

Is utilisation of computed tomography justified in clinical practice? Part I: application in the emergency department

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ABSTRACT

Computed tomography (CT) is currently a widely available imaging technique in clinical practice. Technical developments of CT imaging, especially the emergence of multislice CT, with increased scanning speed and volume as well as higher spatial and temporal resolution, have significantly enhanced the diagnostic value of CT in many clinical applications. CT has become an important diagnostic imaging modality in the emergency department, with high diagnostic accuracy and efficacy in both traumatic and non-traumatic conditions. There is, however, a growing concern about the risk of associated radiation exposure in the population exposed to CT examination. Justification of the application of CT is one of the main principles that physicians need to be aware of when choosing CT as the first-line technique for diagnosis. This article reviews the clinical applications of CT imaging in the emergency department, with a focus on patients presenting with headache, repeat and multiple CT imaging and whole body screening for trauma patients, and explores whether the applications are clinically justified.

Keywords: computed tomography, emergency department, radiation dose, radiation risk, trauma

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INTRODUCTION

Since its first introduction into clinical practice in the early 1970s, the use of computed tomography (CT) has been progressively growing worldwide. According to the 2006 report⁽¹⁾ of the United Nations Scientific Committee on the Effects of Atomic Radiation, the average frequency of CT examinations in developed countries increased yearly from 6.1 per 1,000 population in the 1970s to 48 per 1,000 population in the period between 1991 to 1996.⁽²⁾ At the same time, the average effective dose per CT examination increased from 1.3 mSv in the 1970s to 8.8 mSv in the

period between 1991 to 1996.⁽²⁾ During the last two decades, CT has undergone rapid technical developments, including the introduction of helical and multislice CT scanners which decrease or eliminate motion artifacts, acquire volumetric data in a short time with great anatomic coverage and generate isotropic datasets which facilitate the 3D reconstruction of anatomical areas.^(3,4) These advantages have led to a rapid increase in the utilisation of CT in both adults and children.⁽⁵⁻⁸⁾ The estimated annual number of CT examinations in the United States rose steadily from 2.8 million in 1981 to 20 million in 1995,⁽⁷⁾ 46 million in 2000⁽⁸⁾ and more than 62 million in 2006, including 4 million for children.⁽⁹⁾ Comparable trends have been reported in European countries such as Germany, Switzerland, Norway and the United Kingdom.⁽¹⁰⁾ All these data indicate that CT has become the diagnostic method of choice in many clinical applications in both daily practice and emergency departments.

It is estimated that CT accounts for 10% of all diagnostic radiologic examinations, but it contributes up to 70% of the collective radiation dose delivered to patients.⁽¹¹⁾ The growing use of CT is accompanied by growing concerns about the risks associated with diagnostic CT. The risk is estimated by looking at the expected number of cancers in a specific population and the actual numbers observed in the exposed cohort.⁽¹²⁾ The National Academy of Science has published a series of reports about the health risks of radiation exposure, called the Biological Effects of Ionizing Radiation (BIER VII) reports. It is estimated in the reports that a single population dose of 10 mSv is associated with a lifetime risk for developing a solid cancer or leukaemia by one in 1,000 exposures.⁽¹³⁾ The small potential risk of cancer associated with CT must be considered in the context of the potential survival benefit from undergoing CT examination. Tables I and II show the radiation dose of CT examination in various anatomic regions in comparison to the radiation dose resulting from corresponding conventional radiography.⁽¹⁴⁾ As McCollough et al claimed,⁽¹²⁾ the life risk of a fatal cancer from all causes is 22.8%, and the lifetime potential risk of a fatal cancer from the radiation associated with a body CT scan is approximately 0.05%.

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Table I. Adult effective radiation dose of various conventional radiography examinations (Revised from Mettler et al⁽¹⁴⁾).

Examination	Average effective dose (mSv)	Values reported in the literature (mSv)
Skull	0.1	0.03–0.22
Cervical spine	0.2	0.07–0.30
Thoracic spine	1.0	0.60–1.40
Lumbar spine	1.5	0.50–1.80
Posteroanterior and lateral study of the chest	0.1	0.05–0.24
Posteroanterior study of the chest	0.02	0.07–0.05
Abdomen	0.7	0.04–1.10
Pelvis	0.6	0.20–1.20

Table II. Adult effective radiation dose of various CT examinations (Revised from Mettler et al⁽¹⁴⁾).

Examination	Average effective dose (mSv)	Values reported in the literature (mSv)
Head	2	0.9–4.0
Neck	3	NA
Chest	7	4.0–18.0
Abdomen	8	3.5–25.0
Pelvis	6	3.3–10.0
Spine	6	1.5–10.0

CT: computed tomography; NA: not available

Table III. Guidelines* for neuroimaging (CT) in patients with headache.

Recommendation	Clinical indication
Emergent CT imaging is recommended.	<ul style="list-style-type: none"> • “Thunderclap” headache with abnormal neurological examination.
Emergent CT imaging is recommended to determine if it is safe to do lumbar puncture.	<ul style="list-style-type: none"> • Headache accompanied by signs of increased intracranial pressure. • Headache accompanied by fever, neck stiffness and meningeal signs.
Emergent CT imaging should be considered (under the category of new onset headache, CT is the first line technique, followed by CT angiography or MR imaging to confirm diagnosis).	<ul style="list-style-type: none"> • Isolated “thunderclap” headache. • Headache radiating to neck. • Temporal headache in an older individual (after age 50). • New onset headache in a patient who is HIV positive, has a prior diagnosis of cancer and is in a population at high risk for intracranial disease. • Headache accompanied by abnormal neurological examination, including papilloedema or unilateral loss of sensation, weakness or hyperreflexia.
Emergent CT imaging is not usually warranted.	<ul style="list-style-type: none"> • Migraine and normal neurological examination.
Emergent CT imaging is not recommended (some evidence for increased risk of intracranial abnormality, not sufficient for recommendation).	<ul style="list-style-type: none"> • Headache worsened by Valsalva manoeuvre, which wakes the patient from sleep, or is progressively worsening.
Emergent CT imaging is not recommended (insufficient data).	<ul style="list-style-type: none"> • Tension type headache and normal neurological examination.

* Guidelines developed by the US Headache Consortium, the American College of Emergency Physicians and the American College of Radiology⁽²⁴⁾ have been revised to correspond to emergency situations.

Thus, the benefit-to-risk ratio for any patient will be driven by the benefit and appropriateness of the CT examination. The three fundamental principles of radiation protection in radiology are justification of utilisation, optimisation of protection and limitation of dose limits.⁽¹⁵⁾ Optimisation and limitation have been studied widely in the literature,

while the first principle, justification, is still controversial in many areas with regard to the judicious use of CT. Although difficult to fully assess, it has been reported that 30% or more of the CT scans currently performed may be unnecessary.⁽¹⁶⁾ A substantial increase in the utilisation of CT has been noted over the last decade in the emergency



Fig. 1 Axial CT image of the abdomen shows a hypodense laceration of the liver (arrow).



Fig. 2 Coronal CT image of the abdomen shows laceration of the liver post trauma (arrow).

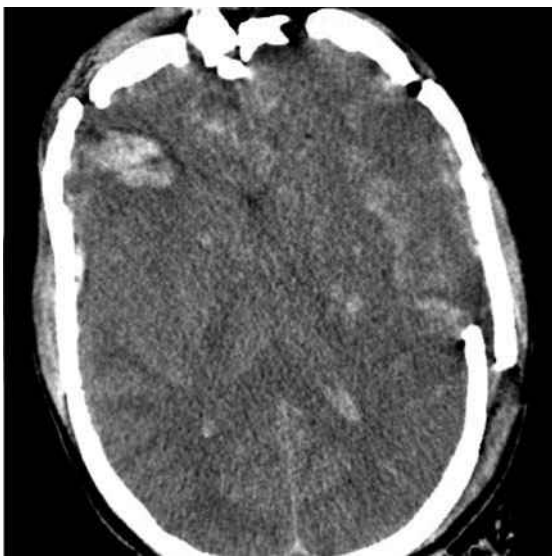


Fig. 3 Extensive head injury sustained due to a fall from height. Subarachnoid bleed, multiple contusions and cerebral oedema are seen in this axial CT of the brain. There are also multiple skull fractures seen. The patient succumbed after two hours.

department, which ranged from an increase of 51% to 463%, depending on the anatomic regions imaged.⁽¹⁷⁻¹⁹⁾ In the following sections, we will discuss the applications of CT in the emergency department with respect to the patients presenting with headache, repeat and multiple CT imagings, and whole body screening in trauma patients.

APPLICATION OF CT IN PATIENTS WITH HEADACHE

Headache accounts for a large number of emergency department visits.⁽²⁰⁾ CT imaging remains the initial imaging investigation of choice for new-onset headache in adults and headache suggestive of subarachnoid haemorrhage.⁽²¹⁾ As pathology presenting solely with headache is uncommon, a large proportion of the imaging studies will have negative findings.^(22,23) Guidelines have been developed for imaging headache by the United States Headache Consortium, the American College of Emergency

Physicians and the American College of Radiology Expert Panel on Neuroimaging.⁽²⁴⁾ The general recommendations are that screening patients with isolated headache by CT or magnetic resonance (MR) imaging is usually not warranted.

Previous studies have shown that CT and MR imagings are of very low diagnostic value when applied as screening tools in patients imaged for isolated nonfocal headaches.^(22,23) Jordan et al recently reported that CT imaging of nonfocal headache in emergency settings has limited cost efficacy due to a lower percentage of positive clinically significant results. 31.8% positive CT findings were found in their study group, but only 1.02% showed clinically significant results which required a change in patient management.⁽²⁵⁾ Similarly, a chief complaint of trauma headache suggested a normal or clinically insignificant CT angiography, according to a recent report.⁽²⁶⁾ In contrast, an abnormal head CT is a strong predictor of clinically significant CT angiography. Jamshidi et al found that 54% of patients had an abnormal non-contrast head CT, and 41% of all CT angiography reports were abnormal.⁽²⁶⁾ Since CT imaging of emergency headache has become a widespread and growing problem with significant economic implications, physicians need to follow the guidelines and justify the use of CT in patients presenting with headache in the emergency department.⁽²⁵⁾ Table III summarises the indications of recommending head CT scans in the emergency department.

APPLICATION OF CT IN PATIENTS WITH REPEAT OR MULTIPLE CT IMAGINGS

Increased use of CT has resulted in growing rates of repeat or multiple imaging in various patient populations presenting with different clinical scenarios. This has emphasised the concerns about appropriateness, cost control and resource utilisation in both emergency and non-emergency situations. A 2007 American College of Radiology white paper on radiation dose in medicine has

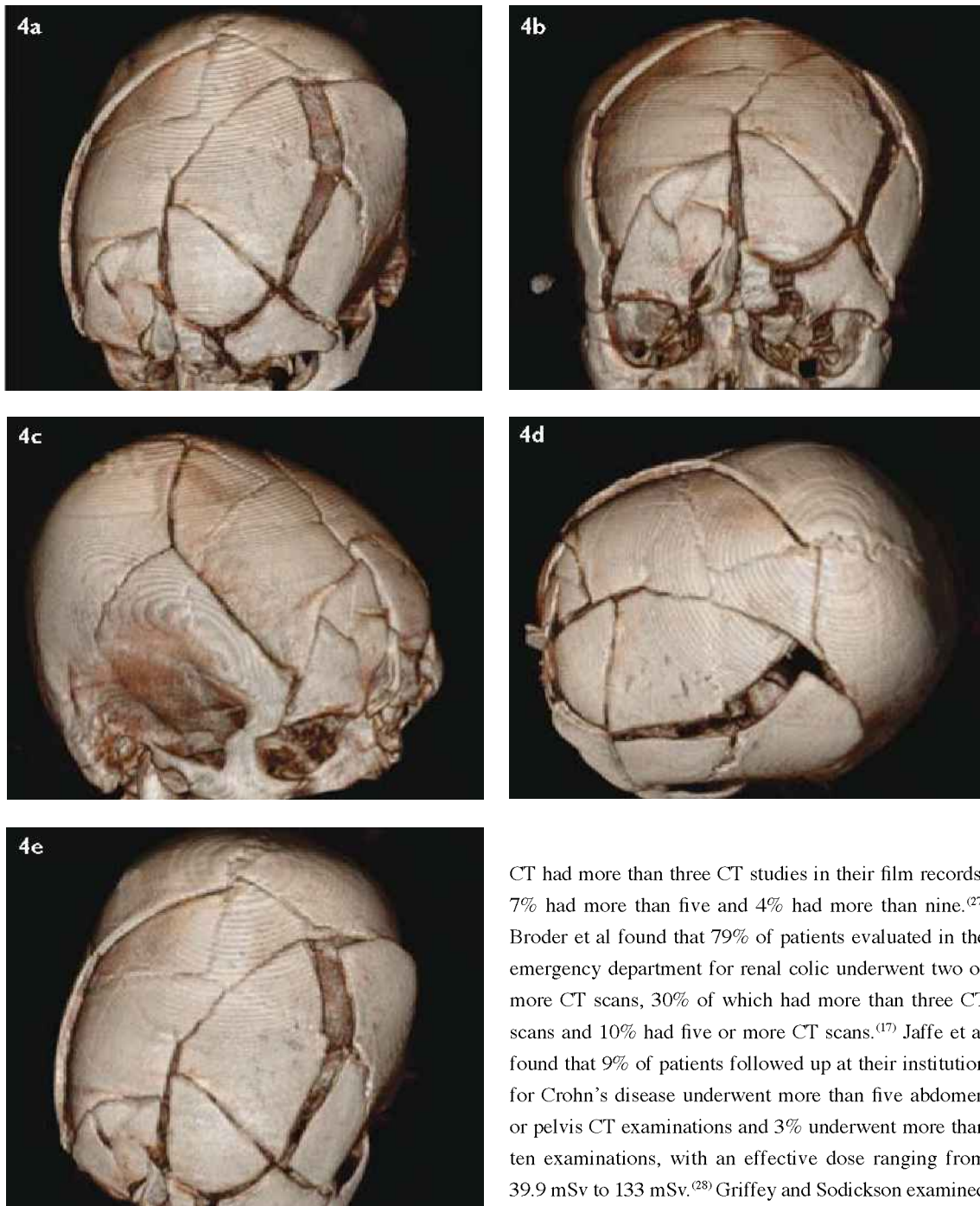


Fig. 4 3D reconstructed images of the skull show extensive fractures due to a fall from height.

provided many innovative suggestions for controlling radiation exposure, including the development of “a surveillance mechanism to identify patients with high cumulative radiation doses due to repeated imaging”.⁽¹⁸⁾ However, data is still limited regarding patients undergoing frequent imaging, the associated radiation risks, as well as the subsequent potential risks of developing fatal malignancy.

Wiest et al reported that 30% of all patients undergoing

CT had more than three CT studies in their film records, 7% had more than five and 4% had more than nine.⁽²⁷⁾ Broder et al found that 79% of patients evaluated in the emergency department for renal colic underwent two or more CT scans, 30% of which had more than three CT scans and 10% had five or more CT scans.⁽¹⁷⁾ Jaffe et al found that 9% of patients followed up at their institution for Crohn’s disease underwent more than five abdomen or pelvis CT examinations and 3% underwent more than ten examinations, with an effective dose ranging from 39.9 mSv to 133 mSv.⁽²⁸⁾ Griffey and Sodickson examined patients undergoing multiple imaging tests at the emergency department at least three times per year. They noticed that over a 7.7-year period, 130 patients underwent 1,744 CT studies, 55% of which were performed in the emergency department. More than half of the patients in their cohort underwent ten or more CT studies and accumulated more than 91 mSv of cumulative radiation dose, with an estimated lifetime risk of developing a radiation-induced cancer of one in 100, or greater.⁽²⁹⁾

This raises the risk-to-benefit equation that clinicians need to face in the emergency department with regard to the decision of whether to subject a patient to another CT imaging or to recommend an alternative imaging technique

so as to reduce the radiation risk associated with multiple CT scans. Approaches to reduce cumulative radiation risks include dose reduction with each CT examination (such as automated tube current modulation, imaging parameter selection or protocol modifications) and the utilisation of standardised reference dose levels. A risk-benefit decision must be made at the level of the individual patient, and should involve balancing the highly context-dependent benefits of CT imaging against the patient-specific cumulative risks.⁽³⁰⁾

APPLICATION OF CT FOR WHOLE BODY SCREENING IN TRAUMA PATIENTS

Rapid imaging along with more accurate and accessible CT scans have changed the indications from being symptom driven to nonsymptom or mechanism driven.⁽³¹⁾ CT and 3D reconstruction visualisations have proven to be invaluable in detecting and characterising injuries associated with trauma patients (Figs. 1–4).^(32,33) Several reports have recommended the use of CT as both a screening and a diagnostic tool, and some have suggested that CT could replace the use of radiography in certain traumatic situations.^(34,35)

Performing whole body imaging on unevaluable patients has become an accepted protocol in many trauma centres.^(36,37) The fear of missing an injury in a patient who cannot be reliably examined has made whole body scanning for these patients routine when compared to diagnostic peritoneal lavage.⁽³⁶⁾ Even in evaluable patients, liberal CT scanning is advocated due to the unreliability of physical examination.^(38,39) Mackerise et al found only a 65% diagnostic accuracy for physical examination alone in evaluating abdominal injury.⁽⁴⁰⁾ Self et al also reported similar imprecision in that 38% of the patients with negative physical examinations had positive CT findings.⁽³⁵⁾ Some would argue that a CT scan has replaced physical examination in trauma patients. Clinical studies have supported the use of CT in whole body imaging in trauma patients in the emergency settings.⁽³⁶⁻⁴¹⁾

Previous studies have reported that CT is performed in up to 67% of patients presenting to emergency departments.^(40,41) Currently, many centres are equipped with dedicated CT scanners to enable fast access for trauma patients and various medical emergencies.^(42,43) The recent introduction of multislice CT (four to 128 slice) in the emergency department has liberated CT from limited transaxial images to a multiplanar imaging technique.^(44,45) The huge improvement in CT performance has reduced scanning times, which favours multislice CT for imaging trauma patients. In addition to the diagnostic value of CT in imaging patients presenting with traumatic injury to

the individual organs,^(34,35,37,46) the CT technique has been reported to be a valuable modality for whole body imaging in terms of better patient management and diagnostic accuracy.⁽⁴⁷⁻⁵⁰⁾

Self et al reported that 38% of the 457 patients who underwent head, thorax, abdominal and pelvic CT imaging in blunt multitrauma had unexpected findings that were not detected by conventional radiographic examinations. Changes of treatment plan were made in 26% of the study group because of the results found on the CT scans, while in the meantime, additional whole body CT scans added minimal costs to the care of trauma patients.⁽³⁶⁾ Salim et al found that 19% of the 1,000 patients without obvious external signs of injuries had a change of treatment based on the results of the whole-body CT scan.⁽⁴⁷⁾ This is also supported by a recent report published in *Lancet*.⁽⁵⁰⁾ Huber-Wagner et al, in their multicentre study, found that whole-body CT is an independent predictor of survival for patients with major trauma. They recommended whole-body CT as a standard diagnostic method during the early resuscitation phase for multitrauma patients.⁽⁵⁰⁾ In addition to the diagnostic value, whole-body CT (a single pass continuous CT scan) was found to result in a lower radiation dose than conventional segmented acquisitions with scanning of individual body segments.⁽⁵⁰⁻⁵²⁾ Ptak et al reported a 17% reduction in radiation dose when a single-pass examination was used when compared with the dose administered in the conventional segmented protocol.⁽⁵²⁾ The estimated lifetime risk of cancer from a single whole-body CT examination is about one in 1,250 for a 45-year-old adult and one in 1,700 for a 65-year-old adult.⁽⁵³⁾ However, the estimated risks for multiple CT examinations are correspondingly higher than those for a single full-body CT examination, with a potentially accumulated estimated life-time cancer risk of up to 1.9% (about one in 50) for a 45-year-old adult undergoing multiple full-body CT examinations.⁽⁵³⁾

SUMMARY AND CONCLUSION

There is no doubt that CT has become the most valuable diagnostic modality in the emergency department. Rapid technical developments in CT imaging and its increased availability reflect the significant increase of CT utilisation in adult emergency departments. The increased use of CT also represents a potentially large radiation exposure for patients. Physicians need to be aware of this potential risk associated with CT imaging. The increase of CT utilisation in the emergency department should ultimately be justified by improving healthcare outcomes. The benefit-to-risk ratio for imaging patients in emergency department must be driven by the benefit

and appropriateness of the CT examination requested by the physicians. The main purpose of utilising CT imaging is to address specific clinical questions without allowing concerns about radiation exposure to dissuade physicians or their patients from obtaining or undergoing the required CT examination. This review has highlighted that CT has been advocated in the diagnosis and management of trauma patients; however, for patients with headache and repeat or multiple CT scans in the emergency department, the use of CT must be justified with regard to the potential risk of radiation exposure.

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