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DIAGNOSTIC VALUE AND RADIATION SAFETY CONSIDERATIONS OF COMPUTED TOMOGRAPHY IMAGING IN NEONATES: LITERATURE REVIEW

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Abstract
Background: Neonatal patients, particularly those in incubators, present unique diagnostic challenges due to physiological variability, high radiosensitivity, and susceptibility to complications. While ultrasound (US) and magnetic resonance imaging (MRI) are commonly preferred to minimize radiation exposure, the use of computed tomography (CT) is increasing in certain clinical contexts.
Purpose: This study aimed to evaluate the advantages and limitations of CT imaging in neonates, compare it with alternative modalities such as US and MRI, and identify strategies to optimize imaging while minimizing radiation exposure.
Methods: A systematic literature review was conducted using search terms including “neonate,” “incubator,” “very low birth weight,” “CT,” and “radiographic imaging.” Relevant studies addressing neonatal imaging techniques, clinical utility, and safety were analyzed. Key factors such as image quality, diagnostic performance, radiation exposure, and procedural feasibility were compared across imaging modalities.
Results: Ultrasound is cost-effective, portable, and safe, providing real-time evaluation for conditions such as intraventricular hemorrhage and hydrocephalus, but it is limited by lower resolution and operator dependency. MRI offers superior soft-tissue contrast, high-resolution imaging, and functional information, but is constrained by long scan times, high cost, need for sedation, and transport-related risks. CT provides rapid, high-resolution imaging, less sensitivity to motion artifacts, reproducibility independent of operator skill, and 3D reconstruction capabilities. Mobile CT further minimizes in-hospital transport. However, ionizing radiation poses long-term carcinogenic risks, particularly in radiosensitive neonatal tissues. Low-dose CT protocols, optimized pitch, gantry rotation, collimation, and neonatal-specific scan parameters can significantly reduce radiation exposure while maintaining diagnostic quality.
Conclusion: CT imaging remains a valuable tool for rapid and precise neonatal diagnostics, especially in acute or complex conditions. Careful justification, use of low-dose protocols, and patient-specific imaging strategies are essential to balance diagnostic benefits with potential radiation risks. Integration of alternative modalities such as US and MRI should be considered when appropriate to minimize cumulative exposure.

Keywords: Neonatal patient, Neonatal Intensive Care Unit, Radiologic examination, Diagnostic value of imaging, Radiation protection

INTRODUCTION

A newborn infant is defined as a baby up to 28 days (4 weeks) after birth. Premature infants, especially those born before 32 weeks of gestation, exhibit high mortality and morbidity rates [1–2]. According to data from the Centers for Disease Control and Prevention (CDC), approximately 10% of infants born in the United States are classified as very low birth weight, and their mortality rate accounts for 0.62% of all neonatal deaths [2]. The number of neonates admitted to incubators due to various medical conditions immediately after birth continues to rise. These neonatal patients require diagnostic and therapeutic approaches that differ from those used for adult and pediatric patients, as their physiological conditions vary widely and are often associated with complex comorbidities [1, 3–4]. Consequently, more precise and individualized clinical decision-making is necessary during diagnosis and treatment.

For instance, neonates are more sensitive to radiation exposure than children or adults; therefore, computed tomography (CT) is generally not preferred as a primary diagnostic tool. Instead, ultrasound and magnetic resonance imaging (MRI) are more commonly utilized [5–6]. Nevertheless, the number of CT examinations performed in neonates has been increasing. One study involving 156 neonates with complex congenital heart disease reported a total of 172 cardiac CT examinations, with some infants undergoing more than one scan [7]. CT imaging allows detailed visualization of neonatal anatomy by positioning the infant within a large circular gantry. Compared to conventional radiography, CT provides clearer delineation of internal structures, minimal

tissue overlaps, and faster image acquisition than ultrasound. It also offers high-resolution, three-dimensional evaluation of targeted organs [5]. Furthermore, CT scans can be performed in a shorter time frame than MRI, which may reduce the physiological stress on neonates [8].
However, several issues are associated with CT imaging in neonatal patients. The relatively high radiation dose may increase the risk of DNA damage during rapid cell division, leading to potential biological effects [9–10]. In addition, the use of contrast media for enhanced vascular visualization carries a risk of contrast-related adverse reactions. Finally, transporting neonates—particularly those in incubators—to the CT suite presents logistical and safety challenges [3–4]. Given these concerns, this study conducted a literature review to evaluate the advantages and limitations of ultrasound, MRI, and CT examinations in neonatal diagnostics and to identify strategies for optimizing imaging decisions that minimize risks while ensuring diagnostic accuracy.

MATERIALS AND METHODS

This study conducted a systematic literature review to evaluate the advantages and disadvantages of computed tomography (CT) examinations performed on neonatal patients receiving care in incubators, and to compare them with alternative imaging modalities such as ultrasound, conventional radiography, and magnetic resonance imaging (MRI).
Relevant literature was identified using search terms including "neonate," "incubator," "very low birth weight," "CT," and "radiographic imaging." Additional related studies were identified through reference tracing and manual searches of academic publications. After screening for relevance, studies addressing neonatal imaging techniques and their clinical implications were selected, and key data were extracted for analysis.
From a methodological perspective, the study synthesized and analyzed existing research in the radiologic field to establish a coherent framework for evaluating neonatal imaging practices. The process involved a stepwise approach: searching databases for studies related to CT examinations in neonates; assessing the clinical utility and safety of these procedures; and comparing the advantages and limitations of CT imaging for neonates, particularly those within incubators.
Based on the findings, the study aimed to identify optimal imaging strategies that could maximize diagnostic benefits while minimizing radiation exposure, and to determine key considerations for performing CT scans in neonatal patients.

RESULT

Ultrasound (US) is a low-cost, radiation-free imaging modality that can be performed at the patient's bedside, enhancing convenience for neonatal patients [11–12]. US is particularly useful for real-time evaluation of intraventricular hemorrhage and hydrocephalus. Traditionally, cranial ultrasound (CUS) can detect major abnormalities, including intraventricular hemorrhage, periventricular hemorrhagic infarction, and post-hemorrhagic ventricular enlargement [13]. In a study of 52 infants, US findings were consistent with CT results, and various conditions—including myelomeningocele, hydrocephalus, intracranial hemorrhage, inflammatory disorders, and extraventricular fluid accumulation—could be diagnosed without additional CT imaging [14–15].
However, US has limitations. The relatively low resolution restricts evaluation of fine brain structures and subtle lesions, often necessitating follow-up CT or MRI to increase diagnostic accuracy [6,13]. Furthermore, the reliability of US depends significantly on the operator's skill level, which can affect diagnostic consistency [16].
Magnetic Resonance Imaging (MRI) provides higher-resolution images than US and CT, with superior diagnostic performance, particularly for brain abnormalities [5,8,17]. MRI is highly effective in detecting white matter changes and other neurological pathologies, offering excellent soft-tissue contrast and functional information regarding cardiac function and hemodynamics. It is also valuable for assessing complex anatomical structures [6,18–20]. MRI is considered essential for neonates presenting with encephalopathy, seizures, unexplained apnea, infection, metabolic disorders, congenital anomalies, or other neurological symptoms [5].
Nonetheless, MRI has several drawbacks. It is time-consuming, expensive, and limited in availability. Neonates are particularly sensitive to motion, requiring additional measures to minimize movement during scanning. Sedation, often necessary for MRI, carries risks of cardiovascular, respiratory, and neurological complications in vulnerable neonates [5,9,21–22]. The sedation-related mortality rate is approximately 1 in 3,900, more than twice that of general anesthesia, and sedation may induce neuronal apoptosis, potentially resulting in long-term impairments in learning, memory, and motor function [16,23–25].
Transporting neonates to the MRI suite also introduces risks. More than 25% of neonates experience cardiovascular or respiratory instability, or temperature fluctuations during in-hospital transport [1,3]. Extended positioning outside the intensive care unit (ICU) can exacerbate physiological instability and increase the risk of falls, equipment dislodgement, infection, and delayed emergency response. Moreover, moving a single patient often requires multiple staff members, potentially disrupting care for other patients in the ward [26–28].
Computed Tomography (CT) offers faster imaging than MRI and higher resolution than US, making it suitable for emergency diagnostics. Although CT involves ionizing radiation, it generally poses lower overall morbidity

and mortality risks compared to sedation-requiring MRI and is useful for evaluating acute conditions such as intracranial hemorrhage [9]. Coronal CT allows precise localization of disease, accurate airway depiction, assessment of airway dilation, detection of atrophic bronchi, and characterization of vascular structures and liver-separated masses [29]. The advent of mobile CT units enables bedside imaging, reducing transport-related risks, wait times, and staff workload [30–31].

However, CT is limited by its use of ionizing radiation, which carries concerns about DNA damage and long-term cancer risk. Neonates and pediatric patients are more radiosensitive than adults, increasing their susceptibility [9–10,16,32–35]. Radiation exposure to sensitive tissues such as the thymus, breast tissue, or gonads further elevates the risk of malignancy [36–37]. Moreover, CT provides lower soft-tissue contrast than MRI, limiting detailed evaluation of certain structures.

DISCUSSION

Computed tomography (CT) offers several advantages in neonatal imaging. As a non-invasive modality, CT provides rapid and accurate diagnostic information, is less sensitive to patient movement than MRI, reducing motion artifacts, and offers higher-resolution imaging than ultrasound. Unlike ultrasound, CT results are largely independent of operator skill, and the use of mobile CT units can minimize patient transport, reducing the risks associated with in-hospital transfers (IHT) [30–31]. CT also allows three-dimensional reconstruction of various organs and pathological conditions, enabling precise anatomical assessment. In the context of neonatal care, CT can provide critical diagnostic information and allow prompt identification of severe conditions.

However, due to the high radiosensitivity of neonatal tissues, CT exposure increases the risk of malignancy in developing organs. Studies have shown that a fetal exposure of approximately 10 mSv corresponds to an estimated 6% excess lifetime cancer risk per sievert during childhood, which aligns with a 14% lifetime cancer mortality risk per sievert for exposed neonates [38–39]. Therefore, CT examinations should be carefully justified and, when indicated, performed using low-dose CT protocols to minimize radiation exposure. Alternative modalities that do not involve ionizing radiation, such as MRI or ultrasound, should also be considered whenever clinically feasible.

Despite the limitations, the benefits of CT can be maximized by adhering to the principle of balancing harm and benefit. By reducing the milliampere-second (mAs) settings during scans, the overall radiation dose to the neonate is decreased, while motion artifacts are minimized, reducing the need for repeat imaging [38–43]. While the linear no-threshold (LNT) model assumes a linear increase in cancer risk even at low doses, evidence suggests that acute exposures below 100 mSv or chronic low-dose exposure may have negligible carcinogenic effects [9,44].

Studies investigating low-dose CT protocols demonstrated that reducing mAs by 60% slightly increased image noise without significantly affecting diagnostic quality, while the dose-length product (DLP) decreased by 35% compared to standard-dose protocols [45–48]. Similarly, low-dose high-resolution CT (HRCT) protocols achieved a 72–80% reduction in radiation dose while maintaining sufficient diagnostic image quality [49]. Reducing gantry rotation time from 1.0 s to 0.5 s further decreased radiation exposure by approximately 50% [36,50].

Helical CT offers the advantage of rapid scan times, which not only shortens the overall procedure but also reduces total radiation exposure in neonates [39,41]. Increasing the pitch further decreases dose, reduces motion artifacts, and shortens breath-hold requirements, which is critical for neonatal imaging [40]. Additionally, using a smaller field of view (FOV) and optimized collimation allows acquisition of target images while minimizing overall radiation exposure [36,45,51].

Given these advantages and limitations, reducing radiation exposure remains a primary consideration in neonatal CT imaging. The development of pediatric- or neonatal-specific CT protocols is essential, as standard adult CT protocols deliver 2–6 times more radiation than necessary for pediatric patients [32,50]. Tailored protocols based on patient size and clinical needs can prevent unnecessary exposure while maintaining diagnostic quality [43,51]. Ultimately, minimizing neonatal radiation exposure involves reducing the number of CT scans performed and implementing patient-specific scan parameters for neonates and children [36].

CONCLUSION

CT imaging provides critical diagnostic information in neonatal patients, offering rapid, high-resolution, and operator-independent assessments, particularly in emergency or complex clinical scenarios. Despite its advantages, ionizing radiation exposure requires careful consideration due to the heightened radiosensitivity of neonatal tissues and long-term cancer risks. Implementing low-dose CT protocols, neonatal-specific scanning parameters, optimized gantry rotation and pitch, and minimizing unnecessary scans can effectively reduce radiation exposure while preserving image quality. Ultrasound and MRI remain essential complementary modalities, offering radiation-free imaging and superior soft-tissue contrast, respectively. Ultimately, a balanced, patient-centered imaging approach—guided by the principles of harm reduction and diagnostic efficacy—is crucial for safe and effective neonatal care.

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