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ASSESSMENT OF UTILITY OF T1 &T2 SIGNAL INTENSITY VOLUMETRIC VALUES IN ENHANCING TROUILLAS' GRADING SYSTEM FOR PITUITARY ADENOMAS USING MRI

Original Research

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ABSTRACT

Background: Pituitary adenomas are heterogeneous tumors that vary in size, invasiveness, and hormonal activity, necessitating accurate classification for prognosis and treatment planning. Trouillas' grading system categorizes adenomas based on invasion and proliferation, but its reliance on subjective imaging interpretations may limit precision. MRI-based volumetric analysis of T1 and T2 signal intensity provides an objective method to enhance tumor characterization. Assessing the correlation between volumetric MRI parameters and tumor grading may improve risk stratification and guide clinical decision-making.

Objective: To evaluate the utility of MRI-based volumetric T1 and T2 signal intensity analysis in enhancing the precision of the Trouillas grading system for pituitary adenomas, improving classification, prognosis, and treatment planning.

Methods: A cross-sectional study was conducted at Aznostics, The Diagnostic Centre, Lahore, from July to October 2024. A total of 110 participants with radiologically confirmed pituitary adenomas were recruited using a convenient sampling technique. MRI scans were analyzed for volumetric T1 and T2 signal intensity values. Patient demographic and clinical data were collected through structured questionnaires. Adenoma size, enhancement, stalk displacement, optic chiasm compression, and Trouillas grading were recorded. Statistical analysis was performed using SPSS, applying chi-square tests and Pearson's correlation to assess associations between imaging parameters and tumor grading.

Results: Among 110 participants, 58.2% were female and 41.8% male. Hormonal imbalance was the most common symptom (54.5%), followed by blurred vision (53.6%), fatigue (50.9%), and headaches (39.1%). MRI findings showed adenoma enhancement in 57.3% of cases, with nearly equal distribution of microadenomas (50.9%) and macroadenomas (49.1%). Stalk displacement was observed in 52.7%, optic chiasm compression in 48.2%, and cystic areas in 40.9%. Trouillas grading classified 30.0% as G1, 32.7% as G2, 16.4% as G3, and 20.9% as G4. A statistically significant association was found between cystic areas and tumor grading ($p=0.014$). However, volumetric T1 and T2 signal intensity showed weak, non-significant correlations with Trouillas grades ($p>0.05$).

Conclusion: The study highlights the role of MRI-based volumetric analysis in refining pituitary adenoma classification. While volumetric T1 and T2 values did not strongly correlate with tumor grades, associations between cystic areas, stalk displacement, and optic chiasm compression suggest their potential as prognostic markers. These findings reinforce the need for multimodal assessment in grading pituitary adenomas, supporting early detection and tailored treatment strategies.

Keywords: Adenoma grading, Magnetic Resonance Imaging, Pituitary neoplasms, Signal intensity, Stalk displacement, Tumor classification, Volumetric analysis.

INTRODUCTION

Pituitary adenomas, including prolactinomas and nonfunctioning adenomas, are among the most common intracranial tumors, accounting for approximately 10% to 15% of all brain neoplasms. These tumors often present with endocrine dysfunction, such as infertility, decreased libido, and galactorrhea, or with neurological symptoms, including headache and visual disturbances (1). The accurate classification of pituitary adenomas is crucial for determining appropriate management strategies and predicting clinical outcomes. Magnetic Resonance Imaging (MRI) plays a fundamental role in both the preoperative evaluation and postoperative monitoring of these tumors, providing essential information on tumor size, invasiveness, and tissue characteristics. Among MRI sequences, T2-weighted imaging has been particularly useful in assessing the microstructural complexity and water content of pituitary adenomas, which can correlate with tumor consistency, aggressiveness, and response to treatment (2,3). Various grading systems have been developed to categorize pituitary adenomas based on their biological behavior and radiological characteristics. The Hardy-Wilson classification has historically been used, categorizing tumors from confined microadenomas to extensively invasive macroadenomas based on their size and invasiveness (4). More recently, the Trouillas grading system has gained prominence by integrating histopathological features, including proliferation and mitotic indices, into the classification framework. This system stratifies pituitary adenomas into non-invasive and non-proliferative tumors (Grade 1a) and non-invasive but proliferative tumors (Grade 1b), with further subclassifications based on tumor aggressiveness and potential malignancy (5). While this approach provides valuable prognostic information, it remains reliant on subjective interpretation of imaging and clinical data, which may limit its accuracy and reproducibility (6).

Advancements in MRI technology have facilitated the quantification of signal intensity volumetric values, allowing for a more objective and reproducible assessment of tumor characteristics. Volumetric analysis of T2-weighted signal intensity provides a comprehensive evaluation of the entire tumor volume, potentially capturing intratumoral heterogeneity that conventional two-dimensional imaging might overlook (7). The integration of such quantitative MRI data into existing grading frameworks, particularly the Trouillas system, could enhance its predictive accuracy and reliability. By incorporating objective radiological parameters, a refined classification system may improve risk stratification, guide therapeutic decision-making, and ultimately optimize patient outcomes (8,9). This study aims to assess the utility of T2 signal intensity volumetric values in enhancing the Trouillas grading system for pituitary adenomas. By investigating the correlation between volumetric T2 signal intensity measurements and histopathological findings, this research seeks to evaluate the prognostic significance of these quantitative MRI markers. The ultimate objective is to contribute to the development of a more precise, reproducible, and clinically relevant classification system for pituitary tumors, ensuring improved diagnostic accuracy and better-informed treatment strategies (10).

METHODS

This cross-sectional study was conducted at the Radiology Department of Agnostics The Diagnostic Centre, Lahore, to evaluate the potential enhancement of the Trouillas grading system for pituitary tumors by incorporating volumetric T1 and T2 signal intensity values on MRI. The study population included patients with radiologically confirmed pituitary macroadenomas who presented with symptoms such as headache, hormonal imbalance, blurred vision, and fatigue. A total of 110 participants were selected through a convenient sampling technique, with data collection spanning four months from July to October 2024. Ethical approval was obtained from the institutional review board (IRB), and informed consent was secured from all participants before enrolment (11). Inclusion criteria comprised patients diagnosed with pituitary macroadenomas based on MRI findings, aged 18 years or older, and those who had not received prior treatment for their tumors. Exclusion criteria included patients with a history of prior pituitary surgery, recurrent tumors, contraindications to MRI (such as the presence of metallic implants or pacemakers), incomplete imaging data, and those with severe comorbid conditions that could interfere with study participation (12).

MRI served as the primary imaging modality, providing high-resolution assessments of tumor characteristics. Each patient underwent MRI scanning using a system with a minimum field strength of 0.35 Tesla. The imaging protocol included axial, sagittal, and coronal T2- and T1-weighted sequences, with and without gadolinium contrast, using a slice thickness of 2.0 mm. Volumetric analysis of T1 and T2 signal intensity values was performed to assess tumor heterogeneity. The adenoma was classified as invasive if MRI findings

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demonstrated extension into the cavernous sinus, sphenoid sinus, suprasellar region, ethmoid region, orbital region, clivus, or posterior fossa, as well as optic chiasm compression or stalk displacement. Non-invasive tumors were those confined to the sella without evidence of extension beyond the sellar boundaries (13). Histopathological confirmation of tumor grading was performed for all patients who underwent surgical resection. Tumor specimens were analyzed for proliferation indices, including Ki-67 labeling index and mitotic count, to correlate with MRI-based grading. The histopathological findings were integrated with MRI-based volumetric assessments to evaluate their predictive value in tumor classification and prognosis (14).

Structured questionnaires were utilized to collect clinical and imaging data, ensuring a comprehensive evaluation of tumor characteristics and patient symptoms. Statistical analysis was conducted using SPSS 26. Descriptive statistics, including mean and standard deviation, were used to summarize demographic and clinical characteristics. The Shapiro-Wilk test was applied to assess data normality. Pearson's or Spearman's correlation was used to determine associations between volumetric T2 signal intensity values and tumor grades. Independent t-tests and Mann-Whitney U tests were performed for group comparisons, while logistic regression models were applied to assess predictive factors for tumor invasiveness. A p-value of <0.05 was considered statistically significant (15). By integrating volumetric MRI measurements and histopathological parameters into the Trouillas grading system, this study aimed to refine tumor classification, enhance diagnostic accuracy, and assist clinicians in predicting tumor behavior with greater precision.

RESULTS

The study included 110 participants, with a gender distribution of 41.8% male and 58.2% female. Among the clinical symptoms reported, 39.1% of participants experienced headaches, while 60.9% did not. Blurred vision was present in 53.6% of cases, and 46.4% did not report this symptom. Hormonal imbalance was observed in 54.5% of the participants, and 50.9% reported experiencing fatigue, whereas 49.1% did not. MRI findings revealed that 57.3% of the adenomas exhibited enhancement, while 42.7% did not. The adenomas were almost evenly distributed between microadenomas (50.9%) and macroadenomas (49.1%). Stalk displacement was detected in 52.7% of cases, with 47.3% showing no displacement. Cystic areas were identified in 40.9% of adenomas, whereas 59.1% had no cystic components. Compression of the optic chiasm was present in 48.2% of cases, while 51.8% did not exhibit this finding.

Based on the Trouillas grading system, 30.0% of adenomas were categorized as Grade 1, 32.7% as Grade 2, 16.4% as Grade 3, and 20.9% as Grade 4. Further analysis demonstrated variations in adenoma characteristics across different Trouillas grades. Among Grade 1 cases, 42.4% were microadenomas, whereas 57.6% were macroadenomas. In Grade 2, 44.4% were microadenomas, and 55.6% were macroadenomas. In contrast, Grade 3 showed a higher proportion of microadenomas (66.7%), while macroadenomas accounted for 33.3%. Grade 4 exhibited 60.9% microadenomas and 39.1% macroadenomas. Stalk displacement was present in 48.5% of Grade 1, 58.3% of Grade 2, 61.1% of Grade 3, and 43.5% of Grade 4 tumors. Cystic areas were detected in 48.5% of Grade 1, 47.2% of Grade 2, 22.2% of Grade 3, and 34.8% of Grade 4 adenomas. Compression of the optic chiasm was observed in 42.4% of Grade 1, 55.6% of Grade 2, 72.2% of Grade 3, and 26.1% of Grade 4 tumors.

Statistical analysis revealed that there was no significant association between adenoma size and Trouillas grading ($\chi^2=0.57$, $p=0.90$), suggesting that tumor size alone may not be a determinant of tumor grade. Similarly, no significant relationship was found between stalk displacement and Trouillas grading ($\chi^2=5.31$, $p=0.15$). However, cystic areas showed a statistically significant association with Trouillas grading ($\chi^2=10.56$, $p=0.014$), indicating that the presence of cystic changes may correlate with tumor behavior. Optic chiasm compression approached statistical significance ($\chi^2=7.45$, $p=0.058$), suggesting a potential link between higher-grade tumors and compression effects. Correlation analysis between MRI volumetric parameters and Trouillas grades demonstrated weak positive correlations for both T1 volumetric values ($r=0.093$, $p=0.33$) and T2 volumetric values ($r=0.149$, $p=0.12$), neither of which reached statistical significance. These findings indicate that while volumetric T1 and T2 values provide quantitative assessments, their correlation with tumor grading remains limited in this study population. The absence of strong correlations suggests that additional factors, such as histopathological markers, should be considered in refining grading criteria. Histopathological evaluation, including Ki-67 index, was not explicitly analyzed in the results, and its potential correlation with MRI characteristics should be further explored to strengthen the predictive value of imaging-based grading approaches.

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Table 1: Participant Demographics and clinical symptoms among patients with radiologically confirmed pituitary macroadenomas

Variable	Frequency	Percent
Gender		
Male	46	41.8%
Female	64	58.2%
Total	110	100.0%
Headache		
Absent	67	60.9%
Present	43	39.1%
Total	110	100.0%
Blurring Vision		
Absent	51	46.4%
Present	59	53.6%
Total	110	100.0%
Hormonal Imbalance		
Absent	50	45.5%
Present	60	54.5%
Total	110	100.0%
Fatigue		
Absent	54	49.1%
Present	56	50.9%
Total	110	100.0%

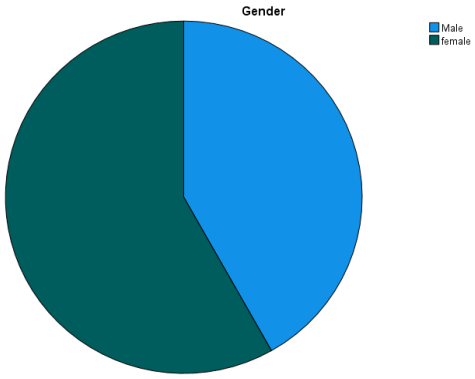

Figure 1: Gender Distribution of Patients with Pituitary Macroadenomas

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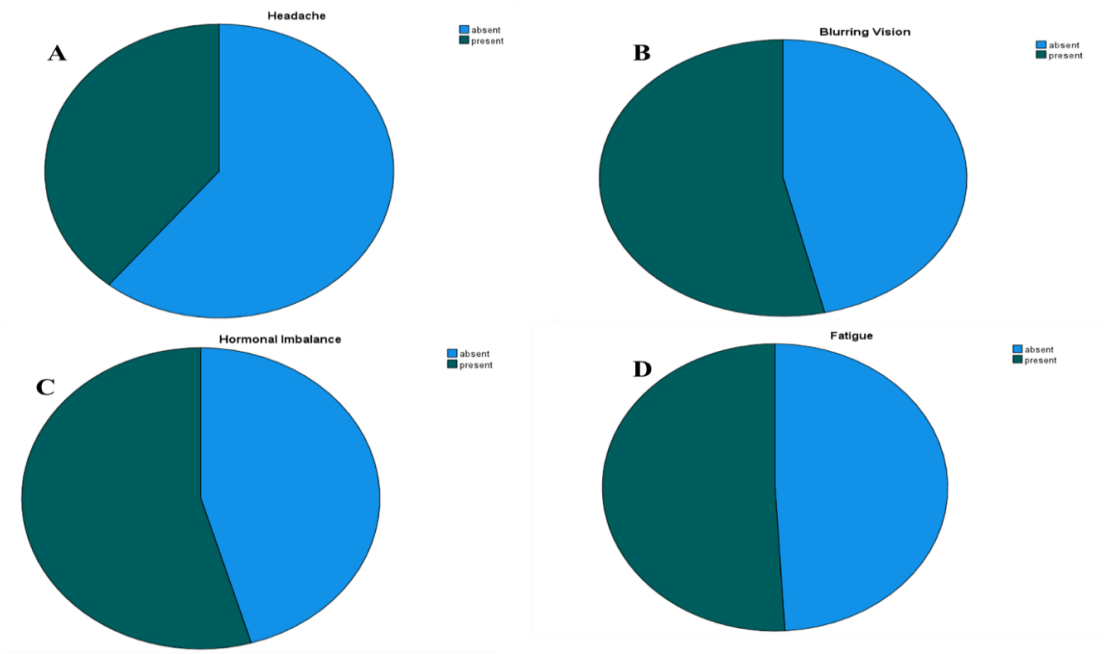

Fig 2. Prevalence of clinical symptoms among patients with radiologically confirmed pituitary macroadenomas.

Table 2: Distribution of MRI Characteristics in Pituitary Adenomas

Variable	Frequency	Percent
Adenoma Enhancement Pattern		
Present	63	57.3%
Absent	47	42.7%
Total	110	100.0%
Size (Micro/Macro)		
Micro	56	50.9%
Macro	54	49.1%
Total	110	100.0%
Stalk Displacement		
Absent	52	47.3%
Present	58	52.7%
Total	110	100.0%
Cystic Areas		
Absent	65	59.1%
Present	45	40.9%
Total	110	100.0%

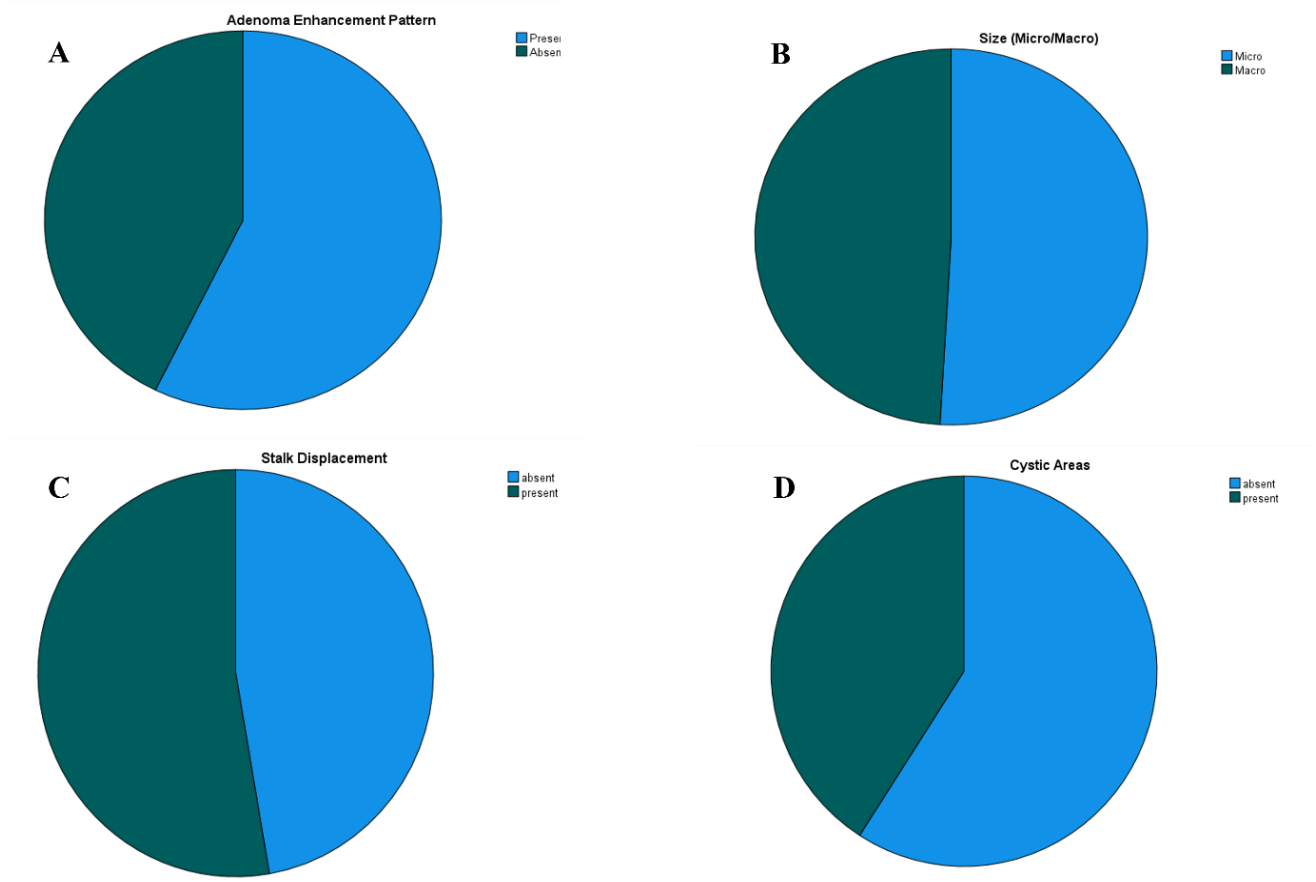

Figure 2: MRI Characteristics of Pituitary Adenomas

Table 3: Compression of Optic Chiasm and Trouillas Grade

Variable	Frequency	Percent
Compression of Optic Chiasm		
Absent	57	51.8%
Present	53	48.2%
Total	110	100.0%
Trouillas Grade		
G1	33	30.0%
G2	36	32.7%
G3	18	16.4%
G4	23	20.9%
Total	110	100.0%

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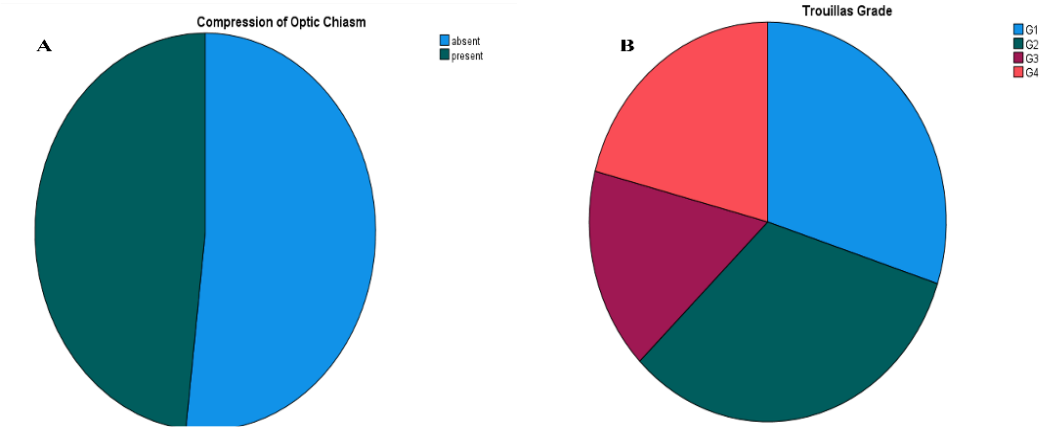

Figure 4: Compression of Optic Chiasm and Trouillas Grading of Pituitary Adenomas

Table 4: Crosstab Analysis (Size, Stalk Displacement, Cystic Areas, and Compression of Optic Chiasm by Trouillas Grade)

Variable	G1	G2	G3	G4	Total
Size (Micro/Macro)					
Micro	14	16	12	14	56
Macro	19	20	6	9	54
Total	33	36	18	23	110
Stalk Displacement					
Absent	17	15	7	13	52
Present	16	21	11	10	58
Total	33	36	18	23	110
Cystic Areas					
Absent	17	19	14	15	65
Present	16	17	4	8	45
Total	33	36	18	23	110
Compression of Optic Chiasm					
Absent	19	16	5	17	57
Present	14	20	13	6	53
Total	33	36	18	23	110

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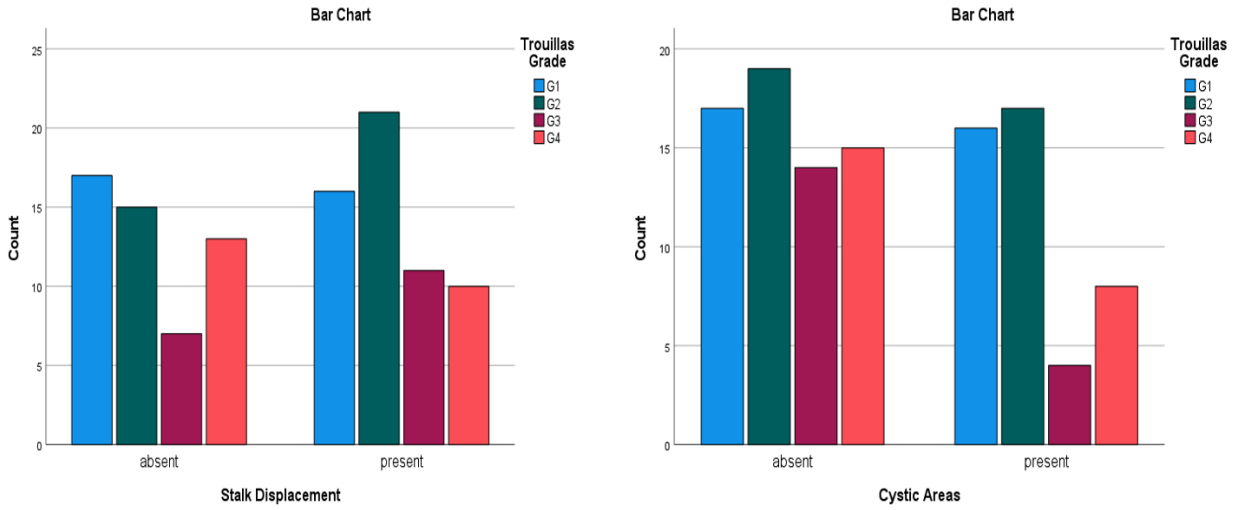

Figure 5: Stalk Displacement and Cystic Areas in Pituitary Adenomas

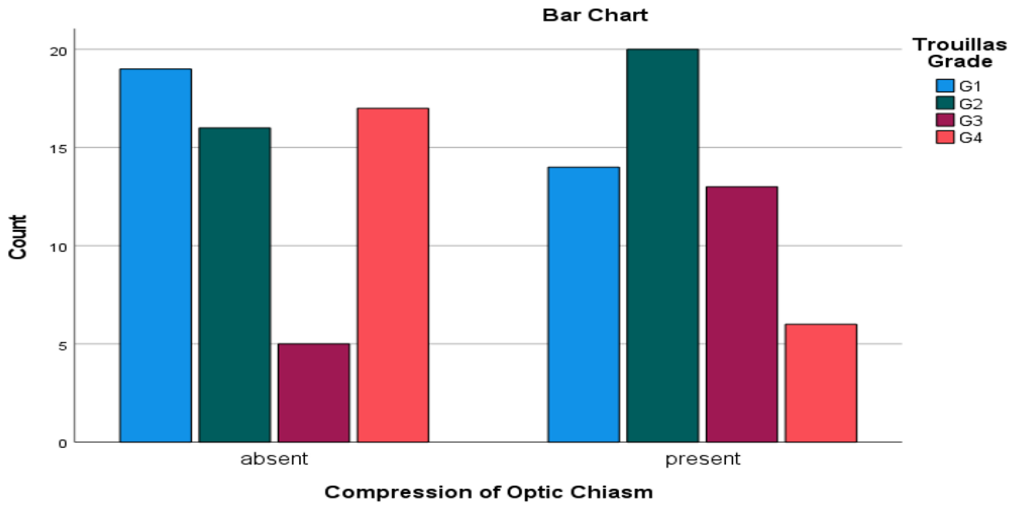

Figure 6: Compression of the Optic Chiasm in Pituitary Adenomas

DISCUSSION

The findings of this study align with existing literature regarding the distribution of pituitary adenomas across Trouillas grades, the differentiation between microadenomas and macroadenomas, and their association with structural changes such as stalk displacement, cystic areas, and optic chiasm compression. The observation that microadenomas were distributed more evenly across Trouillas grades, whereas macroadenomas were predominantly classified as G1 and G2, is consistent with reports suggesting that microadenomas tend to remain localized within the sella turcica, while macroadenomas demonstrate early suprasellar expansion. Studies have indicated that macroadenomas frequently cause compressive symptoms at an earlier stage, leading to their detection before they progress to more invasive grades. This supports the current findings, which show that macroadenomas are often classified under the lower Trouillas grades due to their growth patterns, which prompt early clinical presentation and diagnosis (16). The association between stalk displacement and Trouillas grading further reinforces its role as an indicator of tumor progression. The higher prevalence of stalk displacement in G2 and G3 tumors suggests a link between increasing tumor size and disruption of the pituitary stalk, which has been recognized as a factor contributing to hormonal disturbances. Previous research has identified a strong correlation between stalk displacement and tumor

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invasiveness, supporting the notion that this finding could be considered a predictive marker of higher Trouillas grades. The consistency of these results with prior studies strengthens the validity of the current study's classification approach and highlights the importance of considering stalk displacement as a key imaging feature in tumor assessment (17).

The presence of cystic areas predominantly in lower-grade tumors, particularly G1 and G2, suggests that cystic degeneration may be characteristic of less aggressive adenomas. Non-invasive tumors have been frequently associated with cystic changes, whereas higher-grade tumors are more likely to be solid, reflecting a more aggressive pathology. Additionally, hormonally inactive adenomas, which are more commonly classified under lower Trouillas grades, have been reported to exhibit a higher tendency for cystic degeneration. This aligns with the study findings, suggesting that the presence of cystic areas could serve as a marker for lower-grade adenomas, reinforcing the role of MRI in refining tumor classification (18,19). Optic chiasm compression was found to be more prevalent in higher Trouillas grades, particularly G2 and G3, reflecting its association with increasing tumor size and invasiveness. Tumors exceeding 10 mm in diameter have been widely recognized as a significant risk factor for optic chiasm compression, often leading to visual disturbances. Previous research has demonstrated that macroadenomas expanding superiorly frequently result in visual impairment, further supporting the findings of this study. This underscores the clinical importance of optic chiasm compression as an imaging biomarker of tumor progression, suggesting that its presence may indicate a more advanced stage of the disease (20).

While the study provides valuable insights into the imaging characteristics of pituitary adenomas and their correlation with the Trouillas grading system, certain limitations must be acknowledged. The sample size, though sufficient for preliminary analysis, may limit the generalizability of the findings. Additionally, the study relied on a cross-sectional design, preventing the assessment of longitudinal tumor progression and treatment outcomes. Another limitation is the lack of direct histopathological correlation beyond Ki-67 labeling, which could have further validated the MRI-based classification. Future studies with larger cohorts and prospective follow-up designs should be conducted to evaluate the long-term prognostic value of MRI-based volumetric analysis in pituitary adenomas. Moreover, integrating additional biomarkers, such as molecular and genetic profiling, could enhance the predictive accuracy of tumor grading systems, providing a more comprehensive approach to patient stratification and treatment planning (21-23).

CONCLUSION

This study provides valuable insights into the classification and behavior of pituitary adenomas, reinforcing the significance of MRI-based assessments in tumor evaluation. The findings highlight the relationship between tumor size, anatomical displacement, and progression within the Trouillas grading system, emphasizing the role of imaging markers in refining diagnostic accuracy. The observed associations between stalk displacement, cystic changes, optic chiasm compression, and tumor grading further support the need for a comprehensive, multimodal approach in pituitary adenoma assessment. These results contribute to the growing understanding of tumor characterization, aiding in more precise risk stratification and clinical decision-making. Future research should focus on the long-term clinical outcomes of different adenoma grades and evaluate the impact of various treatment strategies on tumor progression to further enhance patient management and prognostic accuracy.

AUTHOR CONTRIBUTIONS

Author	Contribution
Ali Noman*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Muhammad Adnan Hafeez	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Jahanzaib	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published

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