Abstract:
The objective of this article is to review the use of computed tomography (CT) for the purpose of injury evaluation in pediatric trauma patients. The relative risk of radiation-induced cancer mortality is discussed. Evidence-based indications for obtaining CT and optimization of CT scanner protocols are provided. CT use specific to pediatric trauma is discussed for the following anatomic regions: thorax, abdomen, head, spine, vascular, and musculoskeletal. Limiting unnecessary CT use by understanding when and how to order an appropriate scan in order to adequately diagnose and treat a specific injury is the most practical way for clinicians to help reduce patients' risk of radiation.

Keywords:
computed tomography; pediatric trauma; indications; risks; radiation

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Computed Tomography in the Evaluation of Pediatric Trauma

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Computed tomography (CT) is a form of radiography using ionizing radiation to create two- and three-dimensional representations of anatomy based upon differential absorption of diagnostic range X-rays. This modality has been used in the diagnosis of pathological conditions since 1971.[1] Since that time, improvements in CT technology and availability have allowed reduced scan times, which have rendered it a highly useful tool in the evaluation of trauma patients.[2]

The vast majority of the literature available in utilizing CT for evaluation of trauma patients focuses on adult patients and does not address pediatric patient care, which is notably different.[3] First, children have different injury patterns than adults and therefore have a different likelihood of having certain types of injuries than adults. Second, children are more sensitive to the effects of ionizing radiation and are more likely to be adversely affected by the overuse of CT than adult patients.

RADIATION DOSE CONSIDERATIONS

The only practical radiation dose consideration in pediatric patients undergoing CT is radiation-induced cancer.[4,5] The

specific risk is increased for younger patients and for patients who require higher doses of radiation to produce diagnostic images. The risk can also vary depending on the specific organ exposed to radiation. For an excellent practical guide on how to approach the topic of radiation risks of CT, please refer to http://www.cancer.gov/cancertopics/causes/radiation/radiation-risks-pediatric-CT.[4]

The relative risk of radiation-induced cancer mortality should also be understood at a basic level by all physicians using CT. For example, a 3 mGy average organ dose to a 10-year-old child (which would be obtained from a body CT scan) confers approximately 1/4000 increased lifetime risk of radiation-induced cancer mortality. Another way to think of this is the following: without exposure to the CT study, an otherwise healthy American child has an expected lifetime cancer mortality of 1/5 (800/4000), or 20%. After such a CT scan, this increased risk would be 801/4000 or 20.00025%.[6]

Two other important concepts to remember when ordering CT studies is that: (a) radiation dose is cumulative and related cancer risk is thought to be linear (ie, a second CT study of the same dose in the child in the example raises his/her chance of lifetime cancer mortality to approximately 20.005%), and (b) the most accurate estimates of cancer mortality risk related to ionizing radiation are based on incomplete data and are therefore highly speculative.[6]

The most practical ways for clinicians to help reduce their patients' risk of cancer mortality is to limit use of CT to cases in which it is necessary to diagnose and treat a specific condition, and to limit CT use in pediatric patients to settings which have optimized protocols on the CT scanners. These protocols are put in place in order to reduce the radiation dose to the patient while still producing adequate diagnostic images. Any dedicated pediatric hospital would be expected to meet the last criterion, and any general hospital in North America with up-to-date equipment should have the resources to perform a lower dose CT using the ALARA (As Low As Reasonably Achievable) principle and recording all administered dose data (http://www.imagegently.org/Procedures/ComputedTomography.aspx). In the event of a pediatric patient presenting to an adult trauma hospital, use of CT should be reserved for those cases where it is needed to immediately stabilize the patient before transferring to a pediatric center. If the patient is clinically stable and a transfer is pending, CT use should be directed by the accepting pediatric trauma experts.

"Pan-scanning" refers to a whole body CT, or at least one including the head, neck, chest and abdomen. The use of pan-scanning has increased over the past 30 years for the evaluation of trauma patients. It has shown efficacy in reducing mortality for adult patients in certain circumstances.[7] Despite this evidence in adults, pan-scanning for pediatric trauma without careful clinical examination of each anatomic region is *never* recommended. This methodology has not been validated scientifically, and the only thing certain about its use is that it will cause harm if applied broadly. Unfortunately, pan-scanning still occurs frequently in referring, non-pediatric hospitals prior to transfer to a pediatric trauma center.

THORACIC TRAUMA

Chest CT has demonstrated the ability to identify numerous blunt trauma-related injuries in pediatric patients, many of which may not be visible on a radiograph.[8] Despite this, studies have shown that radiographically occult injuries rarely, if ever, change management. For instance, a chest radiograph will provide enough information regarding pulmonary contusions, pneumothorax, hemothorax, and rib fractures, and management will not be changed by obtaining a CT. Although no currently published guidelines exist to assist clinicians on the decision of when to request CT exams for blunt trauma in the United States, the published guidelines of the English Royal College of Radiology state that CT can be obviated in blunt trauma patients in whom the chest radiograph is normal, and if the patient is conscious and clinically stable.[9–12] CT is definitely recommended for cases of penetrating thoracic trauma or concern for a vascular injury such as an aortic dissection (based on a widened mediastinum on chest radiograph, or due to a concerning mechanism). Intravenous (IV) contrast should be utilized if there is concern for an underlying vascular injury.[13] (Figure 1).

Aortic injuries are uncommon but highly lethal injuries in children presenting with blunt trauma.[14] In the cases where children survive the events prior to hospitalization, mortality remains significantly higher than in adults, and therefore early identification of aortic injuries is extremely important. CT with angiography has shown great efficacy in identifying aortic injuries and guiding treatment; however, due to the low overall incidence of these injuries, it should not be used as a blind screening tool for every child with blunt thoracic trauma. The rule for general thoracic injuries remains valid for thoracic vascular injuries, as a normal upright chest