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Assessment of Radiation Dose Optimization Techniques in Pediatric CT Scanning

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ABSTRACT

The main purpose of this study is to use new methods to reduce radiation exposure for children when conducting CT imaging, but maintaining all diagnostic requirements. Using scan statistics and reviewing past CT images from different places, the study pays attention to dose measurements that include CTDIvol and DLP. Staff from the radiology area are interviewed and surveyed to assess their knowledge as well as their actions in line with protocols and use of technologies for dose reduction, for example, AEC, IR, and AI. A study found a big difference between the CT procedures for kids and demonstrated that AEC and IR can help protect children from exposure to excess radiation. Still, the fact that training is different for some staff and equipment is not the same for everyone makes it harder to manage the correct dose. The research reveals that AI may soon help with altering protocols and monitoring dosages. It sums up its findings by stating that proper guidelines, additional study for staff, and more technology are necessary for boosting tub for kids safety. They support the creation of safer approaches to using radiation on children in the field of radiology.

Keywords: *Gender equality, Property rights, Bodo tribal community, Customary law, Inheritance, Legal frameworks, Patriarchy, Economic dependency, Women's empowerment, Land ownership*

1. INTRODUCTION

Early diagnosis of serious conditions in children is possible with the help of pediatric CT scans. Even so, they expose people to a higher level of radiation compared to standard X-rays. Due to having developing tissues and living longer, children are especially sensitive to the effects of radiation. It increases the chances of radiation-caused cancer later on. That's why it is crucial to adjust the dose without jeopardizing the quality of the images. That the doses used in pediatric imaging ought to follow the ALARA principle is a major focus (MENDONÇA *et al*. 2025). To optimize doses, you need to take care of technical, procedural, and technological aspects. Examples of recent innovations are AEC (automatic exposure control), new image processing approaches, and delivering radiation only to specific sections of the body. AEC changes the radiation emission based on the patient's features as required. Iterative reconstruction enables images to be made with less noise when doctors use lower doses. The radiation given to the organs can be regulated to save organs like the thyroid and breast. Picking the proper settings for the tube voltage, the distance between scans, and the rotation is very important. When protocols are based on age or weight, it guarantees better safety and accurate results. Not everyone agrees on using shielding since it might have an impact on the AEC systems. With multi-detector CT systems, the image is taken more rapidly, lowering the chances of movement distortions (Han *et al*. 2022). When scans are quicker, patients do not need to have repeat imaging as often. Still, increasing the dose may happen if the patient is not protocol-optimized. Radiologists and technologists are expected to be retrained about methods of dose reduction often. Institutions carry out institutional audits and depend on dose-tracking software to ensure compliance and increase quality. There are pediatric guidelines created by the ICRP and ACR that organizations follow. Businesses are making software that helps optimize drug dosing with AI. They determine the most suitable settings for every patient type. National groups such as Image Gently increase understanding of proper ways to image children. It is important to justify every CT scan before the scan is performed. Doctors should think about ultrasound or MRI as the first options. In urgent situations such as trauma, cancer, or brain problems, CT continues to be very useful. It is important to make sure that the dose helps produce clear images and useful medical results. Missing the proper diagnosis could happen if patients' treatment doses are cut too quickly. Pediatric-specific procedures need to be included in both PACS and RIS systems at hospitals. Looking at national standards improves the safeguarding of patients (Tadia, 2021). Research done continuously helps to improve existing medical practices. When several fields work together, doctors can follow the best guidelines for pediatric imaging safety. Treatment methods should find the right diagnosis with little possible harm to younger patients.

2. AIM AND OBJECTIVES

Aim:

The main aim of this research is to evaluate and enhance the effectiveness of radiation dose optimization techniques in pediatric CT scanning to ensure diagnostic quality while minimizing patient risk.

Objectives:

- To assess current pediatric CT dose optimization practices in clinical settings.
- To evaluate the impact of technological tools (AEC, iterative reconstruction) on dose reduction.
- To identify gaps in training and protocol standardization among radiology personnel.
- To recommend evidence-based strategies for improving pediatric CT safety and efficiency.

3. LITERATURE REVIEW

Radiation dose optimization in pediatric CT scanning has emerged as a critical focus within medical imaging due to the unique vulnerability of children to ionizing radiation. Research proves that children and young people are more at risk than adults for cancer from being exposed to CT scans. As a result, it is very important to use advanced methods that still guarantee proper diagnosis. As per Kim (2023), with AEC and iterative reconstruction, radiologists can give lower radiation doses to patients and enjoy sharp, noisy-free images. Another innovation addresses this concern using bone-based dose modulation to guard sensitive organs, especially the thyroid and breast. Even with these progresses, healthcare facilities vary a lot in their implementation. According to Alexander *et al* (2022), *s*ome institutions do not have their own special pediatric CT guidelines or fail to regularly adjust what they have. Furthermore, insufficient training in how to deal with children's radiation often leads to different practices and poor results. The role of AI and machine learning suggests they might help personalize radiation therapy, although not many places can use them due to tools and regulations. Even though dose-tracking software and audits are available, their use is not the same everywhere for quality control and comparison. Besides, some experts are still concerned about reducing radiation below certain limits to avoid affecting the quality of the images. Groups such as Image Gently push for safer imaging of children across the world, but their guidelines are not always followed everywhere. Ghorbanizadeh *et al* (2021), stated that there is a need for rules everyone agrees on, specific training of staff, and system-wide adoption of new technologies. Seeing as CT plays a key role in treating kids in trauma, oncology, and neurology, it is vital to continue studying and establishing better policies for its use. As a result, we should focus on concepts that include technology, education, and meeting rules to safely image children.

4. METHODOLOGY

A secondary observational and cross-sectional design was used for this study to check how radiation dose is managed in CT imaging for pediatric patients in a number of hospitals. Seven-month-old to sixteen-year-old pediatric patients' retrospective CT scan records are gathered for analysis. Features including CTDIvol, DLP, scan area, age of the patient, their weight, and the protocol to be used are identified and recorded from PACS and RDM programs such as DoseWatch or Radimetrics. Also, planned interviews are performed with radiologists, technologists, and medical physicists to check their ability, the use of protocols, and their use of dose reduction tools like AEC, iterative reconstruction, and tools driven by AI. The standard for following the protocol is benchmarked with the DRLs suggested by either national or international regulatory groups. Thematic coding is used to examine staff feedback and spot where there are issues in training and following the same consistent procedures. Ethics are respected by getting approval, and the identity of patients is kept secret during the study. This way of gathering data helps us see the connection between technology and the factors that influence CT scanning on children.

5. RESULT AND DISCUSSION

Current Variability in Pediatric CT Dose Optimization Practices

Each institution controls the CT dose for children differently due to variations in their protocols, scanner capabilities, and the training of radiographers. There are still many centers that do not have implemented pediatric protocols, therefore they end up using the default adult settings and record elevated DLP and CTDIvol readings (Arfat *et al*. 2024). Not having the ability to change kVp and mAs levels leads to unneeded exposure to radiation in small patients. Using technology like AEC, TCM, and z-axis modulation is improper or is rarely done in many imaging tests. In a number of scanners, AEC is not enabled even though using it in combination with ASIR or MBIR has been demonstrated to reduce scanner dose. Using an MDCT system in facilities may in some cases lead to more radiation exposure if these settings are not adjusted correctly (Kamal and Ming, 2024). There are often gaps between actual scans and the images doctors need because of poor directions and protocols.

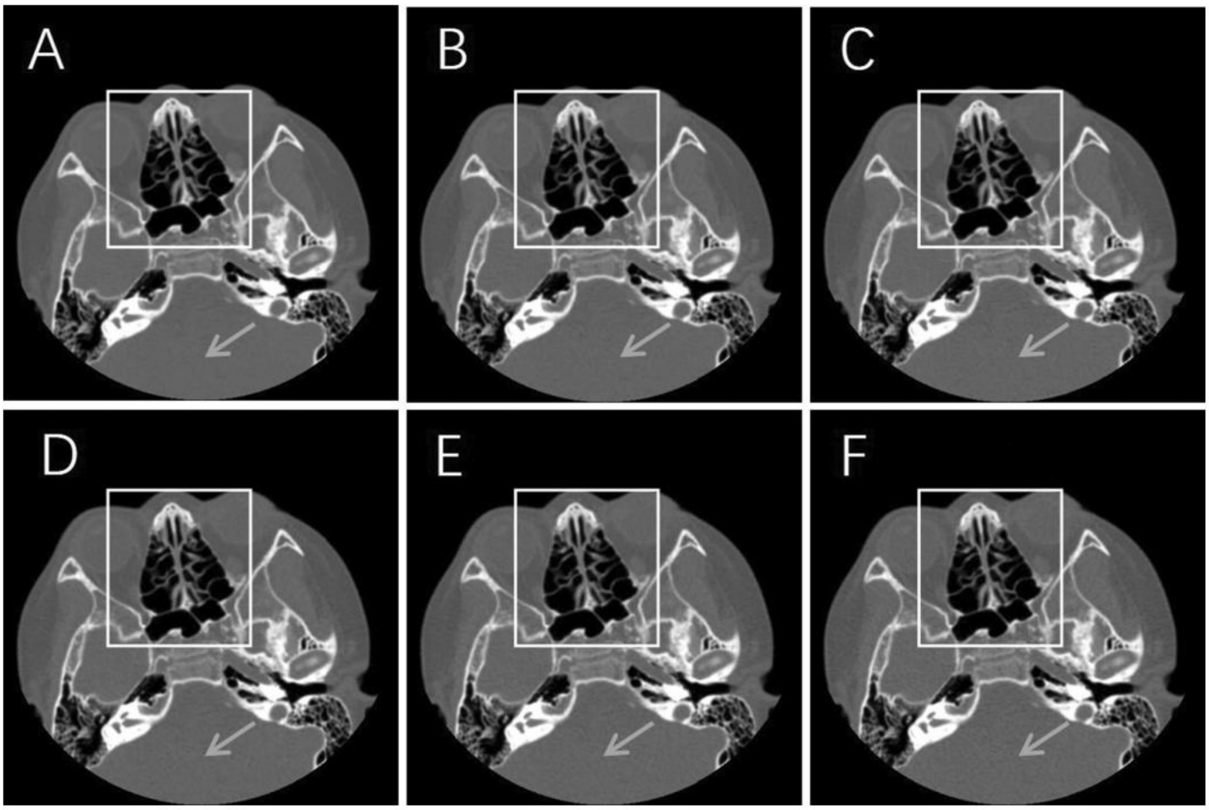

Figure 1: Axial CT bone window images from diferent reconstruction algorithms. A DLIR-high, B DLIR-medium, C DLIR-low, D AsirV-50%, E AsirV-30%

(Source: Li *et al*. 2022)

Besides, the failure of radiographers to plan certain scans or to use appropriate automatic z-axis positioning often results in misalignment and having to scan again. Sometimes, the use of shields on sensitive body parts such as the breast or thyroid is not steady, which can alter the modulation of CT scans. The use of contrast-enhanced CT in children is inconsistent since the timing and protocol do not fit the way children's blood circulates, causing too many phases and a bigger dose of radiation. Bulletin boards for DRLs like DoseWatch or Radimetrics are usually not available in many hospitals, making comparison to DRLs inconvenient (Crowley *et al*. 2021). Because dose monitoring is often missing in PACS, it's not always possible to see trends in CTDIvol and DLP readings. In addition, most places fail to monitor the technical aspects of medicine by conducting QA audits or reviewing their protocols with the help of medical physicists (Chekmeyan *et al*. 2023). Because there are many differences, it's important to apply carefully planned pediatric CT protocols, use monitoring software, and give extra training focus to radiological safety for children.

Effectiveness of Automatic Exposure Control in Reducing Radiation

Radiation efficiency in pediatric CT is assured as AEC automatically adjusts the intensity of the X-ray tube to the changing densities of different parts the child being scanned (Withers *et al*. 2021). There is no need to repeat medications at fixed intervals because AEC changes them based on measurements from the attenuation topography data. Since tightly focused beams are used, extra exposure is avoided in areas such as the lungs or extremities, which do not need intense doses of radiation. For example, AEC saves the mAs during the images of bowel gas, without losing excellent detail in areas like the liver and spine. Recent AEC solutions, for example Toshiba SureExposure 3D and Philips DoseRight, can adjust settings according to a patient's weight (Sulieman *et al*. 2021). It has been observed from practice that forty percent less dose is delivered to patients with weight-based AEC protocols and noise-allowed image limits. Furthermore, AEC manages to shield delicate regions like the eyes and the thyroid by controlling the level of radiation coming from the front of the x-ray. AEC now links with 3D dose mapping, so that the expected radiation load for a patient can be forecasted before starting a scan. Consequently, it allows doctors to manage risks and change scans plans instantly, which is very helpful in pediatric CT scans performed over time (Francone *et al*. 2022). Besides, the use of angular and longitudinal modulation algorithms makes sure that all parts of the image have equal quality, which is necessary for uneven pediatric anatomies. Difficulties continue when AEC includes uncommon scan lengths or needs patients to be placed non-standardly, since this frequently causes extra radiation to be delivered during these parts of the exam. Thus, it is necessary to carry out protocol testing using anthropomorphic pediatric phantoms to confirm that AEC measures are suitable (Kleefeld *et al*. 2024). All in all, AEC helps cut radiation doses to a low and safe level in pediatric CT studies when it is set up according to the manufacturer's rules and carefully monitored on a regular basis.

Impact of Iterative Reconstruction on Image Quality and Dose Management

Due to iterative reconstruction algorithms, it is now possible to use less radiation in pediatric CT imaging without decreasing the quality of the pictures. IR methods are different from traditional FBP, since they use statistics to model noise from the raw data and cycle several times to reduce it. Due to this, images have a high resolution even when images are taken at low mA and kVp, a necessary feature in pediatric imaging.

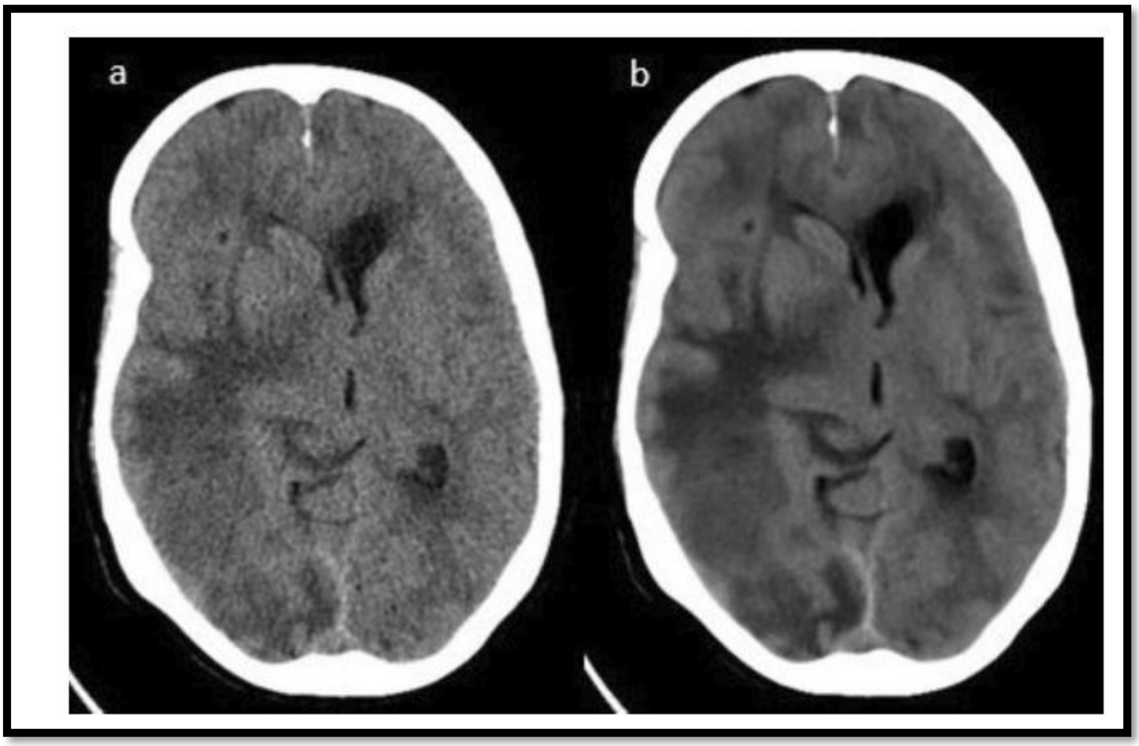

Figure 2: Axial CT images showing the improved image quality with (a) iDose4 compared to (b) DLIR-standard. (Source: Pendem *et al.* 2024)

Using advanced techniques such as ASIR, MBIR, iDose, and SAFIRE, imaging procedures can be done with up to 60% lower dose requirements than when FBP protocols are used (Pendem *et al*. 2024). For instance, in the imaging of children's brains with MBIR, it is possible to see the soft structures clearly and identify tissue differences, even using CTDIvols below 5 milliGray. Using iterative reconstruction in cardiac CT for congenital heart disease makes it possible to detect small details at low dose levels, so people with this condition can be monitored more often without worry about the total dose. IR helps to properly dose the patient by reducing artifacts that could force another scan. Iron reduced reconstruction processes better eliminate beam-hardening artifacts, dental hardware lines, and motion artifacts usually seen in pediatric imaging. It cuts back on the amount of repeated and unnecessary imaging. IR techniques can be used with lower doses of radiation (e.g., 80 kVp, 30–50 mAs) when evaluating lung disease, since they still ensure sufficient diagnosis of bronchiolitis, cystic fibrosis, and cases of viral pneumonitis (Singh and Sukkala, 2021). IR algorithms give radiologists more options to adjust diagnostic confidence and, at the same time, reduce radiation exposure, allowing tailored protocols for different areas and reasons. When CT technology advances, the use of deep learning may help reduce the dose of radiation, maintaining accurate details crucial for the diagnosis of pediatric cases.

Gaps in Radiology Staff Training and Awareness on Pediatric Imaging Safety

Having improved technology for dose reduction is not enough, since many radiology staff are still not familiar enough with safe techniques. A lot of radiographers and radiologists do not receive a lot of formal training about imaging children when they are learning. For this reason, there is usually not enough knowledge about setting specific parameters for pediatric CT, like choosing the tube voltage (kVp), milliampere-seconds (mAs), pitch factor, and scan length (Irsal *et al*. 2022). Then, physicians may choose improper settings, such as adult exposures for small children, bringing about higher CTDIvol and DLP indexes. In clinical audits, it was revealed that almost 40% of radiology staff were not able to choose the correct protocol from the CT library for pediatric cases by adding up the child's weight. Both AEC and iterative reconstruction algorithms are often not used frequently. But this is because most technologists are not used to them and some are afraid that the outcome will not be as good as without using them (Gould *et al*. 2021). If the rate of the contrast dye is incorrect or injection is done at the wrong time, the scan is repeated and the total dose given to the child increases. Apart from this, many staff members may not know the significance of patient positioning and centering on the accuracy of treatment (Tsuda *et al*. 2021). If pediatricians do not use proper supports or do not restrain children who are uncooperative, motion artifacts may occur, necessitating extra scans. Many radiologists are unaware of dose modulation and knowing how to pick ideal scan phases, mainly when working with multiphase scans. Many people get little to no training on how to handle pediatric radiation risks because pediatric radiation safety modules are usually not included in CPD programs, and not all places require retraining (Morgan *et al*. 2023). If they do not keep learning new techniques, even seasoned technologists might apply the same methods they are used to. Ensuring that designated training, certifications, and audits are used helps close the gap in knowledge and makes sure ALARA rules and high safety in pediatric imaging are followed.

Challenges in Standardizing Pediatric CT Protocols Across Institutions

Creating similar CT practices for children in different institutions is a tough task because of the wide spread in equipment, software, the order in which tests are done, and what different institutions prioritize. A main factor is that different manufacturers make CT systems with unique platforms and ability to control exposure, reconstruct images, and alter doses for different organs (Schulz *et al*. 2021). It makes it difficult to use the improved protocols directly in other situations. As an example, the chest protocol with ASIR on a GE scanner set at 100 kVp, weight-adjusted should not be repeated the same way on a Siemens scanner using SAFIRE (Ungania *et al*. 2023). So, it needs to be independently checked. Institutions are not all the same when it comes to having and using advanced features such as z-axis dose modulation, dynamic bolus tracking, or dual-energy imaging. The use of dose management in children becomes less reliable when software designed to lower radiation exposure is not available or has not been updated because of financial reasons. Because not all hospitals have the same standard anthropometric tables for children, you can find different aims or parameters used for kids of the same age or weight. At certain centers, age is used to decide which protocol to follow. At others, weight or body size are important, so the tube current, angle between X-ray beams, and scan range may vary (Samber *et al*. 2021). Most of the time, protocol libraries are not updated with the recent guidelines given by the ACR, ICRP, or Image Gently campaign. There is not much cooperation between radiologists, technologists, and medical physicists, so the creation of protocols becomes scattered and fragmented. Furthermore, when doctors have little time in high volume, they may use "one-size-fits-all" approaches and forget to consider that only adult doses are given (Kadavigere *et al.* 2021). Differences in laws and rules from one region to another have hindered efforts to make things standard. In particular places, there are no legally required standards such as DRLs for pediatric imaging. Ensuring all pediatric CT images are consistent and safe at all institutions remains a big problem and a major risk because there is no set framework.

Potential of AI and Digital Tools for Enhancing Dose Optimization Efficiency

Dose optimization in pediatric CT is being changed by AI and digital technologies, which now help create custom images that are safer for each patient. One big change is using AI algorithms in preparing scans. They review digital scout views and 3D views, and they suggest the ideal tube voltage, tube current, pitch, and scan range instantaneously (Golbus *et al*. 2024). Using AI, software places the patient at the isocenter when it identifies necessary anatomy, which is necessary for proper accuracy and effectiveness of AEC and collimation control. TrueFidelity (GE) and Deep Learning Reconstruction (Canon), through deep learning, give better noise suppression than model-based iterative reconstruction (MBIR) (Beysang *et al*. 2024).

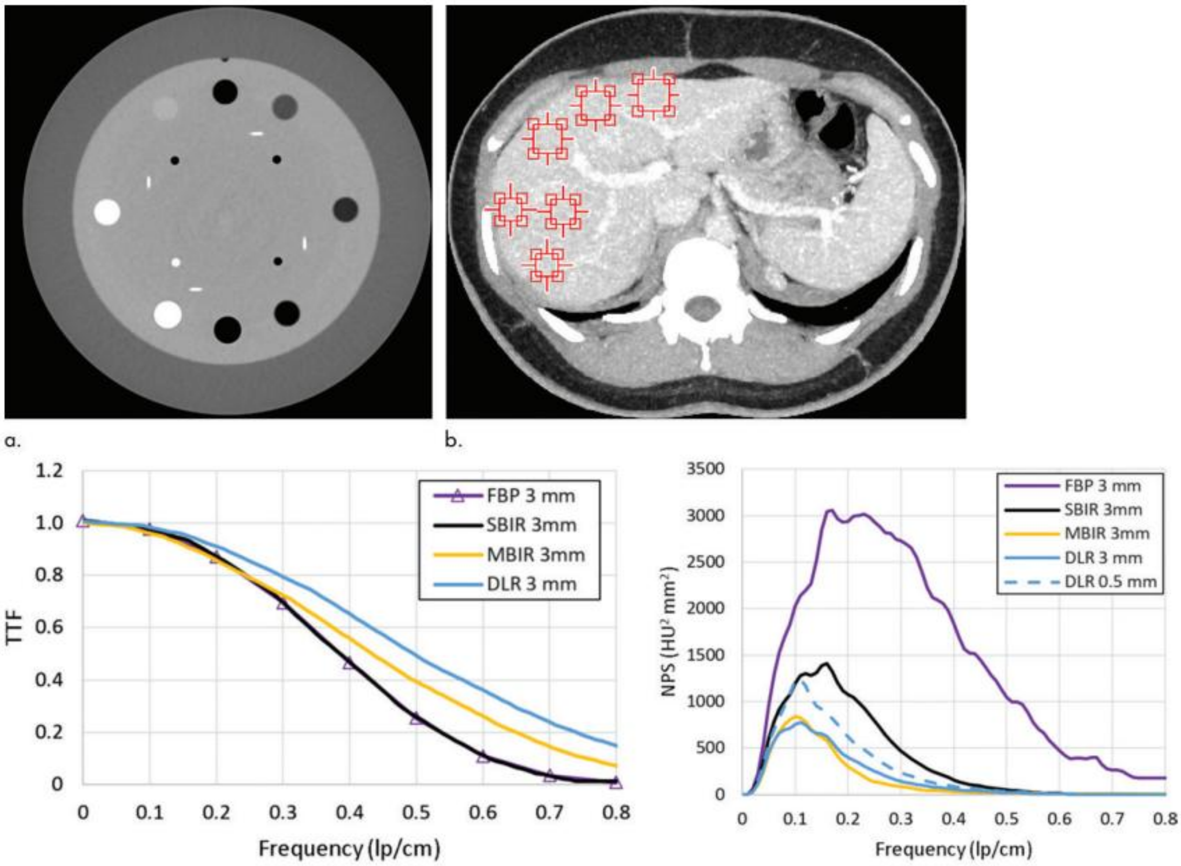

Figure 3: Evaluation of Image Quality Metrics in CT Scanning: TTF and NPS Calculations Using Various Reconstruction Algorithms and Sensitometry Inserts

(Source: Brady *et al*. 2021)

With this technique, very low doses of radiation are used and the clarity and differences in tissues are still good. For instance, in pediatric head CT, deep learning allows for great recognition of gray and white matter, even at less than 2 mGy, so both the diagnosis and safety of the patients are kept high. Monitoring software systems like Radimetrics, DoseWatch, and teamplay Dose gather CTDIvol and DLP data for all patients and make it possible to check whether results are above or below the recommended DRLs (Alanazi *et al*. 2024). Such software sends notifications if scan parameters go beyond allowed standards, which means it's time to review the protocol immediately. AI is able to find noticeable scans and recognize when dangerous amounts of radiation have been used in chronic illnesses such as pediatric oncology. Furthermore, machine learning is using extensive data sets of patients from different hospitals to determine which imaging tests are best for a certain clinical situation, patient age, weight, and his or her previous imaging findings. With this help, mistakes become less common and there is more uniformity among different workers. Support in diagnosis and decision making is guaranteed when AI is linked with PACS and RIS software within the workflow (Orellana García *et al*. 2023). These technologies have limitations, as they should achieve interoperability, meet guidelines, and undergo constant testing in young people from different backgrounds. Even so, AI could play a key role in improving and regulating the safety of children who are scanned in CT machines.

6. CONCLUSION

The research clearly points out the main advancements and ongoing concerns for lowering the doses of CT in children. Automatic Exposure Control and Iterative Reconstruction are able to limit radiation exposure without affecting the results. Even so, diverse treatment techniques, different tools used, and missed training make it difficult to ensure consistent dosing. Even though AI and digital instruments provide solutions for smart optimization, their application needs to be studied further. It is still necessary to use standard protocols and elevate radiology education. All in all, bringing together technology, targeted staff training, and collaboration among different groups is key for safe and high-quality scans in pediatric CT while also cutting down on radiation exposure for children.

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