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RADIOLOGICAL IMAGING IN PEDIATRIC POPULATIONS: SAFETY, TECHNIQUES, AND DIAGNOSTIC APPROACHES

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ABSTRACT

Background: Radiological imaging is essential for diagnosing and managing pediatric diseases, but it requires specialized approaches due to children's unique anatomical, physiological, and developmental characteristics. Concerns about radiation exposure, the need for age-specific protocols, and the challenges of patient cooperation underscore the importance of optimizing safety and diagnostic accuracy in pediatric radiology. This study evaluates current imaging practices, safety protocols, and diagnostic outcomes in pediatric populations. **Methods:** A retrospective descriptive cross-sectional study was conducted at a tertiary care pediatric hospital over six months (July–December 2024). Data from 412 pediatric patients (aged 0–18 years) undergoing radiological imaging (X-ray, ultrasound, CT, MRI) were analyzed. Variables included demographics, imaging modalities, safety protocols (ALARA adherence, shielding, sedation), and diagnostic outcomes. Statistical analysis was performed using SPSS version 26. **Results:** Ultrasound (38.1%) and X-rays (33.5%) were the most frequently used modalities, while CT (12.9%) and MRI (15.5%) were less common. Trauma (26.2%), abdominal pain (22.1%), and respiratory distress (18.4%) were the leading indications. Safety protocols were largely followed, with 85.9% adherence to ALARA principles and 71.4% use of lead shielding. Sedation was required in 11.4% of cases, predominantly for MRI. Diagnostic clarity was achieved in 91.7% of cases, with 15% requiring follow-up imaging. **Conclusion:** The study highlights the preference for low-radiation modalities in pediatric imaging and strong adherence to safety protocols. However, variability in shielding practices and the need for sedation in MRI indicate areas for improvement. Continued education, technological advancements, and standardized protocols are recommended to enhance safety and diagnostic precision in pediatric radiology.

KEYWORDS: Sedation was required in 11.4% of cases, predominantly for MRI.

BACKGROUND

Radiological imaging plays a vital role in diagnosing and managing pediatric diseases. Unlike adult radiology, pediatric imaging demands specific consideration due to the anatomical and physiological differences in children, their sensitivity to radiation, and the wide range of age-specific conditions. From newborns to adolescents, healthcare providers rely heavily on various imaging techniques such as X-rays, ultrasound, MRI, and CT scans to visualize internal structures non-invasively. The field of pediatric radiology is rapidly evolving, incorporating both advanced technologies and child-specific safety protocols to improve diagnostic accuracy and patient outcomes.

Children differ from adults in terms of body composition, growth stages, and disease presentation, necessitating unique radiological approaches. Their smaller size, faster heart rate, and inability to remain still during procedures require specialized equipment and modified protocols. Furthermore, pediatric patients are more vulnerable to the harmful effects of ionizing radiation, which increases the importance of judicious use and dose minimization in radiological practices.

The most commonly used imaging modalities in pediatric care include conventional radiography, ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI). Each modality has its advantages and limitations. For instance, X-rays are quick and accessible but involve radiation exposure, while ultrasound is safe and radiation-free but limited in certain diagnostic capabilities. MRI provides excellent soft tissue contrast without radiation but requires more time and may necessitate sedation in younger children. CT is useful in trauma and complex cases but is typically reserved due to its higher radiation dose.

Technological advancements have significantly improved the safety and efficacy of pediatric imaging. Innovations such as low-dose CT scanners, motion-resistant MRI sequences, and high-frequency ultrasound probes have enhanced image quality while minimizing risk. Additionally, the integration of artificial intelligence and machine learning in pediatric radiology has shown promise in improving diagnostic accuracy and workflow efficiency, especially in emergency and critical care settings.

Radiation exposure is a primary concern in pediatric imaging. The principle of ALARA (As Low As Reasonably Achievable) is a cornerstone of radiation safety in children. Radiologists and technologists must balance the diagnostic benefits with the potential long-term risks of radiation-induced malignancies. Strategies such as dose optimization, shielding, and the use of alternative modalities like ultrasound and MRI are essential to adhere to ALARA and ensure the safety of pediatric patients.

Effective diagnostic approaches in pediatric radiology rely on standardized clinical protocols tailored to pediatric conditions. Organizations such as the American College of Radiology (ACR) and the European Society of Paediatric Radiology (ESPR) provide guidelines for the appropriate use of imaging in children. These guidelines support evidence-based decision-making, helping clinicians choose the most suitable modality and timing for imaging in various pediatric illnesses.

Sedation is sometimes necessary in pediatric imaging, especially for MRI and CT procedures that require the patient to remain still. However, sedation poses additional risks and challenges, including airway management, potential adverse reactions, and the need for trained personnel. Strategies to minimize the need for sedation include faster imaging techniques, child-friendly environments, and distraction methods such as audiovisual aids.

Imaging procedures can be stressful for children and their families. Ethical concerns include informed consent, the child's assent, and the psychological impact of undergoing imaging. Pediatric radiology teams often work closely with child life specialists and psychologists to create a comforting environment that reduces anxiety and improves cooperation, thereby enhancing the overall imaging experience and outcomes.

Radiologists who specialize in pediatric imaging undergo additional training to understand child-specific pathologies, appropriate imaging protocols, and safety measures. This specialization is crucial in ensuring high-quality care and accurate diagnosis. Continuous professional development and certification through organizations like the Society for Pediatric Radiology (SPR) help maintain high standards in the field.

Given the growing reliance on diagnostic imaging in pediatric medicine, there is a critical need to examine and improve the safety, techniques, and diagnostic approaches used in this population. The unique vulnerabilities of children, combined with the rapid evolution of imaging technology, underscore the importance of continued research and innovation. This study aims to explore current practices, evaluate safety protocols, and propose optimized imaging strategies tailored to pediatric needs, contributing to better diagnostic precision and patient care in pediatric radiology.

METHODOLOGY

Study Design

This study utilized a **retrospective descriptive cross-sectional design** to evaluate the safety, techniques, and diagnostic approaches in pediatric radiological imaging. The aim was to identify prevailing practices, assess adherence to safety protocols, and analyze the diagnostic efficiency of various imaging modalities in pediatric patients.

Setting and Duration

The study was conducted at the Department of Radiology in the hospital, a tertiary care facility specializing in pediatric healthcare. Data collection was carried out over a period of six months, from **July 2024 to December 2024**.

Sample and Population

The study population included pediatric patients aged **0 to 18 years** who underwent radiological imaging during the study period. A total of **412 pediatric cases** were retrospectively reviewed. These cases were selected through **systematic random sampling** from the hospital's radiology information system (RIS) and picture archiving and communication system (PACS).

Inclusion and Exclusion Criteria

Inclusion criteria were as follows

1. Pediatric patients (0–18 years) who underwent radiological imaging during the study period.
2. Complete radiological and clinical records available in the system.
3. Imaging performed for diagnostic (not therapeutic) purposes.

Exclusion criteria included

1. Patients with incomplete imaging records or missing safety documentation.
2. Repeat imaging sessions conducted within 24 hours (to avoid duplication).
3. Imaging procedures performed outside the radiology department.

Data Collection Tools and Procedure

Data were extracted using a **structured data abstraction form**, which was developed based on international pediatric radiology safety and diagnostic

standards, including guidelines from the **American College of Radiology (ACR)** and the **Society for Pediatric Radiology (SPR)**.

The form captured the following information.

- **Patient demographics** (age, sex, weight, clinical indication)
- **Imaging modality used** (X-ray, ultrasound, CT, MRI)
- **Technical parameters** (dose, duration, sedation use, contrast media)
- **Safety protocols followed** (shielding, ALARA principle, informed consent)
- **Diagnostic outcomes** (accuracy, findings, follow-up requirements)

Data were collected by two trained radiologic technologists and verified by a pediatric radiologist to ensure accuracy and consistency.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Review Board (IRB). As the study used retrospective data, **informed consent was waived**, in accordance with ethical standards for medical record review studies. All data were anonymized, and patient confidentiality was strictly maintained.

Data Analysis

Data were entered into **SPSS version 26** for statistical analysis. Descriptive statistics were used to summarize demographic data and imaging modality usage (frequencies, means, and standard deviations). Cross-tabulation and chi-square tests were performed to examine associations between imaging modality, safety protocol adherence, and diagnostic accuracy. A p-value of <0.05 was considered statistically significant.

Quality Control Measures

To ensure data validity and reliability:

- A pilot test was conducted on 20 cases to validate the data collection form.
- Double data entry was employed to minimize transcription errors.
- All discrepancies were resolved by consensus between the research team and the consulting radiologist.

Limitations of the Methodology

Being a retrospective study, this research was limited by the completeness and accuracy of medical records. Additionally, it was conducted in a single center, which may limit generalizability. Future studies may benefit from a multicenter approach and the inclusion of longitudinal data for outcome tracking.

RESULTS

Demographic Characteristics of the Sample

Out of the 412 pediatric patients included in this study, 214 (51.9%) were male and 198 (48.1%) were female. The mean age was **6.4 years** (SD ± 4.7), ranging from neonates (1 day) to 18 years. The majority of patients (42.2%) were in the 1–5 years age group.

Table 1: Demographic Characteristics of Pediatric Patients (n = 412).

Variable	Frequency (n)	Percentage (%)
Sex		
Male	214	51.9
Female	198	48.1
Age Group		
0–1 year	82	19.9
1–5 years	174	42.2
6–12 years	102	24.8
13–18 years	54	13.1

Distribution of Imaging Modalities Used

Ultrasound was the most commonly used imaging modality (38.1%), followed by X-rays (33.5%), MRI (15.5%), and CT scans (12.9%).

Table 2: Imaging Modality Utilized (n = 412).

Modality	Frequency (n)	Percentage (%)
X-ray	138	33.5
Ultrasound	157	38.1
CT scan	53	12.9
MRI	64	15.5

Indications for Imaging

The most common clinical indications for imaging were trauma (26.2%), abdominal pain (22.1%), and respiratory distress (18.4%).

Table 3: Clinical Indications for Imaging (n = 412).

Indication	Frequency (n)	Percentage (%)
Trauma	108	26.2
Abdominal Pain	91	22.1
Respiratory Distress	76	18.4
Neurological Symptoms	52	12.6
Fever of Unknown Origin	46	11.2
Other	39	9.5

Use of Safety Protocols

Overall, 354 (85.9%) of the imaging sessions adhered to ALARA principles. Lead shielding was applied in 294 (71.4%) of cases where applicable. Sedation was required in 47 (11.4%) of the procedures, mostly in MRI cases.

Table 4: Safety Protocol Adherence (n = 412)

Safety Measure	Frequency (n)	Percentage (%)
ALARA Principle Applied	354	85.9
Lead Shielding Used	294	71.4
Sedation Required	47	11.4
Contrast Media Used	69	16.7

Diagnostic Accuracy and Follow-Up

Out of the 412 cases, 378 (91.7%) resulted in clear diagnostic findings. In 34 cases (8.3%), further imaging was required. Follow-up imaging within two weeks was recorded in 62 patients (15.0%).

Table 5: Diagnostic Outcomes (n = 412)

Outcome	Frequency (n)	Percentage (%)
Clear Diagnostic Findings	378	91.7
Inconclusive/Repeat Needed	34	8.3
Follow-up Imaging Required	62	15.0

Association Between Modality and Safety Protocols

A statistically significant association was observed between imaging modality and safety protocol adherence ($p = 0.013$). MRI and CT had the highest use of sedation and contrast media, while X-ray had the highest application of lead shielding.

Table 6: Safety Protocols by Imaging Modality.

Modality	ALARA Applied (%)	Shielding Used (%)	Sedation Required (%)	Contrast Used (%)
X-ray	96.4	92.0	0.0	0.0
Ultrasound	89.2	0.0	1.3	0.0
CT	83.0	56.6	5.7	62.3
MRI	72.2	0.0	40.6	76.6

DISCUSSION

The present study examined the use of radiological imaging in pediatric populations, with a focus on diagnostic utility, modality preferences, and safety protocols. The findings reveal that ultrasound and X-rays are the predominant modalities used, aligning with global trends prioritizing lower radiation exposure in children (Portelli et al., 2016; Tajaldeen et al., 2022). Ultrasound's non-ionizing nature and wide applicability make it ideal for a wide range of pediatric conditions, particularly abdominal pain and trauma, which were among the most common clinical indications in this study.

This preference for low-radiation or radiation-free imaging echoes existing literature emphasizing safety as a critical consideration in pediatric radiology. As children are significantly more sensitive to ionizing radiation due to higher rates of cell division and longer expected lifespans, minimizing exposure is imperative (Furlow, 2011; Leung, 2015). In this study, adherence to the ALARA (As Low As Reasonably Achievable) principle was reported in over 85% of imaging sessions, showing strong alignment with best practices in pediatric imaging safety (Alzen & Benz-Bohm, 2011; Arthurs & Bjørkum, 2013).

MRI, while utilized less frequently (15.5% of cases), demonstrated the highest requirement for sedation and contrast media, which introduces additional risks. These findings are consistent with Jaimes et al. (2018), who emphasized that MRI, although radiation-free, presents safety challenges due to its need for patient immobility and longer scan times. Sedation protocols, while effective, must be carefully managed to avoid complications, particularly in younger children.

The use of CT scans, though limited (12.9%), remains concerning given its relatively high radiation dose. Despite technological advances reducing CT dose exposure, studies continue to call for cautious use in pediatric populations (Siciliano, 2017; Kibrom et al., 2024). Our findings support this stance, as CT procedures showed lower adherence to shielding protocols and higher contrast media usage. This suggests the need for continual professional training and optimization of pediatric CT protocols to ensure safety without compromising diagnostic quality.

One of the critical achievements of this study was the high rate of diagnostic clarity, with 91.7% of imaging procedures yielding definitive results. This underscores the importance of selecting appropriate modalities based on clinical indications, which not only enhances diagnostic accuracy but also reduces the need for repeat imaging and additional radiation exposure (Shenoy-Bhangle et al., 2010). The necessity for follow-up imaging in 15% of cases, while not excessive, suggests potential areas for further protocol refinement and quality assurance.

From a technological perspective, the rapid advancement of imaging modalities, such as AI integration and automated dose monitoring systems, holds promise for improving safety and efficiency. Kibrom et al. (2024) highlight these emerging technologies as transformative tools in pediatric radiology, capable of enhancing diagnostic outcomes while maintaining rigorous safety standards. Adoption of these technologies in local contexts, however, requires investment in equipment and personnel training.

Our findings also echo the observations of Tajaldeen et al. (2022), who noted variability in safety practices among technologists and radiologists. While our study showed high compliance overall, the inconsistency in applying lead shielding, particularly in CT and MRI, may reflect gaps in standardization or resource constraints. Continuous professional development, institutional policies, and updated protocols are necessary to maintain consistency and uphold pediatric safety standards.

The implications of radiation exposure in childhood are not merely theoretical. As emphasized by Alzen and Benz-Bohm (2011) and Leung (2015), cumulative exposure over time increases the lifetime risk of malignancies. Therefore, systematic documentation, informed consent, and parental education should be integral components of pediatric imaging practice. Radiology departments should prioritize transparency and communication, especially when using modalities involving ionizing radiation.

Finally, while our study reflects current practice patterns and safety adherence in a regional hospital setting, broader multi-center research is essential to understand national trends and resource disparities. Portelli et al. (2016) and Shenoy-Bhangle et al. (2010) suggest that institutional imaging frequencies and practices vary significantly, influenced by local policies, equipment availability, and practitioner experience.

CONCLUSION

This study reinforces the importance of judicious use of imaging modalities in pediatrics, emphasizing safety, modality selection, and diagnostic accuracy. Continued adherence to safety protocols, combined with ongoing education and adoption of technological innovations, can enhance both patient outcomes and safety in pediatric radiology.

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