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Balancing the Risks of Radiation and Anesthesia in Pediatric Patients

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As health care advances, medical care is becoming more complicated. Pediatric patients with multiple comorbidities are living longer with assistive devices (tracheostomy, ventilators, etc) and often are at risk for serious complications, including those related to device failure or malfunction as well as the acquisition of multiple-drug-resistant infections. Management of these patients and the ensuing complications often requires imaging for diagnosis and monitoring of treatment response. Physicians are often faced with balancing the benefit of obtaining clinical data from imaging with the risks associated with different imaging modalities. Among medical imaging techniques, radiographic, fluoroscopic, CT, and nuclear medicine procedures expose patients to radiation. However, in the pediatric population, radiation is not the only risk that needs to be taken into consideration when choosing an imaging modality. For instance, MRI does not use radiation and provides excellent tissue contrast but often requires anesthesia, especially for young children, because of its longer acquisition time. Moreover, because of magnetic susceptibility at the air-tissue interface, MRI is also not the preferred modality for lung imaging. Fast-sequence MRI is increasingly being used, but it provides only limited information. Ultrasound is also being used more frequently, but it does not provide true 3-D imaging, and it can be operator dependent. In contrast, CT is often the initial go-to imaging technique because it is fast and therefore generally does not require anesthesia. However, the exposure to radiation can deter physicians from choosing this modality. In this short review we compare the risk of anesthesia and the risk of radiation in pediatric patients to provide perspective when choosing imaging modalities.

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Physicians must consider the risks of anesthesia in complicated patients. Anesthetic in children can cause immediate adverse consequence that can range from minor effects such as dental injury, post-operative nausea or vomiting, and hypothermia to serious effects such as hypotension, hypoxia, cardiac arrest, and death [1]. As early as the 1950s, children were recognized to be at greater risk for cardiac arrest from anesthesia than adults, though the overall rates have improved over time with improvements in anesthetic regimen, the addition of pulse oximetry and capnographic monitoring, recognition of high-risk populations, and specialization of pediatric providers (including anesthesiologists and intensivist) [2]. A recent systematic review of perioperative morbidity and mortality by Catre et al [1] demonstrated that although there is great variability in incidences, there is a higher frequency of morbidity and mortality in the first year of life, with a peak among neonates.

In addition to these immediate adverse effects, anesthesia has also been investigated for its long-term effects on neurodevelopment after administration to young children with developing brains. There is a long history of animal studies showing neuronal apoptosis with subsequent long-term adverse effects with neurodevelopment impairment [3]. There have been several clinical studies in children, mostly retrospective, that have investigated the association between exposure to anesthesia in childhood and neurodevelopmental outcomes. A systematic review by Wang et al [3] compared the hazard ratio of seven retrospective and prospective studies and found an association between anesthesia and neurodevelopmental (both cognitive and behavioral) impairment. These investigators also found that the number of exposures to anesthesia before 4 years of age was a more significant risk factor of worse outcomes than time of exposure alone [3]. More recently, a randomized controlled trial demonstrated no difference in neurodevelopmental outcomes at 2 years of age between awake regional anesthesia and general anesthesia in infancy, though this 2 year assessment was a secondary outcome for which the study was not powered to detect differences [4]. Despite the mixed results in the literature, there is sufficient concern that the FDA issued a warning in 2016, which was updated on April 27, 2017 [5]. The warning stated that "exposure to these medications (general anesthetic and sedation medicines) for lengthy periods of time or over multiple surgeries or procedures may negatively affect brain development in children younger than 3 years" [5].

Recent technological developments have significantly lowered radiation exposure. For example, advances in CT technology, such as high-pitch scanning (dual-source CT), wide detectors capable of acquiring large volumes in less time (up to 160-mm coverage in a single CT gantry rotation), maturation of automatic tube current modulation techniques, use of low tube voltage, and availability of iterative reconstruction algorithms that obtain data at lower radiation exposure while still producing high-quality images, are enabling high-resolution CT imaging at remarkably low doses [6]. In addition, increased awareness about radiation dose in children produced by the Image Gently® campaign (http://www.imagegently.org) and other social media venues has aided the continued efforts to review and reform pediatric CT protocols for lower doses. Radiation exposure has also decreased during radiography and fluoroscopy because of advances in digital detection, increased use of pulse fluoroscopy, selective filtration, and other techniques. Additionally, pediatric weight-customized radioisotope doses for nuclear medicine procedures also have enabled relatively lower radiation exposures.

A recent study demonstrated the importance of the utilization of multiple CT studies and the ability to do so with relatively low radiation exposure. In that study, an experimental treatment regimen was used to treat a 2-year-old child with a highly dangerous and drug resistant form of pulmonary tuberculosis; serial chest CT studies were utilized to monitor treatment response because other clinical and microbiologic markers were unable to distinguish treatment response [7]. The effective dose for each CT scan ranged from 0.4 to 0.7 mSv [7]. This dose is equivalent to less than 3 months of US natural background radiation, a single screening mammographic examination, or four trans-Atlantic round trips. Importantly, no sedation was required for this child, as scan times were short (3 seconds). Given that the risk for mortality in patients with multiple-drug-resistant infections is a true risk that is similar to that due to cancers, we need a balanced approach to the use of imaging approaches.

CONCLUSIONS

It is judicious to assess each risk in pediatric studies and compare with the benefits that a particular method provides. Physicians need to examine the benefits of medical radiographic imaging, including CT scans, in the pediatric population especially because low-radiation protocols are possible thanks to the technological advances mentioned here. Although ionizing radiation is not without risk, and studies that produce it should not be performed unless there are clear clinical indications, one should take into account all risks, including those due to anesthesia, and make informed decisions that provide the best clinical information with the least possible overall risks.

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