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Original Research Article

The Role of Pocus in the Neonatal Intensive Care Unit to Detect Early Intracranial Hemorrhages

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Abstract:

Background: Neonatal intracranial hemorrhage, especially germinal matrix hemorrhage and intraventricular hemorrhage, remains a major source of short- and long-term morbidity in preterm and critically ill newborns, and timely diagnosis influences monitoring, prognosis, and subsequent neuroprotective management. Bedside cranial ultrasound has long been used as the principal first-line imaging modality for neonatal brain assessment because it is portable, non-ionizing, repeatable, and feasible through the anterior fontanelle, while newer NICU-focused POCUS models increasingly emphasize clinician-performed serial examinations integrated with real-time decision-making.

Aim: This systematic review examines the role of point-of-care ultrasound (POCUS), particularly cranial ultrasound performed at the bedside in the neonatal intensive care unit (NICU), for early detection of intracranial hemorrhage in neonates. The present review evaluates published evidence regarding diagnostic utility, timing of screening, feasibility, advantages, limitations, and implementation considerations of POCUS in the NICU for identifying early intracranial hemorrhages.

Materials and Methods: A structured narrative systematic review approach was used, drawing on peer-reviewed reviews, policy statements, and observational evidence that addressed neonatal cranial ultrasonography or POCUS for intracranial hemorrhage detection in NICU populations. Core themes extracted from the available literature included the epidemiology and pathophysiology of hemorrhage in preterm neonates, diagnostic performance of cranial ultrasound, optimal timing of bedside scanning, populations at highest risk, technical approaches through cranial acoustic windows, and the organizational issues surrounding training and interpretation. Sources also included consensus-style guidance recommending routine cranial ultrasound in infants born at or before 32 weeks' gestation and literature highlighting that many germinal matrix or intraventricular hemorrhages occur within the first hours to days of life, thereby making serial bedside imaging clinically valuable. Evidence was synthesized qualitatively because the retrieved material was heterogeneous in design and often focused on broad cranial ultrasound use rather than exclusively clinician-performed cranial POCUS.

Result: The reviewed literature consistently supports bedside cranial ultrasound as a central tool in early NICU detection of intracranial hemorrhage. Available evidence indicates that transfontanelle ultrasound is the standard initial modality for significant neonatal intraventricular hemorrhage, with one review citing nearly 100% sensitivity and 93.3% specificity Routine screening recommendations for infants born at or before 32 weeks' gestation and scheduling at around the second and sixth weeks of life underscore both the acute diagnostic role of early scans and the follow-up role of later scans for hemorrhagic sequelae such as ventricular dilatation. Review literature also notes that bedside head ultrasound can identify intraventricular hemorrhage, periventricular leukomalacia, and post-hemorrhagic ventricular dilatation, while emerging neonatologist-performed POCUS frameworks seek to shorten time to diagnosis and improve integration with routine NICU care.

Conclusion: POCUS-based cranial ultrasound in the NICU is a highly practical and clinically important method for early detection of neonatal intracranial hemorrhage, especially in preterm infants and symptomatic high-risk neonates. Its greatest strengths are bedside availability, absence of radiation, repeatability, suitability for serial monitoring, and high utility for identifying clinically significant hemorrhage early enough to inform surveillance and escalation of care. The most evidence-based interpretation is that cranial POCUS should function as a structured, protocol-driven extension of standard neonatal cranial ultrasonography rather than a replacement for radiology support or advanced neuroimaging when uncertainty persists.

Keywords: point-of-care ultrasound; neonatal intensive care unit; intracranial hemorrhage; cranial ultrasound; intraventricular hemorrhage

Introduction

Intracranial hemorrhage in newborn infants remains one of the most consequential neurological problems encountered in the NICU, particularly among very preterm and very low birth weight infants whose immature cerebral vasculature, unstable cerebral blood flow regulation, and susceptibility to cardiorespiratory instability predispose them to germinal matrix and intraventricular bleeding. Hemorrhagic lesions may remain confined to the germinal matrix, extend into the ventricular system, cause ventricular distension, or involve adjacent parenchyma, and these patterns have implications for both immediate management and longer-term neurodevelopmental outcomes. Because many neonatal hemorrhages are clinically silent at onset, reliance on symptoms alone risks delayed recognition.

Conventional cranial ultrasonography has become the main bedside neuroimaging technique in neonatal care because it can be performed through the anterior fontanelle using portable equipment, does not expose infants to ionizing radiation, and can be repeated serially without transport away from intensive monitoring. This is especially important in fragile neonates for whom transport to computed tomography or magnetic resonance imaging may be logistically difficult or physiologically hazardous. In modern NICU practice, the concept of POCUS extends this bedside approach by emphasizing focused clinician-performed ultrasound examinations that answer immediate clinical questions and may be repeated as the infant's condition evolves.

The interest in cranial POCUS has grown alongside broader adoption of neonatal ultrasound for cardiac, pulmonary, abdominal, and procedural indications. Review literature already recognized intraventricular hemorrhage among the relevant diagnostic applications of POCUS in the NICU and highlighted the need for formalized training and evidence-based governance as use expands. A recent study of cranial POCUS training, further reflects this trend by evaluating the feasibility of teaching NICU providers to acquire cranial images, underscoring that bedside neurosonography is increasingly viewed as an operational skill for neonatology teams.

The rationale for early bedside imaging is strong. Literature on screening timing indicates that at least one-third of infants who develop germinal matrix or intraventricular hemorrhage may show echodensities as early as the first hour after birth, about half of hemorrhages occur in the first 6 to 8 hours, and most are evident by the third day. These observations explain why serial early ultrasound is so valuable in the NICU, especially for extremely preterm infants, infants with respiratory instability, those with birth asphyxia, seizures, hypotension, or rapidly changing neurological signs.

Bedside head ultrasound is not merely a binary test for presence or absence of bleeding. It can support grading of hemorrhage, surveillance for progression, recognition of associated ventricular enlargement, and follow-up for post-hemorrhagic ventricular dilatation or white matter injury. In preterm infants, this capacity for repeated assessment is central to prognosis because the neurodevelopmental burden is influenced not only by the initial hemorrhage but also by evolving secondary changes, including hydrocephalus and associated parenchymal injury.

At the same time, important limitations deserve attention. Cranial ultrasound is highly operator-dependent, interpretation varies with expertise, and certain lesions, especially smaller posterior fossa or subtle parenchymal abnormalities, may be underdetected without optimized technique or adjunct imaging. Therefore, the current role of POCUS in detecting early intracranial hemorrhage must be framed in relation to training, quality assurance, scan timing, and the relationship between clinician-performed studies and formal radiology examinations.

This systematic review therefore examines the role of POCUS in the NICU for early detection of neonatal intracranial hemorrhage. The review synthesizes available evidence on clinical indications, diagnostic utility, timing of scans, technical principles, benefits, drawbacks, and implementation considerations, aiming to provide a manuscript-ready overview relevant to neonatal care and academic discussion.

Materials & Method

This review was designed as a systematic narrative review focused on the use of point-of-care cranial ultrasound in NICU settings for early detection of neonatal intracranial hemorrhage. The topic spans a literature base in which terminology varies, with some publications using "cranial ultrasound," "transfontanelle ultrasound," or "neurosonography," and others using the broader POCUS framework for neonatology. Because the literature includes foundational policy statements, narrative reviews, and observational studies rather than a uniform body of randomized diagnostic trials, qualitative synthesis was chosen as the most appropriate method.

Search Strategy: A structured search strategy was undertaken using targeted terms related to neonatal POCUS, cranial ultrasound, NICU, intracranial hemorrhage, intraventricular hemorrhage, germinal matrix hemorrhage, and neonatal neurosonography. Sources retrieved and prioritized included review articles, professional guidance documents, and studies providing information on diagnostic capability, scanning timing, epidemiology, feasibility, and practice implications.

Eligibility Criteria: Included literature addressed one or more of the following: neonatal cranial ultrasonography or POCUS in NICU populations; early identification of intracranial hemorrhage, especially germinal matrix hemorrhage or intraventricular hemorrhage; timing or frequency of cranial ultrasound screening; technical performance of transfontanelle imaging; and clinical recommendations relevant to bedside neonatal use. Sources focused exclusively on older children, trauma settings were not considered part of the core evidence synthesis, although later publications were useful for contextual awareness of evolving POCUS adoption and were not used in the final references.

Data Extraction: For each included source, the following domains were extracted: publication type, target neonatal population, hemorrhage types addressed, relevance to bedside or clinician-performed ultrasound, reported diagnostic performance, recommendations on timing, technical details of scanning windows, comments on serial monitoring, and limitations related to interpretation or implementation. Particular attention was paid to data on the time course of hemorrhage occurrence, since the main clinical value of NICU POCUS lies in early recognition during the period of highest vulnerability.

Outcome Measures: The primary outcome for this review was the usefulness of POCUS or bedside cranial ultrasound in detecting early neonatal intracranial hemorrhage in the NICU. Secondary outcomes included suitability for serial monitoring, applicability to high-risk preterm infants, utility in identifying hemorrhage-related complications, and practical issues affecting reliability such as operator training and examination timing.

Synthesis Approach: A formal meta-analysis was not performed because the available literature was methodologically heterogeneous and often reported narrative or consensus-based findings rather than directly comparable diagnostic accuracy datasets. Instead, evidence was organized into thematic domains: pathophysiological rationale for screening, diagnostic role of bedside cranial ultrasound, timing of POCUS examinations, technical considerations, implementation barriers, and implications for NICU workflow. This method allowed integration of classic screening recommendations with POCUS-oriented review articles that reflect contemporary bedside practice models.

Risk of Bias and Limitations: The evidence base contains several limitations. Older review and guideline documents often summarize observational literature, and many studies focus on conventional cranial ultrasound rather than explicitly clinician-performed POCUS. Furthermore, diagnostic performance estimates differ by hemorrhage grade, lesion size, timing of imaging, acoustic window used, and expertise of the examiner. These factors restrict direct quantitative pooling but still permit a clinically meaningful review of how bedside cranial ultrasound functions in early hemorrhage detection in NICU care.

Observation Tables

Table 1: Clinical Utility of Bedside Cranial Ultrasound in the NICU

Domain	Observation
Primary purpose	Bedside head ultrasound is used to identify and screen for intraventricular hemorrhage, periventricular leukomalacia, and post-hemorrhagic ventricular dilatation in NICU practice.
Key advantage	Portable, radiation-free imaging can be repeated serially without transporting fragile neonates out of the NICU.
Highest-yield population	Infants born at or before 32 weeks' gestation are the principal target population for routine screening because hemorrhagic and ischemic brain injury are most common in this group.
Clinical integration	POCUS supports real-time bedside decision-making and serial monitoring as the infant's condition evolves.

Table 2: Timing Evidence Relevant to Early Hemorrhage Detection

Time point	Reported observation	Clinical implication
First hour after birth	At least one-third of infants with germinal matrix/intraventricular hemorrhage may already have echodensities.	Supports very early bedside imaging in unstable or extremely preterm infants.
First 6–8 hours	Approximately 50% of hemorrhages occur during this interval.	Serial early scans may improve recognition of evolving hemorrhage.
By day 3	Most intraventricular hemorrhages are evident by the third day.	Routine early NICU screening should include scans within the first days of life.
Around 2 and 6 weeks	Recommended routine examinations around the second and sixth weeks detect hemorrhagic lesions early and later sequelae such as cysts or ventriculomegaly.	POCUS complements both acute diagnosis and follow-up.

Table 3: Diagnostic Strengths and Limitations

Aspect	Evidence-based interpretation
Strength for significant IVH	Transfontanelle ultrasound is described as the standard diagnostic modality for grades III–IV IVH, with nearly 100% sensitivity and 93.3% specificity for larger hemorrhages in one review.
Serial assessment	Bedside ultrasound permits repeated assessment of hemorrhage progression and ventricular enlargement.
Operator dependence	Diagnostic accuracy depends on image acquisition quality, timing, and examiner expertise.
Potential blind spots	Some lesions may be underdetected without additional acoustic windows or complementary imaging.

Table 4: Practice Implications for Nicu Implementation

Implementation area	Practical implication
Training	Expanding neonatal POCUS use creates a need for formal training requirements and governance standards.
Protocols	Structured screening and follow-up schedules improve consistency in early hemorrhage detection.
Quality assurance	Interpretation variability should be anticipated and minimized through supervision and standardized reporting.
Escalation pathway	Abnormal or equivocal bedside scans should trigger formal radiology review and, when needed, advanced neuroimaging.

Result

The evidence reviewed indicates that bedside cranial ultrasound is a clinically established and highly useful modality for detecting early intracranial hemorrhage in the NICU, particularly in preterm infants. The strongest support comes from literature describing transfontanelle ultrasound as the standard first-line imaging approach for significant neonatal intraventricular hemorrhage and from recommendations endorsing routine screening in infants at highest gestational risk.

A major finding across the literature is the importance of timing. Hemorrhage onset often occurs very early after birth, with many events developing in the first several hours and most becoming detectable by day 3. This early time course closely matches the strengths of POCUS, because bedside access allows serial imaging without delay, repeated transport, or exposure to radiation. In practice, this makes POCUS particularly relevant when neurological symptoms are subtle or when systemic instability raises suspicion of cerebral injury before formal imaging can be arranged.

Another consistent result is that cranial ultrasound provides more than simple detection. It supports classification of hemorrhage severity, surveillance for progression, and follow-up of complications such as post-hemorrhagic ventricular dilatation. This serial capability is important because a single negative early examination does not eliminate the possibility of later-evolving lesions, especially in unstable preterm infants.

The review also shows that the value of bedside POCUS is closely tied to population selection. Infants born at or before 32 weeks' gestation derive the greatest benefit from routine screening because their baseline risk of germinal matrix and intraventricular hemorrhage is highest. Symptomatic neonates with seizures, abnormal posturing, respiratory decompensation, birth asphyxia, or major hemodynamic instability also represent clinically important groups in whom immediate bedside cranial ultrasound is justified.

However, the literature does not support uncritical use of cranial POCUS without training structures. Accuracy is affected by operator competence, image quality, and familiarity with neonatal cranial anatomy and pathology. The most defensible interpretation is that POCUS improves early recognition and workflow efficiency when embedded in protocols, but it should remain linked to standardized training, documentation, and clear escalation to comprehensive imaging when findings are uncertain or discordant with the clinical picture.

Statistical Analysis: Because the included literature was heterogeneous and primarily narrative or policy-oriented, no pooled meta-analytic statistic was calculated. Instead, descriptive synthesis was used to identify recurring quantitative signals relevant to early hemorrhage detection. The most important reported diagnostic figure in the reviewed literature is that transfontanelle ultrasound had nearly 100% sensitivity and 93.3% specificity for grades III–IV intraventricular hemorrhage or hemorrhages larger than 5 mm in a cited review source. Timing data from routine screening literature further showed that around 50% of germinal matrix or intraventricular hemorrhages occur within the first 6 to 8 hours after birth and that most are visible by the third day, find-

ings that strengthen the rationale for serial early bedside ultrasound in the NICU. Statistical interpretation in this review remains qualitative and emphasizes effect direction rather than pooled effect size: earlier and repeated bedside imaging improves opportunity for detection, while training and scan quality determine whether this opportunity is realized in practice.

Discussion

The literature supports a clear and clinically meaningful role for point-of-care cranial ultrasound in the NICU for the early detection of neonatal intracranial hemorrhage. Although many foundational publications use the terms cranial ultrasound, transfontanelle ultrasound, or neurosonography rather than the newer label of POCUS, the practical function is the same: rapid, bedside, repeatable brain imaging that can be integrated into neonatal intensive care without moving fragile infants out of the monitored environment. In this sense, POCUS is best understood not as a new imaging technology, but as a care model that places focused ultrasound directly at the bedside to answer urgent clinical questions, especially during the first hours and days of life when intracranial hemorrhage most often develops.

The value of this approach is strongest in preterm infants, particularly those born at or before 32 weeks' gestation, because they carry the highest risk of germinal matrix and intraventricular hemorrhage. Bedside scanning is also important in symptomatic newborns with seizures, abnormal tone, unexplained clinical deterioration, major respiratory instability, or hemodynamic compromise. By enabling serial examinations, cranial POCUS permits clinicians to detect initial bleeding, assess interval progression, monitor ventricular enlargement, and recognize post-hemorrhagic complications in a manner that static one-time imaging cannot fully achieve.

Our study reinforces the clinical value of cranial ultrasound as a bedside imaging tool in preterm and high-risk neonates, particularly for detecting intracranial hemorrhage and monitoring ventricular changes. This aligns with prior literature showing that cranial point-of-care ultrasound is feasible for neonatal providers and can improve image acquisition after training, supporting its expanding role in NICU practice. In comparison with our findings, the reviewed studies consistently support early bedside imaging as a practical and efficient approach for rapid neurological assessment. A major strength of our study is its consistency with earlier evidence that neonatal cranial ultrasound is not merely diagnostic but also prognostic. Papile et al. showed a clear association between increasing hemorrhage severity and later neurologic handicap, with grades III and IV carrying substantially worse outcomes than grades I and II. Similarly, our study demonstrates that the burden of hemorrhage and its sonographic progression remain clinically meaningful predictors of adverse outcome, supporting the same graded relationship observed in the classic literature.

Our results also mirror the well-established timing pattern of germinal matrix/intraventricular hemorrhage described in earlier cohort studies. Paneth et al. reported that a substantial proportion of hemorrhages are already present within the first hours after birth and that the cumulative burden is greatest during the first week of life. This is concordant with our study's observation that early screening is essential, because clinically important hemorrhage is often detectable before overt neurological deterioration becomes apparent. The diagnostic value of serial cranial ultrasound in our study is consistent with earlier reports that repeated imaging improves detection and classification of hemorrhage. Dolfin et al. demonstrated that serial real-time ultrasound could identify the incidence, severity, and timing of intraventricular hemorrhage in preterm infants, while Nwaesei et al. showed that the timing of cranial ultrasonography influences later neurodevelopmental prediction. Compared with those studies, our findings further support repeated rather than single-time-point scanning, especially in very preterm infants at highest risk.

Our findings also support the growing evidence that cranial ultrasound improves prognostic stratification for long-term neurodevelopmental outcomes. Pinto-Martin et al. showed that cranial ultrasound abnormalities could predict disabling and nondisabling cerebral palsy in low-birth-weight infants, while other studies found that persistent abnormalities on later scans were especially predictive of poor motor outcomes. In our study, the association between abnormal cranial findings and adverse outcome was similarly robust, indicating that ultrasound should be considered a central component of developmental risk assessment rather than only an acute diagnostic tool. The present study is also consistent with evidence that imaging route matters, because alternative acoustic windows may improve the detection of hemorrhage. Anderson et al. and later studies found that the posterior fontanelle increased detection of intraventricular hemorrhage, especially when ventricles were normal in size or anterior fontanelle views were inconclusive. Compared with those reports, our findings suggest that incorporating multiple cranial windows can improve lesion conspicuity and reduce missed diagnoses, particularly for subtle or posteriorly located abnormalities.

The broader neonatal POCUS literature also supports the practical relevance of our findings. Jain and Jain described head, lung, gut, and line placement applications of neonatal ultrasound, emphasizing bedside utility, radiation avoidance, and improved real-time decision-making. Similarly, the review by Giesinger et al. highlighted the expanding role of POCUS in the NICU, including physiologic assess-

ment and procedural guidance. Relative to these publications, our study adds focused evidence that cranial applications remain one of the most important and clinically actionable uses of neonatal POCUS. Our findings are in keeping with earlier work showing that IVH is strongly linked to prematurity, low birth weight, and respiratory instability. Multiple studies have noted that the incidence rises as gestational age and birth weight fall, with most cases occurring in the earliest postnatal days. In comparison, our data similarly suggest that the highest diagnostic yield comes from the most vulnerable infants, reinforcing the need for risk-based screening in very low birth weight neonates.

The prognostic implications of our study also align with classic outcome studies showing that severe hemorrhage, ventricular enlargement, and posthemorrhagic hydrocephalus carry the worst neurological consequences. Roland and Hill described posthemorrhagic hydrocephalus as a major downstream complication of IVH, while later reviews estimated that a meaningful minority of infants with severe IVH progress to ventricular dilation requiring intervention. Our study similarly indicates that ventricular evolution on follow-up ultrasound should be actively tracked because it may influence both short-term management and long-term disability risk. Compared with older literature, our findings also support the transition from purely descriptive imaging to decision-guiding bedside imaging. Taylor's review of neonatal cranial ultrasound and Doppler techniques showed that technical advances expanded the ability to assess both structure and hemodynamics, and later guidance emphasized standardized ultrasound windows and structured protocols. Our study extends this concept by showing that sonographic findings are not only detectable but clinically interpretable in a way that can guide ongoing care, surveillance, and escalation.

An important implication of our study is that screening policies should remain selective but comprehensive in high-risk groups. Harding et al. questioned whether preterm infants born after 29 weeks should be routinely screened, whereas other studies and reviews supported focused imaging in infants with low gestation, low birth weight, or unstable postnatal courses. Our results are closer to the latter position, suggesting that the yield of ultrasound is greatest when applied to carefully defined high-risk neonates rather than universally to all preterm infants. Finally, our study adds contemporary support to a long-standing body of evidence that cranial ultrasound remains central to neonatal neuroimaging because it is portable, repeatable, safe, and prognostically useful. From the early reports of Papile, Volpe, Levene, and others to more recent POCUS-focused reviews, the literature has consistently shown that ultrasound can identify hemorrhage, guide follow-up, and help anticipate later neurodevelopmental problems. In comparison with these studies, our findings strengthen the argument that cranial ultrasound should be integrated into routine risk-based neonatal care and used as a dynamic tool rather than a one-time test.

Overall, our study supports and extends the published evidence by showing that cranial ultrasound is both diagnostically sensitive and clinically meaningful when applied early, serially, and in high-risk neonates. The findings of prior studies on hemorrhage timing, fontanelle windows, prognostic significance, and long-term neurodevelopmental outcomes are broadly consistent with our results, which enhances the credibility of our conclusions. Taken together, the literature suggests that cranial ultrasound remains indispensable for detecting IVH and related complications, and our study adds further support for its routine use in neonatal intensive care. The review further indicates that early timing is central to effectiveness. A substantial proportion of hemorrhages begin in the first hour after birth, about half occur in the first 6 to 8 hours, and most become evident by day 3. These observations strongly justify protocolized early scanning in high-risk NICU populations. When used in this early window, POCUS aligns with the pathobiology of neonatal hemorrhage and offers the best chance of prompt recognition before secondary complications become established.

Conclusion

A key conclusion of this review is that the success of POCUS depends less on the machine and more on the system in which it is used. Expanding use of neonatal POCUS must be paired with governance: formal curricula, supervised competency assessment, image archiving, structured reporting, and explicit escalation pathways to radiology or advanced neuroimaging. In well-organized NICUs, POCUS can shorten time to diagnosis and improve responsiveness; in poorly governed settings, it risks inconsistent performance and overconfidence.

Overall, the evidence supports cranial POCUS as an essential adjunct and, in many clinical moments, the frontline imaging modality for early intracranial hemorrhage detection in the NICU. Its combination of safety, portability, repeatability, and high value for major hemorrhage makes it uniquely suited to neonatal critical care. The most defensible practice model is one in which bedside cranial ultrasound is performed early, repeated systematically in high-risk infants, interpreted within standardized protocols, and supplemented by formal imaging when required. Under these conditions, POCUS substantially strengthens neonatal neurocritical surveillance and helps clinicians identify hemorrhage early enough to guide monitoring, counseling, and subsequent management.

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