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ORIGINAL ARTICLE

Abnormal computed tomography (CT) brain findings in adult patients presenting with the chief complaint of headache

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ABSTRACT

Objective: To determine abnormal computed tomography (CT) findings in adult patients presenting with the chief complaint of headache without preceding trauma and focal neurological signs.

Methods: A cross-sectional study was conducted at PAC Hospital Kamra from November 4, 2024, to May 4, 2025, enrolling 161 patients aged 18-80 years with headache after obtaining informed consent using non-probability consecutive sampling. Non-contrast CT scans were performed using a 160-slice scanner with contrast-enhanced imaging if indicated. Abnormalities, including space-occupying lesions, paranasal sinus disease, hydrocephalus, intracranial hemorrhage, cerebral infarcts, age-inappropriate cerebral atrophy, dural venous sinus thrombosis, and miscellaneous findings, were recorded. Data was analyzed using SPSS Version 26.

Results: The mean age was 40.5 ± 15.54 years, with 98 females (60.87%) and 63 males (39.13%). The median duration of headache was 12 weeks, and the interquartile range (IQR) of 2-48 weeks (range, 1-96 weeks). Abnormal CT findings were observed in 43 patients (26.7%), including space-occupying lesions in 2 (1.24%), paranasal sinus disease in 30 (18.63%), hydrocephalus in 2 (1.24%), cerebral infarcts in 4 (2.48%), and miscellaneous findings in 5 (3.11%). No age-inappropriate cerebral atrophy, intracranial haemorrhage, or dural venous sinus thrombosis were detected in any of the patients.

Conclusion: Abnormal CT findings were uncommon in adults with non-traumatic headache and no neurological deficits. Paranasal sinus disease was the most frequent abnormality. Selective imaging based on clinical risk factors can reduce unnecessary CT usage.

Keywords: Headache (MeSH); Computed Tomography (MeSH); Brain Abnormalities (Non-MeSH); Neuroimaging (MeSH); Paranasal Sinus Disease (Non-MeSH); Emergency Department (MeSH).

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INTRODUCTION

Headache is a common and often disabling condition that ranks as the fifth most common cause of emergency department (ED) visits, accounting for approximately 3.8 million hospital visits each year, or approximately 2.8% of all ED cases.[1,2] While the high number of such patients allows for readily available diagnostic resources, it also poses significant challenges, particularly when neurological deficits are absent. Up to 14% of headache cases undergo neuroimaging, and approximately 5.5% of these cases have significant abnormalities.[1] Nevertheless, the variable diagnostic yield is a cause of concern for the routine use of imaging, since the costs, radiation exposure, and clinical value of such studies are present.

Computed Tomography (CT) is the most commonly used neuroimaging tool in EDs because it is fast, reliable, and available, and it detects additional causes in 13-15% of headache patients, including cerebral hemorrhage or ischemia.[3] However, more than half of these scans are normal, and their routine use is questionable. A study by Raza S, et al., at PAF Hospital Islamabad found that CT rarely aids in diagnosis without other intracranial signs, whereas a South African study by Simwatachela E, et al., reported space-occupying lesions (9.62%), pathological calcifications (12.37%), complicated paranasal sinus disease (26.8%), hydrocephalus (7.22%), intracranial haemorrhage (11%), acute infarction (26.12%), and age-inappropriate cerebral atrophy (13.75%), all of which have varying diagnostic potentials.[4,5] Magnetic Resonance Imaging (MRI), however, provides better soft tissue detail without radiation risk and is less studied for acute headache, yielding 22% of significant findings. Clinical decisions based on risk factors, such as age >50 years, focal neurological deficits, nausea/vomiting, and altered mental status, can reduce unnecessary imaging.[6,7] Among these radiological examinations, CT, which accounts for 25% of the medical diagnostic radiation, should be considered with caution.[8]

The rationale for the current study was to fill the critical gap in local data on CT utility in non-traumatic headache cases without focal neurological signs, where clinical decisions are often crucial. This study aimed to determine the abnormal CT findings in this group and provide evidence to refine imaging practices. By minimizing unindicated CT scans, this study aimed to reduce unnecessary radiation exposure and the overall healthcare burden. These findings will equip radiologists and emergency physicians with region-specific evidence to develop standardized imaging guidelines to enhance diagnostic precision. This will promote the early detection of serious intracranial pathologies while ensuring more judicious and cost-effective utilization of healthcare resources.

METHODS

This cross-sectional study was conducted at the Department of Radiology in collaboration with the Emergency Medicine Department at Pakistan Aeronautical Complex (PAC)

Hospital, Kamra from 4th November 2024 to 4th May 2025 after approval from the ethical committee (vide letter dated: 18/09/2024). A sample size of 161 was calculated using the World Health Organization (WHO) sample size calculator with a 95% confidence level, 4% margin of error, and an expected frequency of 7.22% for brain pathology in non-trauma patients.[5]

The study population consisted of all adult patients aged 18-80 years who presented to the emergency department (ED) with a primary complaint of headache and were referred for CT brain imaging based on clinical judgment. Inclusion was determined by the attending ED physician according to institutional protocols, ensuring that only patients with clinically justified indications for imaging were enrolled, thereby minimizing selection bias (Table I). A total of 1,083 patients were identified as eligible for the study. Of these, 520 patients were invited to participate, and 359 were excluded at the time of CT for the following reasons: paediatric patients, history of head trauma, confirmed pregnancy (screening was performed by the ED physician through history and urine pregnancy testing, where required), or preexisting brain pathology (such as prior stroke, intracranial malignancy, metastasis, or previous neurosurgical intervention, including aneurysm clipping, coiling, or ventriculoperitoneal shunt placement) (Figure I for flow diagram). All included patients underwent a standardized neurological evaluation performed by the on-duty ED physician before imaging. The assessment included examination of the level of consciousness, cranial nerve function, limb strength, coordination, reflexes, and presence or absence of focal neurological deficits. Only patients without focal neurological signs were included in the final analysis to ensure that the findings represented nontraumatic headache presentations without overt neurological impairment.

Each participant provided informed consent, and basic demographic details (age, gender, weight (measured on a weighing scale), socioeconomic status, duration of headache, and residential status) were documented. A non-contrast-enhanced CT scan was performed using a 160-slice CT scanner with a field of view of 240 mm to encompass the entire cranial vault, and a 512×512 matrix for high-resolution imaging. The CT acquisition parameters were as follows: tube voltage (kVp)= 120, tube current (mAs)=250-300, slice thickness=1-2 mm for the posterior fossa and 3 mm for the rest of the brain, and reconstruction kernel = 0.5 mm. If the initial findings or clinical indications were warranted, a contrast-enhanced scan was performed after

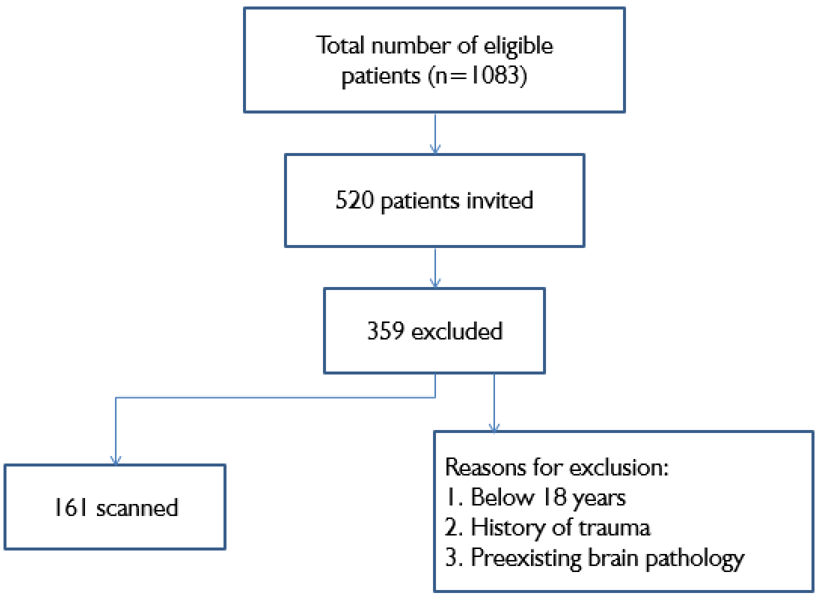

Figure 1: Flow diagram showing patient selection and exclusion process

Figure 2: Partial opacification of bilateral ethmoidal air cells on CT

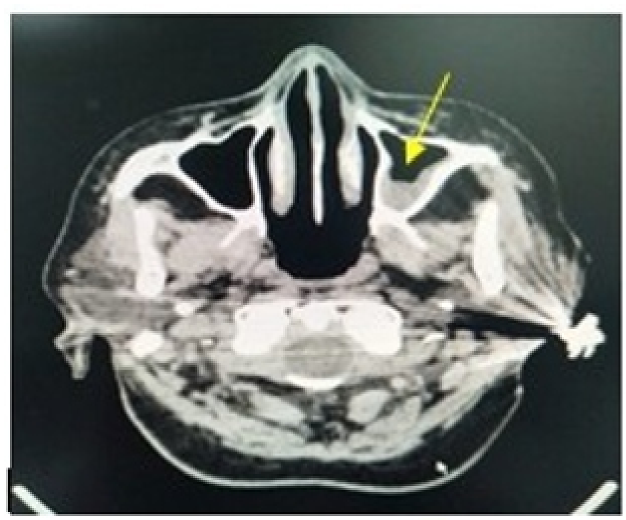

Figure 3: Air fluid level seen in the left maxillary sinus

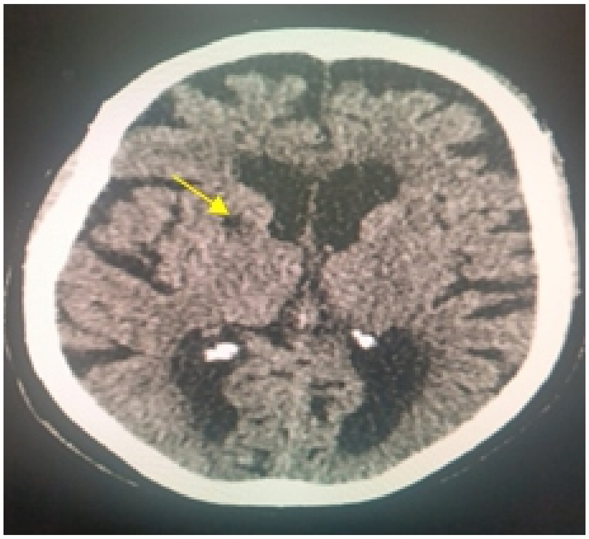

Figure 4: Chronic lacunar infarct in the anterior limb of the right internal capsule

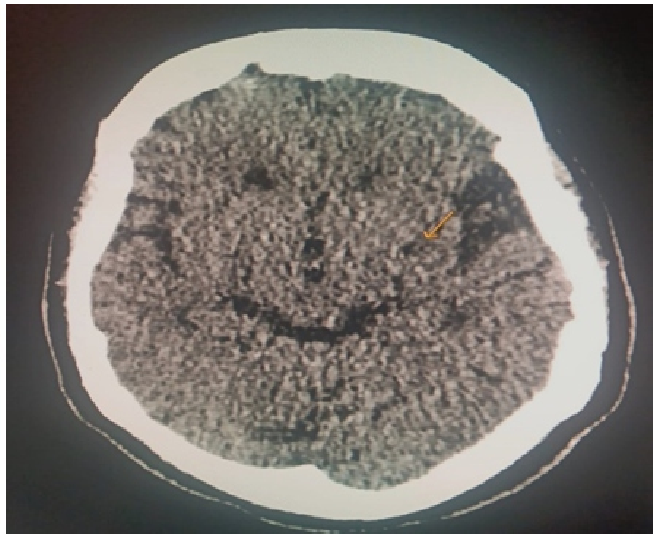

Figure 5: Chronic lacunar infarct involving left basal ganglia

Table I: CT scan indications in patients with headache without neurological deficit and history of trauma

Clinical Indications
• Moderate to severe headache
• Poor response to medications
• Change in headache character
• Persistent anxiety about serious pathology

Table II: Association between abnormal CT brain findings and age groups

Variable	18-30 Years	31-45 Years	46-60 Years	61-80 Years	p-value
Space-occupying lesions	1 (0.62%)	-	1 (0.62%)	-	0.472
Paranasal sinus disease	11 (6.80%)	9 (5.60%)	5 (3.10%)	5 (3.10%)	0.745
Hydrocephalus	1 (0.62%)	-	1 (0.62%)	-	0.472
Intracranial haemorrhage	-	-	-	-	-
Cerebral infarcts	-	-	2 (1.20%)	2 (1.20%)	0.026
Dural venous sinus thrombosis	-	-	-	-	-
Age-inappropriate cerebral atrophy	-	-	-	-	-
Miscellaneous findings	2 (1.20%)	3 (1.90%)	-	-	0.493

administration of iodinated contrast at 1-2 ml/kg body weight. The radiation exposure metrics were CTDIvol 45-60 mGy and DLP 850-1200 mGy*cm. Non-contrast scans took 5-10 minutes, and 5-10 minutes more for contrast-enhanced imaging if necessary. Whole-brain evaluation was performed in the axial, coronal, and sagittal planes using reconstructed images.

Two consultant radiologists independently reviewed and interpreted all the CT scans. Discrepancies in interpretation were resolved through mutual discussion and consensus. The abnormalities assessed included space-occupying lesions (defined as demarcated masses displacing brain structures),[9] paranasal sinus disease (sinus opacification, bone erosion, or fluid levels),[10] hydrocephalus (enlarged ventricles compressing brain tissue),[11] intracranial haemorrhage (high-density areas indicating acute bleeding),[12] cerebral infarcts (hypodense areas classified by location as basal ganglia or cortical, chronicity inferred from CSF-like density and margin clarity), age-inappropriate cerebral atrophy (atrophy greater than expected for the patient's age, assessed by the bicaudate index using age-specific cutoff values),[13] dural venous sinus thrombosis (hyperdense sinus with cord or dense vein signs),[14] and miscellaneous findings not fitting into the above categories.

SPSS Version 26 was used to analyze the data. Categorical variables (gender, socioeconomic status, residential status, and CT findings) were presented as frequencies and percentages. Means and standard deviations are presented for age and headache duration, respectively. Post-stratification analysis was performed using the chi-squared test with a p-value ≤ 0.05, which was considered statistically significant.

Table III: Association between abnormal CT brain findings and gender

Variable	Female	Male	p-value
Space-occupying lesions	1 (0.62%)	1 (0.62%)	0.751
Paranasal sinus disease	16 (9.9%)	14 (8.7%)	0.348
Hydrocephalus	1 (0.62%)	1 (0.62%)	0.751
Intracranial haemorrhage	-	-	-
Cerebral infarcts	3 (1.9%)	1 (0.62%)	0.558
Dural venous sinus thrombosis	-	-	-
Age-inappropriate cerebral atrophy	-	-	-
Miscellaneous findings	2 (1.20%)	3 (1.90%)	0.331

Table IV: Association between abnormal CT brain findings and duration of headache

Variable	1-25 Weeks	26-50 Weeks	51-75 Weeks	>76 Weeks	p-value
Space-occupying lesions	2 (1.24%)	-	-	-	0.822
Paranasal sinus disease	23 (14.3%)	4 (2.5%)	-	3 (1.9%)	0.693
Hydrocephalus	2 (1.24%)	-	-	-	0.822
Intracranial haemorrhage	-	-	-	-	-
Cerebral infarcts	3 (1.86%)	-	-	1 (0.62%)	0.765
Dural venous sinus thrombosis	-	-	-	-	-
Age-inappropriate cerebral atrophy	-	-	-	-	-
Miscellaneous findings	4 (2.5%)	-	-	1 (0.62%)	0.757

RESULTS

The study included 161 patients, with a mean age of 40.5±15.54 years. Among them, 98 (60.87%) were female and 63 (39.13%) were male. The median duration of headache was 12 weeks, and the interquartile range (IQR) of 2-48 weeks (range, 1-96 weeks). Socioeconomic status was categorized as low in 80 patients (49.69%), middle in 57 (35.4%), and high in 24 (14.91%). Most participants, 139 (86.34%), resided in urban areas, and 22 (13.66%) were from rural areas.

On brain CT, space-occupying lesions were observed in two patients (1.24%), while 159 (98.76%) showed no such lesions. On contrast studies these were diagnosed as brain tumors (glioma and lymphoma). Paranasal sinus disease was identified in 30 patients (18.63%), and hydrocephalus was observed in 2 patients (1.24%). Chronic lacunar infarcts were present in 4 patients (2.48%), whereas age-inappropriate cerebral atrophy, intracranial hemorrhage, and dural venous sinus thrombosis were not detected in any patient. Miscellaneous findings were observed in 5 patients (3.11%). Representative CT images are shown in Figures 2-5.

The associations between abnormal CT brain findings and age groups are shown in Table II. A statistically significant association was found between cerebral infarcts and age (p=0.026), whereas the other findings showed no significant age-related differences. Table III shows the association between CT findings and gender, with no significant gender-based variations (p>0.05). Table IV displays the association between CT findings and headache duration, with no significant correlations observed across different duration groups.

DISCUSSION

The current research found that abnormal CT brain imaging in adults who reported non-traumatic headache and no focal neurological deficit is uncommon, as is the case with global and regional evidence. Space-occupying lesions and chronic infarcts were only 1.24% and 2.48%, respectively, in our cohort, which is close to Lemmens CME, et al., who found intracranial pathology in 13% of scanned patients with similar presentations, and Gorleku PN, et al., who reported 2.8% significant findings in Ghana, suggesting that similar diagnostic results were obtained despite geographic differences.[1,3] The reduced frequency of our population could be indicative of a more rigid exclusion of patients with neurological deficits and selective application of CT based on the judgment of an emergency physician. Similar low yields were observed by Rai GS, et al., in India (5.8%), who reported that red flag-based selection was much more effective in improving the diagnostic rate, which supports the idea that the lack of focal signs decreases the utility of routine imaging.[6] Our results on paranasal sinus abnormalities (18.63%) are similar to those of Plawecki AM, et al., with a true sinus-related headache rate of 5%, and Hansen AG, et al., with no statistical correlation between sinus opacification and headache type on MRI.[15,16] Similarly, Mudgil SP, et al., demonstrated a low correlation between sinus tenderness or facial pain and CT-demonstrated sinus pathology, and a large proportion of incidental opacifications were not associated with symptoms.[17] Kalidindi and Gandhi also discovered that sinus mucosal changes were equally common in CTs performed on non-headache indications, which confirms that sinus opacities are usually incidental findings and not actual causes of pain.[18] These findings justify a tentative approach to sinus opacification on CT, where clinical correlation is more important than imaging in the diagnosis of sinus headache.

Our study had a low rate of hydrocephalus (1.24%), which is similar to the low rate of acute findings in non-trauma headache cohorts. According to Nesselroth D, et al., acute intracranial findings were only 12% of headache-related CTs, and they increased primarily with age and focal neurological symptoms, which our study population did not have.[19] Simwatachela E, et al., found abnormal CT in 73.5% of patients, but their sample contained cases with focal deficits and an altered sensorium, explaining their higher yield compared with our neurologically intact sample.[5] These comparisons demonstrate that the inclusion criteria have a significant effect on yield: studies of high-risk or symptomatic populations (for example, focal deficits, altered consciousness, or HIV-positive cohorts) report higher abnormalities,[20] but low-risk groups, such as ours, always yield less than 5%.

The median headache duration in our sample was 12 weeks (IQR 2-48), representing a chronic, non-acute group that was scanned to rule out secondary pathology following the failure of medical treatment. Other articles, such as Mahmood S and Krishnaswamy D, et al., however, covered acute-onset and mixed manifestations, with abnormal CT rates of 80% and 22.7%, respectively.[10,21] This difference could be due to disparities in referral thresholds and symptom profiles, i.e., acute severe headache and neurological impairment in hospital-based samples and chronic primary headache in outpatient samples. Lemmens CME, et al., and Alimohammadi H, et al., reported that a large proportion of CT requests in emergency departments were not necessarily appropriate, and 25-30% conducted for headache alone without supporting red flags.[3,22] This trend of excessive use resonates with our results, which show that routine CT does not contribute to diagnosis in low-risk patients. Regional differences may also explain variability across studies. Non-probability sampling and minimal application of standardised clinical algorithms may bias the diagnostic pattern in developing nations, such as Pakistan, Ghana, and Iran, where resources to perform imaging are scarce.[1,22] In comparison, European studies that used structured decision tools recorded a lower scan volume, but greater diagnostic results.[3,19] Variations in the quality of equipment, training of radiologists, and referral patterns also influence the yield. Both Moodley and Bhigjee and Simwatachela E, et al., were tertiary centers with advanced imaging, whereas the population of our center is more representative of general emergency presentations, possibly explaining the lower rate of clinically significant abnormalities.[5,20]

The finding that only age correlated significantly with infarcts ($p=0.026$) is consistent with the findings of Nesselroth D, et al., who reported that the yield of acute findings increased with age.[19] Simwatachela E, et al., observed that age >61 years was a predictor of abnormal CTs on its own, supporting the idea that age-based triage can enhance imaging efficiency.[5] Some authors support selective neuroimaging in terms of age and symptom presentation, instead of scanning all headache presentations.[1,3,6]

Incidental findings, such as sinus opacification, should be interpreted carefully in terms of their clinical relevance. Hansen AG, et al., established no correlation between paranasal mucosal thickening and either migraine or tension-type headache, and Mudgil SP, et al., established that the location of facial pain was not associated with abnormalities of the sinus CT.[15,17] Plawecki AM, et al., indicated a low level of agreement ($k<0.20$) between pain location and CT-identified sinus pathology.[16] Kalidindi and Gandhi revealed that sinus mucosal thickening occurred in 33% of headache scans and 30% of non-headache scans, confirming that these results are mostly incidental.[18] These data confirm our conclusion that most sinus variations in our series were non-specific or asymptomatic. Our exclusion of trauma, pregnancy, and previous neurological disease enhanced homogeneity, but yielded results less than Shamshad L, et al., and Rai GS, et al., the more inclusive studies.[6,23] The abnormal CT findings in both studies were 9-19% and which was partly attributed to the inclusion of patients with systemic or focal symptoms. Lemmens CME, et al., identified an abnormal rate of 13% in mixed EDs, and Krishnaswamy D, et al., identified an abnormal rate of 22.7% in a tertiary environment where vascular and haemorrhagic events were included.[3,21] Mahmood found that 80% of patients with extra weakness had abnormalities, indicating that comorbidity and symptom burden are strong determinants of yield variation.[24] These trends indicate that clinical preselection is central to maximising diagnostic efficiency.

The patterns in different areas, such as South Africa, Ghana, Europe, and South Asia, prove that severe intracranial pathology among non-traumatic and neurologically intact headache patients is uncommon, ranging between 1-6% of scans.[1,3,6,20,21] The slightly lower rate in our study is probably due to our limited inclusion criteria, which is also consistent with low-yield studies in Pakistan and India.[4,6] The differences in prevalence can also be explained by the fact that, in resource-limited and high-income environments, there is a difference in healthcare-seeking behaviour, access to imaging, and referral threshold.

Our findings suggest that CT can still be useful with clinical suspicion, especially in the elderly or in patients with unusual or progressive headache, but has little diagnostic usefulness in young, neurologically normal patients. The most frequent incidental finding is paranasal sinus disease, which is not likely to be associated with true sinus headache, as shown in population studies by Hansen AG, et al., Mudgil SP, et al., and Kalidindi and Gandhi.[15,17,18] The combination of these findings supports the idea of selective neuroimaging based on the severity of symptoms, their duration, and red flags, to ensure the rational use of resources and reduce the amount of unnecessary radiation.

This study had several limitations. The sample size of 161 patients from a single-centre setting may not represent the broader population, and the non-probability consecutive sampling technique introduced a potential selection bias. Key clinical covariates such as headache type, onset pattern, severity, fever, vomiting, immuno-suppression, anticoagulant use, and altered mental status were not systematically recorded, which limits the interpretation of pre-test probability and diagnostic yield. Although imaging was performed based on the recognised clinical risk factors, a formal checklist was not applied. Future studies with larger multicentre samples and standardised clinical decision tools are recommended to improve the generalisability and refine imaging recommendations.

CONCLUSION

This study found that abnormal CT brain findings in adult patients presenting with nontraumatic headache and no focal neurological signs were relatively uncommon. The most frequent abnormality was paranasal sinus disease, followed by chronic lacunar infarcts, space-occupying lesions, and hydrocephalus. Age showed a significant association with cerebral infarcts, while no relationship was found with gender or headache duration. These findings suggest that routine CT imaging in patients without neurological deficits may often be unnecessary, and selective use based on clinical risk factors and age can help reduce radiation exposure, minimize costs, and improve resource utilization in healthcare settings.

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AUTHORS' CONTRIBUTION

The Following authors have made substantial contributions to the manuscript as under:

SW, NP & JA: Conception and study design, acquisition, analysis and interpretation of data, drafting the manuscript, critical review, approval of the final version to be published

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

Authors declared no conflict of interest, whether financial or otherwise, that could influence the integrity, objectivity, or validity of their research work.

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DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request

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