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ROLE OF COMPUTED TOMOGRAPHY SCAN IN THE DIAGNOSING OF PEDIATRICS NEUROLOGICAL DISORDERS, A FOCUS ON CRANIOSYNOSTOSIS

Original Research

Maydah Rafiq[1], Hamna Yaqoob[2], Maryam Noor[2], Loqman Shah[3]*, Esha Iman[2], Mauwiya Amanat[2], Raees Awais[2]

[1]Demonstrator, MIT, Department of Radiological Sciences & Medical Imaging Technology (DRS&MIT), Superior University, Lahore, Punjab, Pakistan.

[2]BS, MIT, Student, Department of Radiological Sciences & Medical Imaging Technology (DRS&MIT), Superior University, Lahore, Punjab, Pakistan.

[3]BSRT (Hons), MSAHS-MIT, Demonstrator, MIT/Research Coordinator, Department of Radiological Sciences & Medical Imaging Technology (DRS&MIT), Superior University, Lahore, Punjab, Pakistan.

Corresponding Author: Loqman Shah, BSRT (Hons), MSAHS-MIT, Demonstrator, MIT/Research Coordinator, Department of Radiological Sciences & Medical Imaging Technology (DRS&MIT), Superior University, Lahore, Punjab, Pakistan., loqman.shah@superior.edu.pk

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ABSTRACT

Background: Pediatric neurological disorders such as craniosynostosis demand timely and accurate diagnosis to prevent complications like developmental delays and increased intracranial pressure. Among available imaging modalities, computed tomography (CT) remains the gold standard due to its superior ability to visualize cranial sutures and detect premature fusion, which is central to diagnosing craniosynostosis and planning appropriate intervention.

Objective: To evaluate the diagnostic role of CT scans in pediatric neurological disorders with a focus on craniosynostosis and to assess their association with clinical outcomes including developmental delay, increased intracranial pressure (ICP), and surgical necessity.

Methods: This cross-sectional study was conducted at Tehsil Head Quarter Hospital, Arif Wala, Punjab, Pakistan, involving 80 pediatric patients aged 1–12 years who presented with suspected neurological disorders. Non-contrast CT brain scans were performed using a standardized pediatric protocol, including multiplanar reconstructions and 3D volume rendering to assess cranial sutures. Inclusion criteria were newly suspected cases, and patients with prior diagnoses or non-diagnostic imaging were excluded. Ethical approval was obtained, and informed consent was secured from guardians. Data were collected using structured questionnaires and analyzed using SPSS Version 25.

Results: Out of 80 children (mean age: 5.83 ± 3.16 years; 56.3% female), CT scans confirmed craniosynostosis in 69 cases (86.3%). Developmental delay was noted in 63 patients (78.8%), while increased ICP was seen in 36 (45%). Surgical intervention was deemed necessary in 23 patients (28.8%). Common cranial deformities included positional molding (25%) and scaphocephaly (18.8%). CT attenuation was low in 38 patients (47.5%) and high in 34 (42.5%).

Conclusion: CT scans demonstrated high diagnostic accuracy for craniosynostosis and proved essential for identifying cranial abnormalities, planning surgeries, and predicting clinical outcomes in pediatric patients. Their precision makes CT an indispensable tool in early diagnosis and management of craniosynostosis.

Keywords: Cranial Sutures, Craniosynostosis, Computed Tomography, Intracranial Pressure, Pediatric Neurology, Skull Abnormalities, Tomography Scans.

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INTRODUCTION

Craniosynostosis, a congenital condition marked by the premature fusion of one or more cranial sutures, presents a significant diagnostic and therapeutic challenge in pediatric neurology. These sutures—fibrous joints connecting the bones of a developing skull—are essential for accommodating brain growth during infancy and early childhood. When they fuse earlier than normal, skull growth becomes restricted perpendicular to the involved suture, leading not only to characteristic cranial deformities but also to potential increases in intracranial pressure and risks of neurodevelopmental impairment if left untreated (1). The condition may manifest as non-syndromic, where it occurs in isolation, or as syndromic, where it is part of a broader genetic disorder such as Crouzon or Apert syndrome. Non-syndromic cases constitute approximately 80–85% of all presentations, while syndromic cases—often more complex and associated with additional anomalies—account for the remainder (2,3). Epidemiologically, craniosynostosis affects approximately 1 in every 2,000 to 2,500 live births, with a higher prevalence in males, especially in sagittal synostosis where the male-to-female ratio can reach 2:1 (4). The sagittal, coronal, metopic, and lambdoid sutures are most commonly affected, with sagittal synostosis being the most prevalent form, typically leading to a long, narrow head shape termed scaphocephaly. In contrast, metopic fusion results in trigonocephaly, and coronal synostosis often causes asymmetry of the forehead and orbits (5). Lambdoid synostosis, particularly when unilateral, remains the rarest type and is frequently confused with positional plagiocephaly—a non-synostotic condition linked to external mechanical forces, such as prolonged supine positioning during infancy (6).

Despite advances in clinical examination protocols, accurate diagnosis of craniosynostosis—particularly in complex or multi-suture cases—relies heavily on imaging. Historically, plain skull radiographs were the mainstay, providing valuable clues to suture fusion. However, the advent of high-resolution computed tomography (CT), particularly with 3D reconstruction capabilities, has revolutionized diagnostic accuracy. CT imaging not only delineates the fused sutures with exceptional clarity but also aids in preoperative planning, monitoring of intracranial volume, and identification of associated anomalies (7,8). Although CT scans provide unmatched anatomical detail, concerns about radiation exposure in young children have prompted refinement of protocols, such as low-dose CT and limited-field imaging, to minimize potential risks while maintaining diagnostic efficacy (9). The clinical impact of craniosynostosis extends beyond cosmetic deformities. Children affected by this condition may face a spectrum of complications, including increased intracranial pressure, visual and auditory impairments, and neurocognitive deficits. These outcomes are influenced by the type and number of fused sutures, timing of intervention, and presence of underlying syndromic associations (9,10). Syndromic forms, often involving multi-suture synostosis, are associated with more severe complications and a greater likelihood of surgical revision and re-synostosis (10). Moreover, emerging data suggest that even isolated, single-suture synostosis may subtly affect cognitive development, underscoring the need for early identification and multidisciplinary follow-up (11).

Clinical differentiation between true craniosynostosis and other mimicking conditions such as positional plagiocephaly is essential. While clinical hallmarks—such as frontal bossing and asymmetry—guide initial assessment, radiologic confirmation remains critical in ambiguous cases. The anterior fontanel serves as a crucial clinical landmark during infancy, and its premature closure can be an early sign of metopic or coronal suture involvement (12). Advances in genetic testing have further enhanced diagnostic precision, with many cases once considered non-syndromic now reclassified due to identifiable genetic mutations (13). Despite the increasing incidence of certain forms, such as metopic synostosis, in Europe and North America, the etiology of craniosynostosis remains multifactorial. It involves a complex interplay of genetic predisposition and environmental factors, including fetal head constraint, maternal smoking, and certain teratogens (14). With improvements in surgical techniques and perioperative care, outcomes have improved, yet a subset of patients continues to experience long-term neurodevelopmental challenges even after successful cranial reconstruction. Given the potential for lasting cognitive and neurological impairment, particularly in undiagnosed or late-diagnosed cases, early and accurate identification is paramount. This study aims to evaluate the diagnostic role of CT imaging in craniosynostosis, with particular focus on its clinical utility, diagnostic precision, identification of suture involvement, and potential complications. Ultimately, the goal is to enhance early intervention strategies and improve neurodevelopmental outcomes in children with craniosynostosis by equipping clinicians with robust, evidence-based diagnostic tools.

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METHODS

This cross-sectional study was conducted at Tehsil Head Quarter (THQ) Hospital, Arif Wala, Punjab, Pakistan, and involved a total of 80 pediatric patients aged 0 to 12 years who presented with clinical suspicion of neurological disorders. The primary objective was to evaluate the diagnostic role of non-contrast computed tomography (CT) brain scans in the assessment of craniosynostosis. Participants were selected using a non-probability sampling technique, where only those meeting the pre-established inclusion criteria were enrolled. These criteria included pediatric patients who were referred for CT scans for diagnostic evaluation of suspected neurological abnormalities and whose legal guardians provided written informed consent for participation. Exclusion criteria were carefully applied to enhance the reliability of findings (1,5). Patients with a previously confirmed diagnosis of craniosynostosis or other neurological disorders were excluded, as the study focused on new and undiagnosed cases. Additionally, patients with incomplete, low-quality, or non-diagnostic CT scans, as well as those who underwent imaging using protocols other than the CT Plain Brain protocol, were excluded. Guardians who declined to give consent for their child's participation were also not included in the study.

Imaging was performed using standard non-contrast CT brain protocols tailored for pediatric patients. Scans were acquired in axial sections and further evaluated using multiplanar reconstructions and 3D volume rendering techniques to enhance visualization of cranial sutures and detect possible early suture fusion. All scans were interpreted by a board-certified radiologist with subspecialty expertise in pediatric neuroimaging to ensure diagnostic consistency and minimize interobserver variability. Data collection was carried out using a structured questionnaire designed to capture relevant clinical and radiological findings. This included demographic information, clinical symptoms, imaging results, and other pertinent observations. Ethical approval for this study was obtained from the institutional review board or local ethical committee at THQ Hospital, Arif Wala. Informed consent was obtained from the guardians of all participants prior to inclusion, ensuring adherence to ethical standards and the Declaration of Helsinki. Collected data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS), Version 25. Descriptive statistics were used to summarize demographic and clinical variables, while inferential statistics were applied where appropriate to evaluate the associations and diagnostic trends. The methodology adhered to best practices for clinical research in pediatric imaging, ensuring both accuracy in imaging interpretation and ethical responsibility in participant selection and data handling.

RESULTS

A total of 80 pediatric patients aged between 1 and 12 years were included in the study. The most frequently represented ages were 2 years (12.5%), 3 and 8 years (11.3% each), and 5 and 6 years (10% each), with the least represented being 12 years (2.5%). Males comprised 35 participants (43.8%) and females 45 (56.3%). Regarding head shape abnormalities, positional molding was the most prevalent finding, observed in 25% of patients, followed by scaphocephaly in 18.8%, plagiocephaly in 12.5%, and various other morphologies such as trigonocephaly, brachycephaly, and oxycephaly, each seen in 11.3%. Torticollis was identified in 10% of patients. Developmental delay was observed in 63 out of 80 patients (78.8%), while increased intracranial pressure (ICP) was detected in 36 cases (45%). Craniosynostosis was confirmed in 69 children (86.3%), leaving 11 cases (13.8%) without the condition. Among those with craniosynostosis, 23 cases (28.8%) were categorized as requiring surgical intervention, while 57 cases (71.3%) did not require surgery. CT attenuation patterns showed that 38 patients (47.5%) had low attenuation, 34 (42.5%) exhibited high attenuation, and 8 (10%) showed variable attenuation features.

In the gender-wise breakdown, craniosynostosis was present in 32 out of 35 males and 37 out of 45 females. Increased ICP was more common in females (24 cases) than males (12 cases), while developmental delay was similarly distributed with 31 males and 32 females affected. With respect to abnormal head shapes, scaphocephaly was the most common in females (10 cases) while positional molding remained prevalent across both genders. Cross-tabulation of CT attenuation and craniosynostosis revealed that 33 of the 38 patients with low attenuation, 29 of the 34 with high attenuation, and 7 of the 8 with variable attenuation had positive findings for craniosynostosis. Similarly, patients with increased ICP demonstrated a varied distribution: 19 with low attenuation, 11 with high attenuation, and 6 with variable patterns. Developmental delay correlated strongly with CT attenuation, as 31 patients with low, 26 with high, and 6 with variable attenuation patterns exhibited delays. Regarding head shape variations, low CT attenuation was most frequently associated with scaphocephaly (11 cases) and trigonocephaly (8 cases), while variable attenuation was least represented. Surgical intervention was exclusively recommended in cases with confirmed craniosynostosis (23 out of 69), and not in any of the negative cases. Increased ICP was noted in 12 of those needing surgery and 24 of those not requiring it. Developmental delay was found in all surgical candidates. Most surgical candidates had either trigonocephaly, torticollis, or scaphocephaly, with no cases involving oxycephaly marked for surgery.

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Table1: Descriptive Statistics of Clinical and Radiological Findings in Pediatric Patients Suspected of Craniosynostosis (N = 80)

Variable	Category	Frequency (n)	Percent (%)
Age (Years)	1	5	6.3
	2	10	12.5
	3	9	11.3
	4	7	8.8
	5	8	10.0
	6	8	10.0
	7	7	8.8
	8	9	11.3
	9	3	3.8
	10	6	7.5
	11	6	7.5
	12	2	2.5
Head Shape	Torticollis	8	10.0
	Trigonocephaly	9	11.3
	Brachycephaly	9	11.3
	Scaphocephaly	15	18.8
	Plagiocephaly	10	12.5
	Positional Molding	20	25.0
	Oxycephaly	9	11.3
Developmental Delay	Yes	63	78.8
	No	17	21.3
Increased ICP	Yes	36	45.0
	No	44	55.0
Craniosynostosis	Yes	69	86.3
	No	11	13.8
Surgical Plan	Necessary	23	28.8
	Not Necessary	57	71.3
CT Attenuation	Low	38	47.5
	High	34	42.5
	Variable	8	10.0

Table 2: Gender-wise Distribution of Craniosynostosis, Clinical Features, and Head Shape Abnormalities in Pediatric Patients (N = 80)

Variable	Category	Female (n = 45)	Male (n = 35)	Total (n = 80)
Craniosynostosis	Yes	37	32	69
	No	8	3	11
Increased ICP	Yes	24	12	36
	No	21	23	44
Developmental Delay	Yes	32	31	63
	No	13	4	17
Head Shape	Torticollis	3	5	8
	Trigonocephaly	7	2	9
	Brachycephaly	4	5	9
	Scaphocephaly	10	5	15
	Plagiocephaly	5	5	10
	Positional Molding	13	7	20
	Oxycephaly	3	6	9

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Table 3: Distribution of CT Attenuation Patterns with Craniosynostosis, Clinical Features, and Head Shape Abnormalities in Pediatric Patients (N = 80)

Variable	Category	Low (n = 38)	High (n = 34)	Variable (n = 8)	Total (n = 80)
Craniosynostosis	Yes	33	29	7	69
	No	5	5	1	11
Increased ICP	Yes	19	11	6	36
	No	19	23	2	44
Developmental Delay	Yes	31	26	6	63
	No	7	8	2	17
Head Shape	Torticollis	7	1	0	8
	Trigonocephaly	8	1	0	9
	Brachycephaly	4	5	0	9
	Scaphocephaly	11	4	0	15
	Plagiocephaly	1	6	3	10
	Positional Molding	6	11	3	20
	Oxycephaly	1	6	2	9

Table 4: Association of Surgical Planning with Craniosynostosis, Clinical Indicators, and Head Shape Abnormalities in Pediatric Patients (N = 80)

Variable	Category	Surgical Plan: Necessary (n = 23)	Surgical Plan: Not Necessary (n = 57)	Total (n = 80)
Craniosynostosis	Yes	23	46	69
	No	0	11	11
Increased ICP	Yes	12	24	36
	No	11	33	44
Developmental Delay	Yes	23	40	63
	No	0	17	17
Head Shape	Torticollis	6	2	8
	Trigonocephaly	6	3	9
	Brachycephaly	2	7	9
	Scaphocephaly	4	11	15
	Plagiocephaly	3	7	10
	Positional Molding	2	18	20
	Oxycephaly	0	9	9

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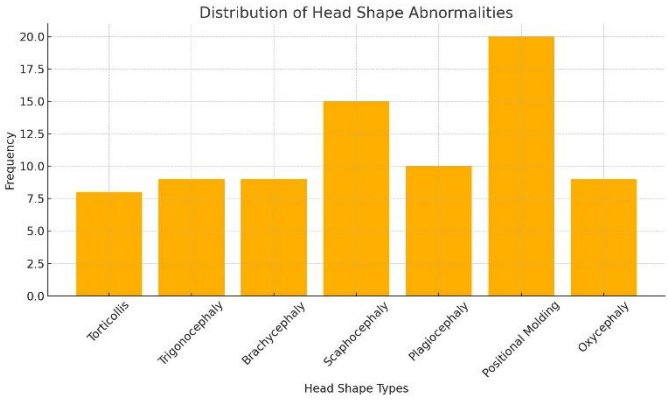


Figure 1 Distribution of Head Shape Abnormalities

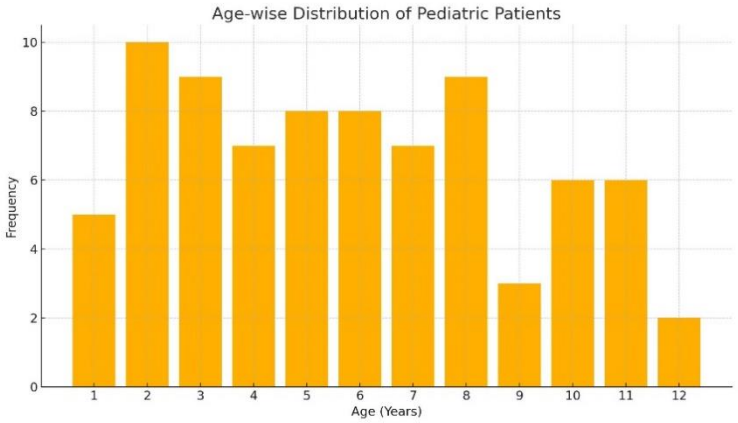


Figure 2 Age-Wise Distribution of Pediatric Patients

DISCUSSION

The findings of this study offer significant insight into the clinical and radiological spectrum of craniosynostosis in a pediatric population aged 1 to 12 years, emphasizing the diagnostic and prognostic value of CT-based evaluation, particularly when enhanced with cranial suture thickness (CST) measurement. The mean age of the study population was 5.83 years, which is notably older than the typical window for craniosynostosis diagnosis, commonly reported to peak during infancy. This suggests either delayed diagnosis, prolonged clinical follow-up, or late presentation, potentially influenced by variations in healthcare access or diagnostic awareness criteria. Comparable studies focusing on complex craniosynostosis have similarly observed delayed diagnoses extending into later childhood, reinforcing the need for earlier surveillance and screening. The gender distribution, although showing a slight female predominance in this sample, revealed that males had a higher proportion of developmental delays and craniosynostosis. This aligns with earlier evidence suggesting increased neurodevelopmental risk in males, possibly attributed to sex-linked genetic or hormonal vulnerabilities. Interestingly, positional molding accounted for 25% of head shape anomalies and was more common among females, indicating potential environmental influences such as sleeping posture, which is consistent with trends observed post-infant sleep safety campaigns promoting supine positioning (15,16).

The diversity in head shape abnormalities—particularly scaphocephaly, plagiocephaly, trigonocephaly, brachycephaly, and oxycephaly—reflects a broad cranial morphology spectrum in affected children. Scaphocephaly, linked to sagittal suture fusion, emerged as the second most common deformity, consistent with its established prevalence (17). The relatively high frequency of torticollis, a condition more typically musculoskeletal in origin, highlights the importance of distinguishing craniosynostotic head shapes from positional or orthopedic conditions to avoid misclassification. A key observation was the markedly high rate of developmental delay (78.8%), which far exceeds previously reported estimates of 35–50% in craniosynostosis cohorts. This may reflect the inclusion of a clinically enriched population or suggest underrecognized neurodevelopmental burden in routine practice. The association between craniosynostosis and developmental impairment was particularly evident in male patients, reinforcing the need for neurocognitive evaluation as part of standard care. Additionally, nearly half the sample showed signs of increased intracranial pressure, underscoring the urgency of early identification to prevent irreversible neurological damage (18,19).

Surgical planning was considered necessary in approximately one-third of patients with confirmed craniosynostosis, while none of the non-affected children required surgical intervention. These findings are congruent with literature advocating for operative management in confirmed synostosis cases to address both functional impairment and cosmetic concerns. The strong correlation between craniosynostosis and surgical necessity further supports the utility of CT imaging as a decisive tool in treatment planning. One of the study's key strengths lies in its inclusion of both structural CT imaging and CST analysis, demonstrating a statistically significant agreement with volumetric methods. The addition of CST to radiologic assessments offers a simplified yet accurate technique for quantifying suture fusion severity, especially beneficial in cases with complex head shapes or early-stage fusions that may not

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significantly alter cranial volume. This diagnostic advancement holds promise for use in busy clinical settings, particularly in resource-limited environments where volumetric analyses may not be feasible (20,21).

However, the study does present several limitations. The cross-sectional nature precludes long-term outcome tracking, and the relatively small sample size limits the generalizability of findings to wider populations. Furthermore, the absence of inferential statistical models, such as logistic regression or multivariate analysis, restricts the ability to establish independent predictors of surgical need, developmental delay, or increased ICP. While descriptive associations are clear, a more robust analytical approach would strengthen the evidence base. Additionally, while CST was emphasized, the study did not explore interobserver variability or repeatability, both critical to validating CST as a standardized diagnostic metric. Despite these limitations, the study contributes meaningful data supporting the integration of cranial suture thickness into CT-based diagnostic pathways. It provides compelling evidence for its relevance in assessing craniosynostosis severity, complementing traditional volume and shape analyses. Future research should aim to validate these findings in larger, multicentric cohorts, ideally incorporating prospective follow-up and neurodevelopmental outcomes. Incorporating functional neuroimaging or genetic profiling could further elucidate underlying mechanisms and refine the precision of craniosynostosis diagnostics and treatment planning in pediatric populations.

CONCLUSION

This study concludes that evaluating craniosynostosis severity through cranial suture thickness on computed tomography offers a practical, reliable, and clinically valuable method for diagnosing head shape abnormalities in pediatric patients. By incorporating cranial suture thickness into routine imaging assessments, clinicians can enhance diagnostic accuracy and streamline surgical planning, ultimately supporting earlier and more tailored interventions. This simplified approach holds significant potential to improve pediatric neurosurgical care and optimize outcomes for children affected by craniosynostosis.

AUTHOR CONTRIBUTION

Author	Contribution
Maydah Rafiq*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hamna Yaqoob	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
Maryam Noor	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Loqman Shah	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Esha Iman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Mauwiya Amanat	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Raees Awais	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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