

COMPARATIVE DIAGNOSTIC EFFICACY OF ULTRASOUND VS. CT IN DETECTING SKULL FRACTURES

Dr Karunakaram Sriram^{1*}, Dr Karthik Krishna Ramakrishnan², Dr Amogh Diwakara³,

Dr Paarthipaan Natarajan⁴

¹ MBBS, Postgraduate, Department of Radiology, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu – 602105, India. Email: drsriram.1797@gmail.com

² MD, Associate Professor, Department of Radio-Diagnosis, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu – 602105, India. Email: kkdrkr@gmail.com

³ Postgraduate Resident, Department of Radiology, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu – 602105, India. Email: amoghdwakar3@gmail.com

⁴ Professor and Head of the Department, Department of Radiology, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai, Tamil Nadu – 602105, India. Email: drpaarthipan@gmail.com

**Corresponding Author: Dr Karunakaram Sriram, drsriram.1797@gmail.com
ORCID: 0009-0001-1669-3062**

ABSTRACT

Background: Computed tomography (CT) is the reference standard for skull-fracture detection and assessment of associated intracranial injury; however, it involves ionizing radiation and requires scanner access. Point-of-care ultrasonography (POCUS) offers a rapid, bedside, radiation-free method for evaluating superficial cortical discontinuity. **Objective:** To determine the diagnostic accuracy of high-frequency skull ultrasonography (USG) compared with non-contrast multidetector CT in patients with suspected skull fracture following head trauma. **Methods:** This prospective observational diagnostic-accuracy study enrolled 100 patients aged 2 months to 60 years between January 2024 and April 2025. Targeted USG was performed using a Philips Affiniti system with a 12-MHz linear transducer. All participants underwent non-contrast CT with 1.5-mm bone-window reconstructions, interpreted by two radiologists blinded to the USG findings. Reported diagnostic measures included sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Cohen's kappa. **Results:** Falls were the most frequent mechanism of injury (55%), followed by road-traffic accidents (32%) and assault (13%). Fractures involved the frontal bone in 35%, parietal bone in 27%, temporal bone in 22%, occipital bone in 11%, and were complex in 5%. Relative to CT, USG showed 92.6% sensitivity, 95.0% specificity, 96.0% PPV, and 91.0% NPV. Interobserver agreement was strong (kappa=0.88). **Conclusion:** Targeted high-frequency USG demonstrated high diagnostic accuracy for accessible linear skull fractures and may be used as an adjunctive first-line examination in selected clinically stable patients. CT remains essential when intracranial injury, skull-base involvement, complex fracture, or inadequate sonographic visualization is suspected.

Keywords: computed tomography, diagnostic accuracy, head trauma, point-of-care ultrasound, skull fracture

INTRODUCTION

Head trauma is a common indication for emergency evaluation across all age groups. Skull fracture is clinically important because it reflects the site and magnitude of impact and may coexist with epidural or subdural hematoma, cerebral contusion, pneumocephalus, vascular injury, or open cranial trauma. Rapid identification of patients who require neuroimaging, observation, neurosurgical consultation, or urgent intervention is therefore central to acute trauma care. CT remains the principal imaging modality because it depicts the entire calvarium, skull base, intracranial compartments, and associated soft-tissue abnormalities in a single rapid examination.¹

Non-contrast head CT provides high spatial resolution for cortical bone and allows simultaneous evaluation of intracranial hemorrhage and mass effect. Thin-section bone-window reconstructions improve visualization of linear, depressed, diastatic, comminuted, and skull-base fractures. Nevertheless, CT involves ionizing radiation, requires transport to a scanner, and

may necessitate immobilization or sedation in selected patients. Although the risk from an individual optimized examination is small, radiation exposure remains an important consideration, particularly in children and in patients requiring repeated imaging.^{2,3}

Validated clinical decision rules, including PECARN, reduce unnecessary CT by identifying children at very low risk of clinically important traumatic brain injury.^{4,5} These rules estimate the probability of clinically important intracranial injury but do not directly visualize a focal calvarial defect. In patients with localized scalp swelling, tenderness, or hematoma, a rapid bedside test capable of demonstrating cortical disruption may complement clinical risk assessment and help prioritize further imaging.

High-frequency USG depicts the superficial calvarium as a continuous echogenic cortical line with posterior acoustic shadowing. A fracture may appear as a focal interruption, step-off, depression, or hypoechoic defect traversing the cortex. USG is portable, repeatable, relatively inexpensive, and free of ionizing radiation. Systematic reviews and diagnostic studies

have reported high specificity and clinically useful sensitivity for pediatric skull-fracture detection, particularly when scanning is focused on a localized scalp abnormality.⁶⁻¹²

The principal limitations of skull USG are operator dependence, restricted acoustic access, and potential confusion with sutures, vascular channels, developmental irregularities, hair, soft-tissue air, and irregular scalp contours. Most published evidence concerns children with minor blunt head trauma, whereas adult and mixed-age populations remain less well studied. Accordingly, POCUS should be considered an adjunct to structured clinical assessment and not a replacement for CT when intracranial injury or complex fracture is suspected.

This study compared targeted skull USG with CT in 100 patients aged 2 months to 60 years following head trauma. The primary objective was to determine the sensitivity, specificity, PPV, and NPV of USG using CT as the reference standard. Secondary objectives were to describe injury mechanisms and fracture distribution, assess agreement, and identify clinical settings in which USG may complement CT.

MATERIALS AND METHODS

Study Design, Setting, and Participants

A prospective observational diagnostic-accuracy study was conducted from January 2024 to April 2025 at Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India. The study evaluated targeted high-frequency skull ultrasonography as the index test, with non-contrast multidetector computed tomography serving as the reference standard. The study was reported in accordance with the principles of STARD 2015, with methodological considerations guided by the relevant domains of QUADAS-2.^{16,17}

A total of 100 patients aged 2 months to 60 years were included. Eligible participants were patients presenting after head trauma with a clinical suspicion of skull fracture. Patients who were hemodynamically unstable or had a history of previous cranial surgery were excluded. The available study dataset did not provide information on the total number of patients screened, the recruitment strategy, detailed reasons for exclusion, sex distribution, age-group distribution, neurological findings, or other baseline clinical characteristics; therefore, these variables were not inferred.

Imaging Protocol

Targeted skull ultrasonography was performed using a Philips Affiniti ultrasound system equipped with a high-frequency 12-MHz linear transducer. The examination focused on the clinically suspected region of injury and was used to identify cortical discontinuity or other sonographic features suggestive of skull fracture.

The reference-standard examination was non-contrast multidetector computed tomography of the brain with 1.5-mm bone-window reconstructions. CT images were independently interpreted by two radiologists who were blinded to the ultrasonography findings. This blinding was intended to reduce review bias and preserve the independence of the reference-standard assessment.

Clinical assessment and test sequence: Clinical stabilization preceded imaging. Eligible participants underwent targeted skull USG followed by CT during the same diagnostic episode. CT was obtained as part of clinical care and was not replaced by USG. The exact time interval between examinations and whether the USG operator had access to detailed clinical findings were not reported in the source dataset.

Index test—ultrasonography: USG was performed using a Philips Affiniti ultrasound system with a 12-MHz high-frequency linear-array transducer. The clinically suspected region was examined over the superficial calvarium. A positive examination was defined by focal cortical discontinuity, step-off, depression,

or interruption of the normally continuous echogenic cortical line. Scalp hematoma alone was not considered diagnostic of fracture. The source dataset did not specify operator number, professional background, training duration, examination time, use of orthogonal planes, image-archiving procedures, or the handling of technically indeterminate examinations.

Reference standard—computed tomography: All participants underwent non-contrast multidetector CT of the head with 1.5-mm bone-window reconstructions. Two radiologists interpreted the CT examinations while blinded to the USG findings. CT fracture categories included frontal, parietal, temporal, occipital, and complex fractures. CT also served as the modality for assessment of complex osseous injury and intracranial abnormalities. The source material did not describe the CT scanner model, radiation-dose parameters, multiplanar reconstruction protocol, or adjudication process for reader disagreement.

Blinding and agreement: The two CT radiologists were reported to be blinded to USG results. Interobserver agreement was summarized using Cohen's kappa. The source dataset did not identify the readers included in the kappa analysis or provide the corresponding confidence interval; consequently, the reported kappa value was interpreted as a summary measure of agreement without further subgroup analysis.

Outcome measures: The primary outcome was the diagnostic performance of USG for detection of CT-confirmed skull fracture. Prespecified summary measures were sensitivity, specificity, PPV, and NPV. Secondary outcomes were mechanism of injury, anatomical fracture distribution, and interobserver agreement. CT findings related to intracranial injury were not available as analyzable outcomes in the supplied dataset.

Statistical analysis: Categorical variables were summarized as frequencies and percentages. Diagnostic performance was reported as sensitivity, specificity, PPV, and NPV using CT as the reference standard. Agreement was reported using Cohen's kappa. The patient-level 2x2 contingency table and 95% confidence intervals were not available in the supporting dataset; therefore, no additional inferential statistics, likelihood ratios, subgroup analyses, or recalculation of the reported percentages were performed. Statistical software and version: [TO BE PROVIDED].

Sample size: The final sample comprised 100 participants. A priori sample-size calculation was not provided; accordingly, the analysis should be interpreted as an exploratory diagnostic-accuracy evaluation, and precision estimates should be added when the verified 2x2 dataset becomes available.

Data quality and integrity: The principal analysis used the aggregate diagnostic indices reported in the supporting dataset. A source-provided diagnostic-category illustration contained counts that did not mathematically reproduce the stated sensitivity, specificity, PPV, and NPV. Those counts were not used for inference and are retained only as a supplementary source figure pending reconciliation with the original case-level data.

Ethical considerations: The approving institutional ethics committee, approval number, approval date, and consent procedure were not supplied and must be completed from the approved protocol before submission. Institutional ethics committee: [TO BE PROVIDED]; approval number/date: [TO BE PROVIDED]; informed-consent procedure: [TO BE PROVIDED].

RESULTS

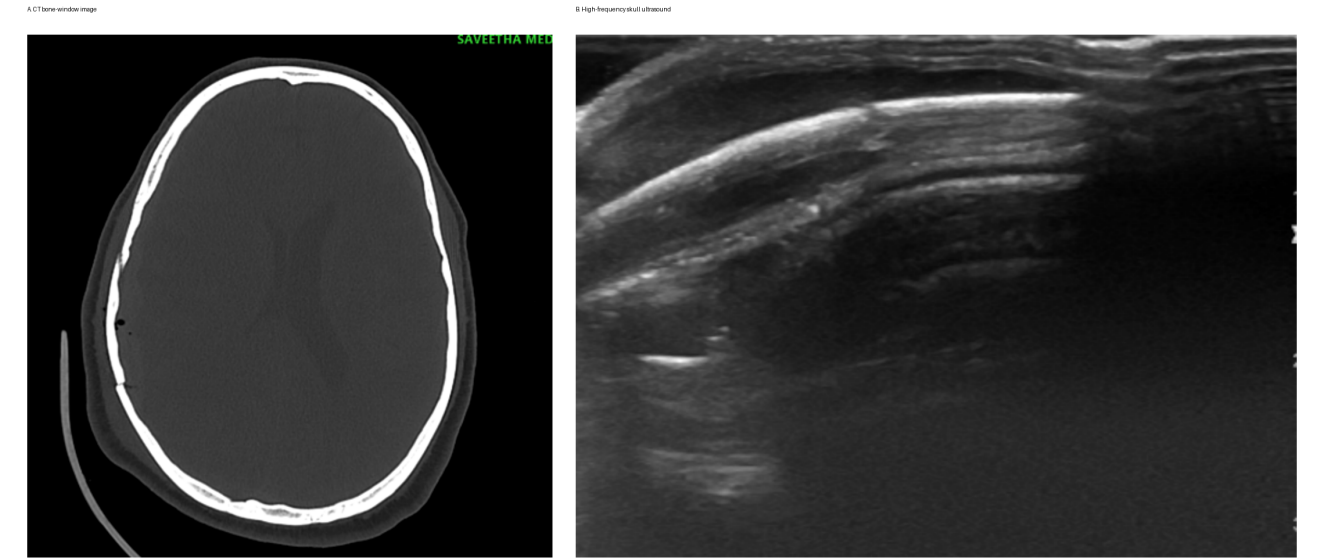
Participant characteristics: A total of 100 patients, ranging in age from 2 months to 60 years, underwent both targeted skull ultrasonography and non-contrast computed tomography. The available dataset did not report the mean or median age, age-group distribution, sex distribution, Glasgow Coma Scale scores, presenting symptoms, scalp examination findings, or the interval between injury and imaging; therefore, these variables were not included in the analysis.

Falls were the most common mechanism of injury, occurring in 55 patients (55%), followed by road-traffic accidents in 32 (32%) and assault in 13 (13%) (Table 1).

Mechanism of injury and fracture distribution (N=100)

Variable	Category	n or %
Mechanism	Falls	55 (55%)
Mechanism	Road-traffic accidents	32 (32%)
Mechanism	Assault	13 (13%)
Fracture location	Frontal	35%
Fracture location	Parietal	27%
Fracture location	Temporal	22%
Fracture location	Occipital	11%
Fracture location	Complex	5%

Fracture distribution: Frontal fractures were most frequent (35%), followed by parietal (27%), temporal (22%), occipital (11%), and complex fractures (5%) (Table 2). Complex fractures were reported to be best demonstrated on CT.

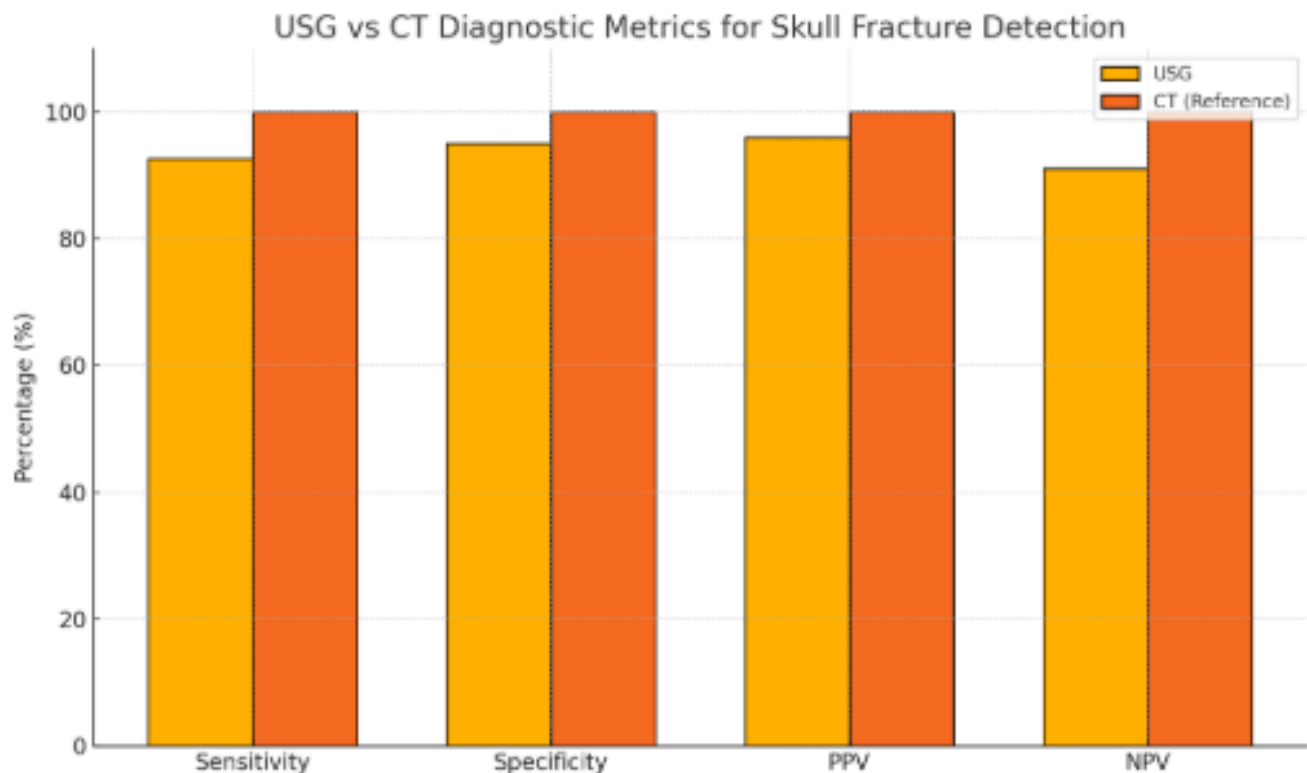


Source-provided representative imaging appearances. (A) Axial CT bone-window image showing circumferential cranial cortical detail. (B) High-frequency linear-probe ultrasound showing the superficial echogenic calvarial cortex. Images should be confirmed as de-identified and paired or relabeled as independent representative examples before submission.

Diagnostic performance: Using CT as the reference standard, 2x2 table was unavailable, 95% confidence intervals, overall accuracy, and likelihood ratios could not be calculated reliably. Underlying table was unavailable, 95% confidence intervals, overall accuracy, and likelihood ratios could not be calculated reliably.

Diagnostic performance of skull USG using CT as the reference standard

Measure	Reported value	Clinical interpretation
Sensitivity	92.6%	High detection rate among CT-positive fractures
Specificity	95.0%	Low false-positive rate among CT-negative patients
Positive predictive value	96.0%	Positive USG strongly supported fracture in this cohort
Negative predictive value	91.0%	Negative USG reduced but did not eliminate fracture probability
Cohen's kappa	0.88	Strong interobserver agreement



Reported diagnostic-performance measures for USG compared with CT. CT is plotted as the study reference benchmark. PPV: positive predictive value; NPV: negative predictive value.

Agreement: Cohen's kappa was 0.88, indicating strong agreement beyond chance. The source dataset did not specify the readers included in this analysis or provide a confidence interval.

Representative imaging: Figure 1 presents the source-provided CT and high-frequency USG images. The CT image demonstrates circumferential osseous detail, whereas the USG image illustrates focal visualization of the superficial echogenic cortical interface. The images should be confirmed as de-

identified and identified as paired or unpaired examples before submission.

Modality-specific observations: USG was reported to perform best for accessible linear fractures of the frontal and parietal bones. CT remained superior for complex and occipital fractures and was required for assessment of intracranial injury. A practical comparison of the modalities is provided in Table 3.

Practical comparison of USG and CT in suspected skull fracture

Domain	Ultrasound	Computed tomography
Radiation	None	Ionizing radiation
Portability	Bedside/portable	Scanner-based
Best use	Targeted accessible linear cortical fractures	Comprehensive skull and intracranial assessment
Strengths	Rapid, repeatable, focal, low resource burden	High spatial coverage; complex and skull-base fractures; hemorrhage
Limitations	Operator dependent; narrow field; sutures and acoustic windows	Radiation; transport; access; occasional sedation
Clinical position	Adjunct or first-line focused screening in selected stable patients	Reference test when high-risk features or intracranial injury are suspected

DISCUSSION

Targeted high-frequency skull USG showed high reported diagnostic accuracy relative to CT, with sensitivity of 92.6%, specificity of 95.0%, PPV of 96.0%, and NPV of 91.0%. These findings indicate that a clearly demonstrated cortical defect strongly supports the presence of fracture in a clinically selected population. The NPV, although high, is not sufficient to exclude fracture or intracranial injury when clinical suspicion remains substantial. This pattern is consistent with systematic reviews that position skull POCUS as an adjunctive rule-in or risk-refinement test rather than a universal substitute for CT.^{6,7}

The present estimates are broadly consistent with systematic reviews and prospective diagnostic studies of pediatric skull POCUS. Alexandridis et al. and Gordon et al. reported high specificity with useful sensitivity, while emphasizing heterogeneity in operator experience, scanning protocol, fracture prevalence, and patient selection.^{6,7} Studies by Dehbozorgi et al., Masaeli et al., Sik et al., and Huang et al. also support the ability of focused high-frequency USG to identify superficial skull

fractures in children with localized traumatic findings.⁸⁻¹¹ Shogan and Bhangu further highlighted its role as a focused adjunct in pediatric emergency assessment.¹² The inclusion of adults in the present cohort broadens potential applicability, but the absence of age-stratified data prevents direct comparison of pediatric and adult performance.

The favorable performance of USG over frontal and parietal regions is anatomically plausible because these surfaces are broad, superficial, and relatively accessible to a linear transducer. Fractures typically appear as a persistent cortical interruption or step-off in orthogonal planes.⁶⁻¹² Diagnostic difficulty increases over the occiput, temporal region, and skull base because of curvature, hair, muscle, sutures, and complex osseous anatomy. CT remains superior for depressed, comminuted, basilar, multiple, or complex fractures and for complete assessment of the intracranial contents.^{1,6,7,13}

False-positive USG findings may result from normal sutures, accessory sutures, vascular grooves, or developmental irregularities. False-negative examinations may occur when the

fracture lies outside the scanned field, is very fine or nondisplaced, or is located beneath an acoustically difficult region. Published protocols emphasize correlation with the site of impact, multiplanar scanning, and recognition of age-appropriate cranial anatomy.^{6,8-12} These technical limitations reinforce the need for formal training, image documentation, and explicit escalation to CT when the examination is incomplete or discordant with clinical findings.

POCUS should be integrated with neurological examination, mechanism of injury, scalp findings, and validated clinical decision rules. In a stable patient with a localized superficial injury and low pretest probability of intracranial trauma, a positive USG finding may support expedited CT, observation, or specialist review. A negative USG result should not delay CT when PECARN or other clinical criteria indicate imaging, when neurological abnormalities are present, or when the suspected fracture involves the skull base or an inaccessible region.⁴⁻⁷

The principal potential benefit of skull USG is reduction of avoidable ionizing radiation in carefully selected patients. Contemporary epidemiological studies and systematic reviews indicate that the absolute radiation-associated cancer risk from pediatric head CT is low but measurable, particularly with repeated exposure.^{2,3,14} Structured clinical pathways can reduce CT use while preserving safety.^{4,5,15} USG may contribute to such pathways only when it answers the focused clinical question and immediate access to CT is preserved for higher-risk presentations.

Bedside availability, rapid acquisition, and absence of radiation make POCUS attractive in emergency departments and settings with delayed CT access.⁶⁻¹² Safe implementation requires standardized training, competency assessment, image archiving, quality assurance, and clear criteria for technically inadequate or discordant examinations. The present study reported strong agreement ($\kappa=0.88$), but the lack of reader-level details limits conclusions about reproducibility outside the study setting.

The inclusion of patients aged 2 months to 60 years introduces clinically relevant variation in skull thickness, suture anatomy, mechanism of injury, and acoustic accessibility. Most published evidence relates to infants and children with localized scalp hematoma.⁶⁻¹² Without age-stratified results, the aggregate diagnostic estimates should not be assumed to apply equally to pediatric and adult patients.

Detection of a skull fracture is important, but patient management is determined primarily by neurological status, fracture type, intracranial injury, and clinical evolution. Isolated linear fractures without intracranial injury are often managed conservatively, whereas depressed, open, basilar, and complex fractures may require specialist treatment.^{1,13} USG provides focal information about superficial cortical continuity; CT and serial clinical assessment provide the broader evaluation needed for patient safety.

Strengths include the prospective design, direct comparison with CT, inclusion of a mixed-age population, and blinded CT

interpretation. Important limitations are the single-center design, absence of patient-level data, lack of a verified 2x2 table and confidence intervals, incomplete demographic and clinical characterization, unspecified USG operator training, absence of age-stratified analysis, and uncertainty regarding the readers included in the kappa calculation. The conflicting source-provided diagnostic-category counts further require reconciliation before submission.

External generalisability is limited because diagnostic performance depends on fracture prevalence, operator expertise, scanning completeness, patient age, and anatomical site.^{6,7} Future multicenter studies should use consecutive recruitment, report a STARD flow diagram and complete 2x2 table, provide confidence intervals and likelihood ratios, stratify results by age and fracture location, and evaluate whether adding POCUS to validated clinical rules safely reduces CT utilization, transfer, cost, or emergency-department length of stay.^{4,5,15,16}

LIMITATIONS

The study is limited by the absence of patient-level diagnostic data, a verified 2x2 contingency table, and confidence intervals. Detailed demographic, neurological, and clinical variables were unavailable, and USG operator experience, training, examination time, and handling of indeterminate scans were not reported. The broad age range was not analyzed by subgroup, and the source dataset did not quantify intracranial CT findings. In addition, the diagnostic-category counts shown in a source figure conflict with the reported aggregate indices and must be reconciled before journal submission. These limitations preclude independent recalculation of accuracy and restrict generalisability.

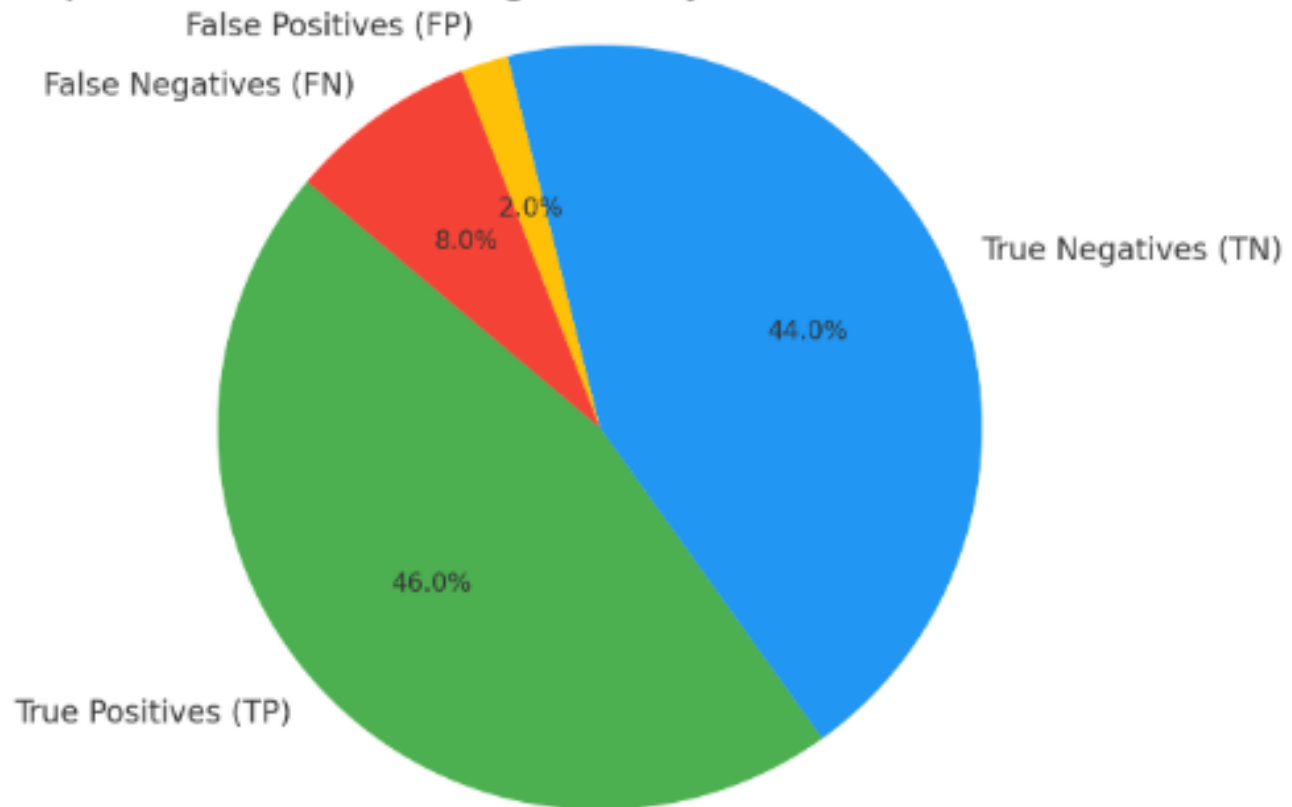
CONCLUSION

Targeted high-frequency skull USG demonstrated high reported sensitivity, specificity, PPV, and NPV relative to CT and showed strong agreement. It appears most useful for accessible linear fractures of the frontal and parietal bones in clinically stable patients. USG should be regarded as an adjunct to clinical assessment rather than a replacement for CT. CT remains essential when intracranial injury, skull-base involvement, complex or multiple fracture, or inadequate sonographic visualization is suspected. Final publication requires verification of the patient-level 2x2 dataset, confidence intervals, ethics information, and remaining author-supplied details.

SUPPLEMENTARY SOURCE FIGURE

Supplementary Figure S1 reproduces the confusion-category chart supplied with the supporting presentation. The displayed counts (TP=46, TN=44, FP=2, FN=8) do not reproduce the reported aggregate sensitivity, specificity, PPV, and NPV and therefore were not used in the analysis. The investigators must reconcile this figure with the final case-level dataset before submission.

Proportion of Correct Diagnoses by USG (Out of 100 Cases)



Supplementary Figure S1: Source-provided diagnostic-category illustration. This figure is retained for source completeness but requires data verification before journal submission.

ACKNOWLEDGEMENTS

The author acknowledges the emergency medicine, radiology, and imaging personnel involved in patient assessment and image acquisition. Individual contributors should be named only after confirming their permission and contribution.

DATA AVAILABILITY

The availability of de-identified participant-level data must be confirmed by the corresponding author and the institution. The verified 2x2 diagnostic table should be retained with the study records and supplied to the journal if requested, subject to ethical and institutional restrictions.

REFERENCES

1. Maas AIR, Menon DK, Manley GT, Abrams M, Akerlund C, Andelic N, et al. Traumatic brain injury: progress and challenges in prevention, clinical care, and research. *Lancet Neurol*. 2022;21(11):1004-1060. doi:10.1016/S1474-4422(22)00309-X.
2. Lee S, Kim HY, Lee KH, Cho J, Lee C, Kim KP, et al. Risk of hematologic malignant neoplasms from head CT radiation in children and adolescents presenting with minor head trauma: a nationwide population-based cohort study. *Eur Radiol*. 2024;34(9):5934-5943. doi:10.1007/s00330-024-10646-2.
3. Smith-Bindman R, Chu PW, Azman Firdaus H, Stewart C, Malekheadat M, Alber S, et al. Projected lifetime cancer risks from current computed tomography imaging. *JAMA Intern Med*. 2025;185(6):710-719. doi:10.1001/jamainternmed.2025.0505.
4. Lorton F, Poullaouec C, Legallais E, Simon-Pimmel J, Chene MA, Leroy H, et al. Validation of the PECARN clinical decision rule for children with minor head trauma: a French multicenter prospective study. *Scand J Trauma Resusc Emerg Med*. 2016;24:98. doi:10.1186/s13049-016-0287-3.
5. Holmes JF, Yen K, Ugalde IT, Ishimine P, Chaudhari PP, Atigapramoj N, et al. PECARN prediction rules for CT imaging

of children presenting to the emergency department with blunt abdominal or minor head trauma: a multicentre prospective validation study. *Lancet Child Adolesc Health*. 2024;8(5):339-347. doi:10.1016/S2352-4642(24)00029-4.

6. Alexandridis G, Verschuuren EW, Rosendaal AV, Kanhai DA. Evidence base for point-of-care ultrasound for diagnosis of skull fractures in children: a systematic review and meta-analysis. *Emerg Med J*. 2022;39(1):30-36. doi:10.1136/emered-2020-209887.
7. Gordon I, Sinert R, Chao J. The utility of ultrasound in detecting skull fractures after pediatric blunt head trauma: systematic review and meta-analysis. *Pediatr Emerg Care*. 2021;37(12):e1701-e1707. doi:10.1097/PEC.0000000000001958.
8. Dehbozorgi A, Mousavi-Roknabadi RS, Hosseini-Marvast SR, Sharifi M, Sadegh R, Farahmand F, et al. Diagnosing skull fracture in children with closed head injury using point-of-care ultrasound versus computed tomography scan. *Eur J Pediatr*. 2021;180(2):477-484. doi:10.1007/s00431-020-03875-w.
9. Masaali M, Chahardoli M, Azizi S, Shekarchi B, Sabzghabaei F, Shekar Riz Fomani N, et al. Point of care ultrasound in detection of brain hemorrhage and skull fracture following pediatric head trauma: a diagnostic accuracy study. *Arch Acad Emerg Med*. 2019;7(1):e53. PMID:31875207.
10. Sik N, Ozturk A, Yilmaz D, Duman M. The role of ultrasound in pediatric skull fractures: determination of fracture and optic nerve sheath diameter measurements. *Pediatr Emerg Care*. 2023;39(2):91-97. doi:10.1097/PEC.0000000000002895.
11. Huang JS, Huang SY, Liao HZ, Cai RZ, Zeng Q, Xiang XT, et al. Point-of-care ultrasound diagnosis of skull fracture in Chinese children 0-6 years old with scalp hematoma from minor head trauma: a preliminary prospective observational study. *Heliyon*. 2023;9(4):e15255. doi:10.1016/j.heliyon.2023.e15255.
12. Shogan H, Bhangu AK. Detection of paediatric skull fractures using POCUS. *Emerg Med J*. 2025;42(3):209-210. doi:10.1136/emered-2024-214540.
13. Donaldson K, Li X, Sartorelli KH, Weimersheimer P, Durham SR. Management of isolated skull fractures in pediatric patients: a systematic review. *Pediatr Emerg Care*. 2019;35(4):301-308. doi:10.1097/PEC.0000000000001808.

14. Sheppard JP, Nguyen T, Alkhalid Y, Beckett JS, Salamon N, Yang I. Risk of brain tumor induction from pediatric head CT procedures: a systematic literature review. *Brain Tumor Res Treat.* 2018;6(1):1-7. doi:10.14791/btrt.2018.6.e4.
15. Appelbaum R, Hoover T, Azari S, et al. Development and implementation of a pilot radiation reduction protocol for pediatric head injury. *J Surg Res.* 2020;255:111-117. doi:10.1016/j.jss.2020.05.051.
16. Bossuyt PM, Reitsma JB, Bruns DE, Gatsonis CA, Glasziou PP, Irwig L, et al. STARD 2015: an updated list of essential items for reporting diagnostic accuracy studies. *BMJ.* 2015;351:h5527. doi:10.1136/bmj.h5527.
17. Whiting PF, Rutjes AWS, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med.* 2011;155(8):529-536. doi:10.7326/0003-4819-155-8-201110180-00009.