders, prior histopathological diagnosis of the mass, or refusal to provide informed consent. A non-probability consecutive sampling technique was used to recruit eligible participants.

All participants underwent Doppler ultrasound using a high-resolution Mindray® scanner equipped with a 7.5-12 MHz linear-array transducer. Patients were examined in a lateral decubitus or supine position with the head turned to the contralateral side to provide optimal exposure of the parotid region. A standardized scanning protocol was followed. Gray-scale ultrasound was used to assess lesion size, shape (round, oval, irregular), margin (well-defined or ill-defined), echogenicity (hypoechoic, isoechoic, hyperechoic), internal architecture (homogeneous or heterogeneous), and the presence of calcification or cystic components. Color Doppler Ultrasound was employed to evaluate vascular distribution patterns—categorized as peripheral, central, or mixed. Vascular density was graded as avascular, mildly vascular, or richly vascular. Pulsed Doppler Ultrasound was used to quantify vascular parameters, including peak systolic velocity (PSV) and resistive index (RI). An RI <0.7 was suggestive of malignancy, while benign lesions generally showed RI >0.7, based on prior validated criteria.

All patients subsequently underwent ultrasound-guided Fine Needle Aspiration Cytology (FNAC) or surgical biopsy under sterile conditions. FNAC was performed using a 3-5 cc syringe and 23-gauge needle under real-time ultrasound guidance following local anesthesia. The obtained samples were labeled and sent for histopathological examination under strict aseptic technique by experienced pathologists who were kept blinded to ultrasound results.

Patient's sociodemographic, ultrasound and Doppler features, and histopathological diagnoses were recorded in a structured proforma. Data analysis was performed using IBM SPSS version 25.0. The diagnostic performance of Doppler ultrasound was evaluated by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy using 2×2 contingency tables. Histopathology served as the reference standard for all calculations.

PAROTID TUMORS ON HISTOPATHOLOGY

	+	-
+	**a**	**b**
-	**c**	**d**

a = True Positive, b = False Positive, c = False Negative, d = True Negative

PAROTID TUMORS ON DOPPLER ULTRASOUND

Sensitivity of Doppler Ultrasound = (a / a + c) ×100

Specificity of Doppler Ultrasound = (d / b + d) × 100

Positive predictive value (PPV) for Doppler Ultrasound = (a / a + b) ×100

Negative predictive value (NPV) for Doppler Ultrasound = (d / c + d) ×100

Accuracy of Doppler Ultrasound = (a + d) / overall patients.

Results

Table 1 shows the mean and standard deviation of age and duration of disease. The mean age of the study participants was 42 ± 15.2 years (approximately 27 to 57 years). This reflects a wide age range, suggesting that parotid tumors can affect both younger and older adults. The mean duration of disease was 7.0 ± 3.5 months, implying that, on average, patients had symptoms for about seven months, but some experienced shorter or longer disease durations.

Table 1: Mean ± Standard Deviation of Quantitative Variables (n=124)

Variables	Mean ± Standard Deviation
Age (Years)	42 ± 15.2
Duration of Disease (Months)	7.0 ± 3.5

Table 2: Frequencies and Percentages of Qualitative Variables (n=124)

Variables		Frequency	Percentage
Age Group Distribution	18-30 Years	39	31.5%
	31-40 Years	27	21.8%
	41-50 Years	17	13.7%
	51-60 Years	19	15.3%
	61-70 Years	22	17.7%
Gender	Male	68	54.8%
	Female	56	45.2%
Duration of Disease Distribution	01-04 Months	37	29.8%
	05-08 Months	34	27.4%
	09-12 Months	53	42.7%
Parotid Tumors on Doppler US	Yes	79	63.7%
	No	45	36.3%
Parotid Tumors on Histopathology	Yes	80	64.5%
	No	44	35.5%

Table 2 shows the distribution of qualitative variables like age groups, gender, duration of disease groups, parotid tumors on Doppler US, and parotid tumors on histopathology. The age group distribution shows that the highest number of participants (31.5%) were aged between 18-30 years, followed by 21.8% in the 31-40 years range, and smaller proportions 13.7% in the 41-50 years, 15.3% in 51-60 years, and 17.7% in 61-70 years. This indicates that parotid tumors are not restricted to older populations but also affect a significant number of young adults. The gender distribution reveals that 54.8% of the participants were male and 45.2% female, showing a slight male predominance in this cohort.

Next, the duration of disease distribution categorizes patients based on how long they had symptoms before diagnosis. The largest group (42.7%) experienced symptoms for 9-12 months, suggesting that most patients had long-standing disease, possibly due to slow progression or delayed consultation. Additionally, 29.8% had a disease duration of 1-4 months, and 27.4% had symptoms for 5-8 months, indicating a varied timeline in presentation. The variable "Parotid Tumors on Doppler Ultrasound" showed that 79 patients (63.7%) were found to have parotid tumors, while 45 (36.3%) were not. In comparison, histopathology, used as the gold standard, confirmed tumors in 80 cases (64.5%) and found no tumors in 44 cases (35.5%). The close percentages between Doppler findings and histopathology suggest that Doppler ultrasound is relatively reliable in initial tumor detection.

Table 3 presents the diagnostic accuracy of Doppler ultrasound in comparison with histopathology. The results are categorized into four standard outcomes. True Positives (56%) were patients correctly identified by Doppler ultrasound as having parotid tumors, which were later confirmed by histopathology. False Positives (8%) were cases where Doppler ultrasound incorrectly identified a tumor, but histopathology showed none. False Negatives (9%) were patients in whom Doppler failed to detect a tumor that was confirmed histologically.

True Negatives (27%) were correctly identified as tumor-free by both methods. The sensitivity of Doppler ultrasound was 86.3%, meaning it successfully detected 86.3% of all true tumor cases. The specificity was 77.3%, reflecting its ability to correctly rule out tumors in 77.3% of patients without disease. The positive predictive value (PPV) was 87.3%, indicating that when Doppler ultrasound identified a tumor, there was a 87.3% chance it was correct. The negative predictive value (NPV) was 75.6%, meaning that when Doppler did not detect a tumor, there was a 75.6% likelihood that the patient truly had no tumor. The overall diagnostic accuracy was 83.1%, which measures how often Doppler ultrasound correctly identified or excluded tumors out of all cases.

Table 3: Diagnostic Accuracy of Doppler Ultrasound Keeping Histopathology as Gold Standard (n=124)

Parotid Tumors on Histopathology

	+	-
+	a = 69 (56%)	b = 10 (8%)
-	c = 11 (9%)	d = 34 (27%)

Parotid Tumors on Doppler Ultrasound

a = True Positive = 69 (56%)
b = False Positive =10 (8%)
c = False Negative = 11 (9%)
d = True Negative = 34 (27%)
Sensitivity of Doppler Ultrasound = (69 / 69 + 11) ×100 = 86.3%
Specificity of Doppler Ultrasound = (34 / 10 + 34) × 100 = 77.3%
Positive predictive value (PPV) for Doppler Ultrasound = (69 / 69 + 10) ×100 = 87.3%
Negative predictive value (NPV) for Doppler Ultrasound = (34 / 11 + 34) ×100 = 75.6%
Accuracy of Doppler Ultrasound = ((a + d) / Overall Patients) × 100 = 83.1%.

Discussion

This study evaluated the diagnostic accuracy of Doppler ultrasound in detecting parotid tumors among 124 patients, revealing a sensitivity of 86.3%, specificity of 77.3%, positive predictive value (PPV) of 87.3%, negative predictive value (NPV) of 75.6%, and overall accuracy of 83.1%. These outcomes indicate that Doppler ultrasound is an effective non-invasive tool for initial parotid tumor assessment.

The sensitivity observed aligns closely with earlier findings. El-Khateeb SM et al. in 2011 reported a sensitivity of 87.5%, specificity of 85.7% and accuracy of 86% for spectral Doppler in parotid tumor evaluation (16), while Zulfiqar Z et al. in 2021 reported the color and pulsed Doppler US in achieving a sensitivity of 100% and specificity of 68% and diagnostic accuracy of 80% in evaluating the parotid gland tumors (14). These results are close to our sensitivity (86.3%) and specificity (77.3%), suggesting consistent diagnostic reliability of Doppler across different cohorts.

High-resolution ultrasound combined with Doppler has shown favorable diagnostic metrics. Polish researchers reported a sensitivity of 60%, specificity of 95.2%, and accuracy of 90.3% using combined gray-scale and Doppler evaluation in a cohort of 72 parotid lesions (16). Compared to their higher specificity and accuracy, our results highlight a trade-off: moderately lower specificity (77.3%) is balanced by higher sensitivity. Practically, a high sensitivity is valuable for screening in tertiary centers, reducing the risk of missed malignancies.

Recently, multiparametric ultrasound (MPUS), including contrast-enhanced and elastography, has been investigated. A 2021 study found that contrast-enhanced ultrasound (CEUS) achieved sensitivity of 86%, specificity of 95%, and overall accuracy of 90%, compared with our better specificity and accuracy (83.1%) that relied solely on color and pulsed Doppler (17). This suggests that traditional Doppler remains competitive, especially in resource-constrained settings where advanced modalities may not be available.

At tertiary care facilities in Pakistan like Hayatabad Medical Complex, Peshawar, Doppler ultrasound remains a pragmatic diagnostic modality. Its high sensitivity ensures most malignancies are detected early, while acceptable specificity reduces false positives. The modest PPV and NPV support its use as a screening tool guiding further investigation, e.g., recommending FNAB or MRI for suspicious cases, similar to protocols endorsed by international studies.

From a clinical standpoint, Doppler ultrasound offers key advantages including real-time imaging, portability, and cost-effectiveness, particularly in resource-constrained settings where access to CT or MRI is limited. It enables visualization of vascular patterns—central or peripheral flow, resistive indices, and peak systolic velocities—which assist in differentiating tumor types. Malignant parotid tumors tend to show increased central vascularity and lower resistive indices. In contrast, benign tumors display peripheral or no vascular flow, findings consistent with those observed in our imaging analysis (18).

While Doppler ultrasound demonstrated robust diagnostic performance in this study, it is not without limitations. The technique remains operator-dependent, and lesions with ambiguous features or overlapping sonographic characteristics may lead to misclassification, contributing to false positives or negatives. For instance, cystic or necrotic changes within tumors or inflammatory masses can sometimes look like malignancy on Doppler scans. Hence, while Doppler ultrasound serves as a powerful screening and triaging tool, it should ideally be complemented by cytological or histological confirmation before definitive treatment planning.

Conclusion

In conclusion, the current study supports the clinical utility of Doppler ultrasound in the diagnostic evaluation of parotid gland tumors. Its high sensitivity, specificity, and diagnostic accuracy make it particularly valuable in confirming suspected tumors, while its non-invasive nature adds practical value in outpatient and low-resource settings. These findings reinforce recommendations from prior literature and highlight the need for continued training and standardization in ultrasound techniques to improve diagnostic reliability further.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRB)

Consent for publication

Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

QUAI (Assistant Professor)
Review of Literature, Data entry, Data Collection, Data analysis, Manuscript drafting, and Study Design,
KAK (Medical Specialist)
Study Design, manuscript review, and critical input.
Conception of Study, Development of Research Methodology Design

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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