Radiation Dose Considerations in Emergent Neuroimaging

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KEYWORDS

• Emergency radiology • Neuroimaging • Radiation dose • Computed tomography • CT angiography • CT perfusion • Trauma CT

KEY POINTS

- Appropriate computed tomography use with defined imaging algorithms or clinical decision support tools is a crucial step in a patient-centered approach to radiation dose management in emergent neuroimaging.
- Thoughtful computed tomography neuroimaging protocol design reduces radiation exposure by limiting the range and phases of the scan to the minimum necessary to achieve the diagnostic goal.
- Modern scanner and image postprocessing technologies, when properly applied, can synergistically reduce radiation dose while maintaining diagnostic image quality.
- Radiation exposure monitoring on a population level is critical to ensure quality and identify outliers.

INTRODUCTION

Patients presenting with acute problems of the head, neck, spine, and central nervous system frequently require 1 or more diagnostic imaging studies as part of their initial diagnostic evaluation. For many such patients, particularly hospital inpatients and patients presenting to the emergency department (ED), the first imaging test is often a computed tomography (CT) scan of the relevant anatomic region. When appropriate, the benefits of CT typically far outweigh the potential risks. However, for young patients and/or patients with chronic conditions, the cumulative radiation dose from serial diagnostic imaging studies over time raises the concern for possible increased cancer risk as a result of medical imaging.[1,2] Public perception of CT use and radiation dose issues has been heavily influenced by heightened media attention to potential radiation risks in recent years, such as articles published in the *New York Times*' series "Radiation Boom," which have highlighted prominent radiation dose overexposure events[3] as well as the increasing use of CT and concerns regarding the potential cancer risk of the attendant radiation dose.[4,5] As a result, patients are more likely than in the past to have questions about CT radiation dose that prompt a risk–benefit discussion before or after a scan. Referring physicians and physician extenders should have some familiarity with the topic, because they will often be the recipients of such questions. However, radiologists should be prepared to serve as consultants in this regard, and to have these discussions directly with patients. A framework to prepare for such conversations is provided as a reference.[6] Ultimately, the responsibility for managing radiation dose falls on radiologists as the custodians of diagnostic imaging, albeit with considerable collaboration from referring providers, radiologic technologists, medical physicists, and equipment manufacturers.

When considering the risk–benefit calculus of CT radiation dose in emergency neuroimaging, it

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is critical to remember that CT has become a vital tool for efficiently diagnosing and excluding neurologic conditions that require emergent intervention. To avoid CT or minimize the dose at the expense of adequate diagnostic quality would be folly, because failure to diagnose such conditions in an expedient manner puts patients at far greater risk in the short term, rendering the potential risks associated with radiation exposure irrelevant. However, it is equally important to design CT protocols and monitor the resulting radiation dose to help mitigate both the short-term deterministic effects of a single radiation dose event and the potential long-term, stochastic effects of cumulative radiation dose.

In this article, we explore strategies for a patient-centered approach to managing radiation dose in emergent neuroimaging from the patient's initial presentation to after the scan. This discussion reviews methods for facilitating the appropriate use of diagnostic CT in emergent neuroimaging, taking full advantage of commonly available scanner and image postprocessing technologies in the design and modification of CT examination protocols, and tracking data from these examinations at a population level to inform future iterations of these processes. We conclude with a brief discussion of emerging CT technologies that may facilitate further decreases in radiation exposure from CT in the future. Detailed discussions of more general strategies for reducing CT radiation dose and the concerns regarding cumulative radiation exposure are beyond the scope of this article, although examples from the literature are provided as references.[1,2,7,8]

BEFORE THE SCAN: THE APPROPRIATE USE OF COMPUTED TOMOGRAPHY IMAGING

The most important consideration in patient-centered management before the patient arrives in the CT scanner suite is the determination of the most appropriate imaging study for a given phase of a patient's care. This is no longer simply part of best practices in patient care, but a legal requirement for reimbursement when providing diagnostic imaging services to Medicare patients. In 2014, the US Congress passed bill H.R. 4302, or the Protecting Access to Medicare Act of 2014 (PAMA), which will require medical providers to consult appropriate use criteria (AUC) using an approved clinical decision support (CDS) mechanism before ordering advanced diagnostic imaging for Medicare patients in the outpatient setting, including the ED.[9] As of January 1, 2017, this rule is in effect and any diagnostic imaging services provided to a Medicare patient will be reimbursed by CMS only if documentation indicating the CDS mechanism consulted and supporting whether (a) the service provided adheres or does not adhere to the available AUC or (b) if no applicable AUC were available. It is pertinent to note that there are exceptions defined for patients with "emergency medical conditions" and for providers exempted on a case-by-case basis owing to "significant hardship" in consulting a CDS mechanism. It is also pertinent to note that Sec. 218(a) of PAMA, in which these requirements for AUC and CDS are defined, is titled "Quality Incentives to Promote Patient Safety and Public Health in Computed Tomography Diagnostic Imaging," suggesting that the lawmakers involved in writing PAMA were motivated by concerns for potential overuse of CT imaging and its attendant radiation exposure to patients.

The Medicare Appropriate Use Criteria Program maintains a list[10] of qualified "provider-led entities" that have been approved for the development and endorsement of AUC. For example, the American College of Radiology has been named by the Centers for Medicare & Medicaid Services as a provider-led entity, which means that the American College of Radiology Appropriateness Criteria,[11] a freely available, searchable online database of evidence-based guidelines for both diagnostic and interventional radiology, meet the requirements for AUC as defined in PAMA. For each topic in the Appropriateness Criteria database, "Narrative & Rating Table" and "Evidence Table" documents are provided. Examples of common indications for neuroimaging that can be found in the Appropriateness Criteria database include focal neurologic deficit, head trauma, headache, and low back pain. The Medicare AUC Program also maintains a list of qualified CDS mechanisms, including commercially available software packages that can be integrated into an electronic health record or computerized physician order entry (CPOE) systems.

The authors of this article advocate for the use of CPOE-integrated CDS, given the support in the literature for its role in facilitating appropriate CT use. In a recent study of interphysician variability in head CT ordering among emergency physicians, the authors identified 2-fold variability for all indications, increasing to nearly 3-fold for patients diagnosed with atraumatic headaches.[12] A subsequent study from another institution found that head CT was ordered for minor head injuries with an excess of 37% in comparison with the number of scans expected by application of the Canadian CT Head Rule.[13,14] This observation was particularly pronounced in younger patients. In their analysis of ordering patterns, the authors