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, 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 focus on patients presenting with headache, repeat and multiple CT imaging and whole body screening for trauma patients, and explore whether the applications are clinically justified.

Keywords: computed tomography (CT), emergency department, trauma, radiation dose, radiation risk

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 frequency of CT examinations in developed countries increased on average from 6.1 per year per 1,000 population in the 1970s to 48 per year 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 (millisieverts) 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 which include the introduction of helical CT 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 3D reconstruction of anatomical areas (3, 4). These advantages have led to a rapid increase of CT utilisation 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 CT scans in 2006 including 4 million for children (9). Comparable trends have been reported in European countries such as Germany, Switzerland, Norway and UK (10). All these data indicate that CT has become the method of choice in many clinical applications in both daily practice and emergency department.

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 comes with growing concern about 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 report on the Biological Effects of Ionizing Radiation (BIER VII) estimated that a single population dose of 10 mSv is associated with a lifetime risk for developing a solid cancer or leukaemia by 1 in 1000 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%. 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). Substantial increases of CT utilisation were noted over the last decade in the emergency 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 scan, 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). Because 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 imaging are of very low diagnostic value when applied as screening tools in patients imaged for isolated nonfocal headaches (22, 23). Jordan et al (25) recently reported that CT imaging of nonfocal headache in emergency setting had limited cost efficacy due to 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. Similarly, a chief complaint of trauma headache predicted 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 (26) found that 54% of patients had an abnormal non-contrast head CT, and 41% of all CT angiography were abnormal. Since CT imaging of emergency headache has become a widespread and growing problem with significant economic implications, the physicians need to follow 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 scans

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, resource utilisation in both emergency and non-emergency situations. A recent American College of Radiology white paper (2007) on radiation dose in medicine provides many innovative suggestions for controlling radiation exposure, including development of "a surveillance mechanism to identify patients with high cumulative radiation doses due to repeated imaging" (18). However, data are still limited regarding patients undergoing frequent imaging and the associated radiation risks, as well as subsequent potential risks of developing fatal malignancy.

Wiest et al (27) 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. Broder et al (17) 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. Jaffe et al (28) found that 9% of patients followed at their institution for Crohn's disease underwent more than five abdomen or pelvis CT examinations and 3% more than 10 examinations, with effective dose ranging from 39.9 to 133 mSv. Griffey and Sodickson (29) looked at the patients visiting the emergency department at least three times per year undergoing multiple imaging tests. They noticed that over a 7.7-year period, 130 patients underwent 1744 CT studies, of which 55% were performed in the emergency department. More than half of the patients in their cohort underwent 10 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 as to whether to image the patient again with CT or recommend another imaging technique to reduce the radiation risk associated with multiple CT scans. Approaches to reduce cumulative radiation risks to these patients include dose reduction of each CT examination (such as automated tube current modulation, imaging parameter selection or protocol modifications) and 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, more accurate and more accessible CT scans have changed the indications from being symptom driven to nonsymptom or mechanism driven (31). CT along with 3D reconstruction visualisations has proven to be valuable in detecting and characterising injuries associated with trauma patients (32, 33). Several reports recommended the use of CT as both a screening and diagnostic tool, and some 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 centers (36, 37). The fear of missing an injury in a patient who cannot be reliably examined has made whole body scanning these patients routine when compared to diagnostic peritoneal lavage (36). Even if in evaluable patients, liberal CT scanning is advocated due to the unreliability of physical examination (38, 39). Mackerise et al (40) found only a 65% diagnostic accuracy for physical examination alone in evaluating abdominal injury. 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 supported the use of CT in whole body imaging in trauma patients in the emergency settings (36-41).

Previous studies 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 allow fast access for trauma patients and various medical emergencies (42, 43). The recent introduction of multislice CT (16 and 64-slice) in the emergency department has changed CT from a conventional transaxial sectional imaging to a 3D isotropic imaging technique (44, 45). The huge improvement in CT performance reduces scanning time and section collimation, therefore this 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 (36) reported that 38% of 457 patients who underwent head, thorax, abdominal and pelvic CT scans 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. Salim et al (47) found that 19% of 1000 patients without obvious external signs of injuries resulted in a change of treatment based on the results of whole-body CT scan. This is also supported by a recent report published in the 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 the whole-body CT as a standard diagnostic method during the early resuscitation phase for multitrauma patients.

In addition to the diagnostic value, whole body CT (a single pass continuous CT scan) was found to result in lower radiation dose than do conventional segmented acquisitions with scanning of body segments individually (50-52). Ptak et al (52) 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. The estimated lifetime risk of cancer from a single whole-body CT examination is about 1 in 1250 for a 45-year-old adult and 1 in 1700 for a 65-year-old adult (53). However, the estimated risks for multiple CT examinations are correspondingly higher with potentially accumulated estimated life-time cancer risk of up to 1.9% (about one in 50) (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 the increased availability reflect the significant increase of CT utilisation in the adult emergency department. 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 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 question without allowing concerns about radiation exposure to dissuade physicians or their patients from obtaining or undergoing the needed 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, use of CT must be justified with regard to the potential risk of radiation exposure.

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

Examination	Average effective dose (mSv)	Values reported in the literature (mSv)
Skull	0.1	0.03-0.22
Cervical spine	0.2	0.07-0.3
Thoracic spine	1.0	0.6-1.4
Lumbar spine	1.5	0.5-1.8
Posteroanterior and lateral study of chest	0.1	0.05-0.24
Posteroanterior study of chest	0.02	0.07-0.050
Abdomen	0.7	0.04-1.1
Pelvis	0.6	0.2-1.2

Table II. Adult effective radiation dose of various CT examinations (Revised from reference 14. NA-not available)

Examination	Average effective dose (mSv)	Values reported in the literature (mSv)
Head	2	0.9-4
Neck	3	NA
Chest	7	4.0-18
Abdomen	8	3.5-25
Pelvis	6	3.3-10
Spine	6	1.5-10

Table III Guidelines for neuroimaging (CT scans) in patients with headache (* Guidelines developed by US Headache Consortium, the American College of Emergency Physicians, and the American College of Radiology (24) were revised to correspond to the emergency situations)

Emergent CT imaging recommended/not recommended	**Clinical Indications**
Emergent CT imaging is recommended	"Thunderclap" headache with abnormal neurological exam
Emergent CT imaging is recommended to determine if it is safe to do lumbar puncture	• Headache accompanied by signs of increased intracranial pressure • Headache accompanied by fever and 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)	• Isolated "thunderclap" headache • Headache radiating to neck • Temporal headache in an older individual (after age 50) • New onset headache in patient who is o HIV positive o has a prior diagnosis of cancer o is in a population at high risk for intracranial disease • Headache accompanied by abnormal neurological examination, including papilledema or unilateral loss of sensation, weakness, or hyperflexia
Emergent CT imaging is not usually warranted	• Migraine and normal neurological exam
Emergent CT imaging is not recommended (Some evidence for increased risk of intracranial abnormality, not sufficient for recommendation)	• Headache worsened by Vasalva maneuver, wakes patient from sleep, or is progressively worsening
Emergent CT imaging is not recommended (insufficient data)	• Tension type headache and normal neurological exam

References

1. United Nations Scientific Committee on the Effects of Atomic Radiation report to the general assembly, Vol II, Annex D: Medical radiation exposures. United Nations, New York, 2006
2. Verdum FR, Gutierrez D, Vader JP, et al. CT radiation dose in children: a survey to establish age-based diagnostic reference levels in Switzerland. Eur Radiol 2008; 18: 1980-1986
3. McCollough CH, Zink FE. Performance evaluation of a multi-slice CT system. Med Phys 1999; 26: 2223–2230
4. Rybicki FJ, Otero HJ, Steigner ML, et al. Initial evaluation of coronary images from 320-detector row computed tomography. Int J Cardiovasc Imaging 2008; 24: 535-546
5. Altes TA. Multislice CT computed tomographic scanning: technological innovations bring new indications in pediatric chest CT. Pediatr Ann 2002; 31: 761-675
6. Salamipour H, Jimenez RM, Brec SL, et al. Multidetector row CT in pediatric musculoskeletal imaging. Pediatr Radiol 2005; 35: 555–564
7. Brenner D, Ellison C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. Am J Roentgenol 2001; 176: 289-296
8. Brenner DJ, Hall EJ. Computed tomography: an increasing source of radiation exposure. N Engl J Med 2007; 357: 2277-2284
9. IMV 2006 CT Market Summary Report. Des Plains, IL: IMV Medical Information Division, 2006
10. Heyer CM, Hansmann J, Peters SA, Lemburg SP. Paediatrician awareness of radiation dose and inherent risks in chest imaging studies-A questionnaire study. Eur J Radiol 2009 (in press)
11. Fazel R, Krumholz HM, Wang YF, et al. Exposure to low-dose ionizing radiation from medical imaging procedures. N Engl J Med 2009; 361: 849-857
12. McCollough CH, Guimaraes L, Fletcher JG. In Defense of body CT. Am J Roentgenol 2009; 193: 28-39

13. Committee to Access Health Risks from Exposure to Low Level of Ionizing Radiation, National Research Council, Health risks from exposure to low level of ionizing radiation. BEIR VII Phase 2. Washington, DC: National Academies Press, 2006
14. Mettler FA, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: A catalog. Radiology 2008; 248: 254-263
15. International Commission on Radiological Protection (1977) Recommendations of the ICRP, publication 26. Pergamon, Oxford
16. Smith-Bindman R, Lipson J, Marcus R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med 2009; 169: 2078-2086
17. Broder J, Bowen J, Lohr J, Babcock A, Yoon J. Cumulative CT exposures in emergency department patients evaluated for suspected renal colic. J Emerg Med 2007; 33:161–168
18. Amis ES Jr, Butler PF, Applegate KE, et al. American College of Radiology white paper on radiation dose in medicine. J Am Coll Radiol 2007; 4:272–284
19. Broder J, Warshauer DM. Increasing utilization of computed tomography in the adult emergency department, 2000–2005. Emerg Radiol 2006; 13: 25–30
20. Nawar EW, Niska RW, Xu J. National Hospital Ambulatory Medical Care Survey:2005 Emergency Dept Summary. Advance data from vital and health statistics; no. 386. Hyattsville, MD; National Center for Health Statistics; 2007
21. Medina LS, D'Souza B, Vasconcellos E. Adults and children with headache: evidence-based diagnostic evaluation. Neuroimaging Clin N Am 2003; 13: 225-232
22. Grosskreutz ST, Osborn RE, Sanchez RM. Computed tomography of the brain in the evaluation of the headache. Mil Med 1991; 156: 137-140
23. Weingarten S, Kleinman M, Elperin L, Larson EB. The effectiveness of cerebral imaging i nthe diagnosis of chronic headache [see comments]. Arch Intern Med 1992; 152: 2457-2462
24. Jordan, JE. Expert Panel on Neurologic Imaging, American College of Radiology, ACR Appropriateness Criteria: Headache. Am J Neuroradiol 2007; 28:1824-1826

25. Jordan YJ, Lightfoote JB, Jordon JE. Computed tomography imaging in the management of headache in the emergency department: cost efficacy and policy implications. J Natl Med Assoc 2009; 101: 331-335
26. Jamshidi S, Kandiah PA, Singhal AB, et al. Clinical predictors of significant findings on head computed tomographic angiography. J Emerg Med 2009 (in press)
27. Wiest PW, Locken JA, Heintz PH, Mettler FA Jr. CT scanning: a major source of radiation exposure. Semin Ultrasound CT MR 2002; 23:402–410
28. Jaffe TA, Gaca AM, Delaney S, et al. Radiation doses from small-bowel follow-through and abdominopelvic MDCT in Crohn's disease. Am J Roentgenol 2007; 189:1015–1022
29. Griffey RT, Sodickson A. Cumulative radiation exposure and cancer risk estimates in emergency department patients undergoing repeat or multiple CT. Am J Roentgenol 2009; 192: 887-892
30. Sodickson A, Baeyens PF, Andriole KP, et al. Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. Radiology 2009; 251: 175-184
31. Hayward R. VOMIT (victims of modern imaging technology)—an acronym for our times. BMJ 2003;326:1273
32. Heyer CM, Rduch GJ, Wick M, et al. Evaluation of multiple trauma victims with 16-row multidetector computed tomography (MDCT): a time analysis. ROFO 2005; 177: 1677-1682
33. Gralla J, Spycher F, Pignolet C, Ozdoba C, Vock P, Hopper H. Evaluation of a 16-MDCT scanner in an emergency department: initial clinical experience and workflow analysis. Am J Roentgenol 2005;185:232-238
34. Brown CVR, Antevil JL, Sise M, Sack DI. Spiral computed tomography for the diagnosis of cervical, thoracic, and lumbar spine fractures: its time has come. J Trauma 2005;58:890-896
35. Rhee PM, Bridgeman A, Acosta JA, et al. Lumbar fractures in adult blunt trauma patients: axial and single-slice helical abdominal and pelvic computed tomographic scans versus portable plain films. J Trauma 2002;53:663-667

36. Self ML, Blake AM, Whitley M, et al. The benefit of routine thoracic, abdominal, and pelvic computed tomography to evaluate trauma patients with closed head injury. Am J Surg 2003;186:609-614
37. Pal JD, Victorino GP. Defining the role of computed tomography in blunt abdominal trauma. Arch Surg 2002;137: 1029-1033
38. Poletti PA, Mirvis SE, Shanmuganathan K, et al. Blunt abdominal trauma patients: can organ injury be excluded without performing computed tomography? J Trauma 2004;57: 1072-1081
39. Schurink GW, Bode PJ, van Luijt PA, van Vugt AB. The value of physical examination in the diagnosis of patients with blunt abdominal trauma: a retrospective study. Injury 1997;28: 261-265
40. Mackerise R, Tiwary AD, Shackford SR, Hoyt DB. Intra-abdominal injury following blunt abdominal trauma: Identifying the high-risk patient using objective risk factors. Arch Surg 1989; 124: 809-813
41. Hauser H, Bohndorf K. Radiologic emergency management in multiple trauma cases. Radiologe 1998; 38:637–644
42. Nunez DB Jr, Ledbetter MS, Farrell L. Dedicated CT scanner in an emergency department: quantification of factors that contribute to lack of use. Am J Roentgenol 2002; 179:859–862
43. Novelline RA, Rhea JT, Rao PM, Stuk JL. Helical CT in emergency radiology. Radiology 1999; 213: 321-339
44. Kuettner A, Trabold T, Schroeder S, et al. Noninvasive detection of coronary artery lesions using 16-detector row multislice spiral computed tomography technology: initial clinical results. J Am Coll Cardiol 2004; 44: 1230-7
45. Raff GL, Gallagher MJ, O'Neill WW, et al. Diagnostic accuracy of non-invasive coronary angiography using 64-slice spiral computed tomography. J Am Coll Cardiol 2005, 46: 552-557
46. Langner S, Fleck S, Kirsch M, Petrik M, Hosten N. Whole-Body CT trauma imaging with adapted and optimized CT angiography of the craniocervical vessels: Do we need an extra screening examination? Am J Neuroradiol 2008; 29:1902– 07

47. Salim A, Sangthong B, Martin M, Brown C, Plurad D, Demetriades D. Whole body imaging in blunt multisystem trauma patients without obvious signs of injury: Results of a prospective study. Arch Surg 2006;141: 468-475
48. Wurmb TE, Fruhwald P, Hopfner W, et al. Whole-body multislice computed tomography as the first line diagnostic tool in patients with multiple injuries: the focus on time. J Trauma 2009; 66: 658-665
49. Rieger M, Czermak B, El AttaI R, et al. Initial clinical experience with a 64-MDCT whole-body scanner in an emergency department: better time management and diagnostic quality? J Trauma 2009; 66: 648-57
50. Huber-Wagner S, Lefering R, Qvick L-M, et al. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. Lancet 2009; 373: 1455-61
51. Fanucci E, Fiaschetti V, Rotili A, et al. Whole body 16-row multislice CT in emergency room: effects of different protocols on scanning time, image quality and radiation exposure. Emerg Radiol 2007; 13: 251-257
52. Ptak T, Rhea JT, Novelline RA. Radiation dose is reduced with a single-pass whole-body multi-detector row CT trauma protocol compared with a conventional segmented method: initial experience. Radiology 2003; 229: 902-905
53. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening. Radiology 2004; 232: 735-738

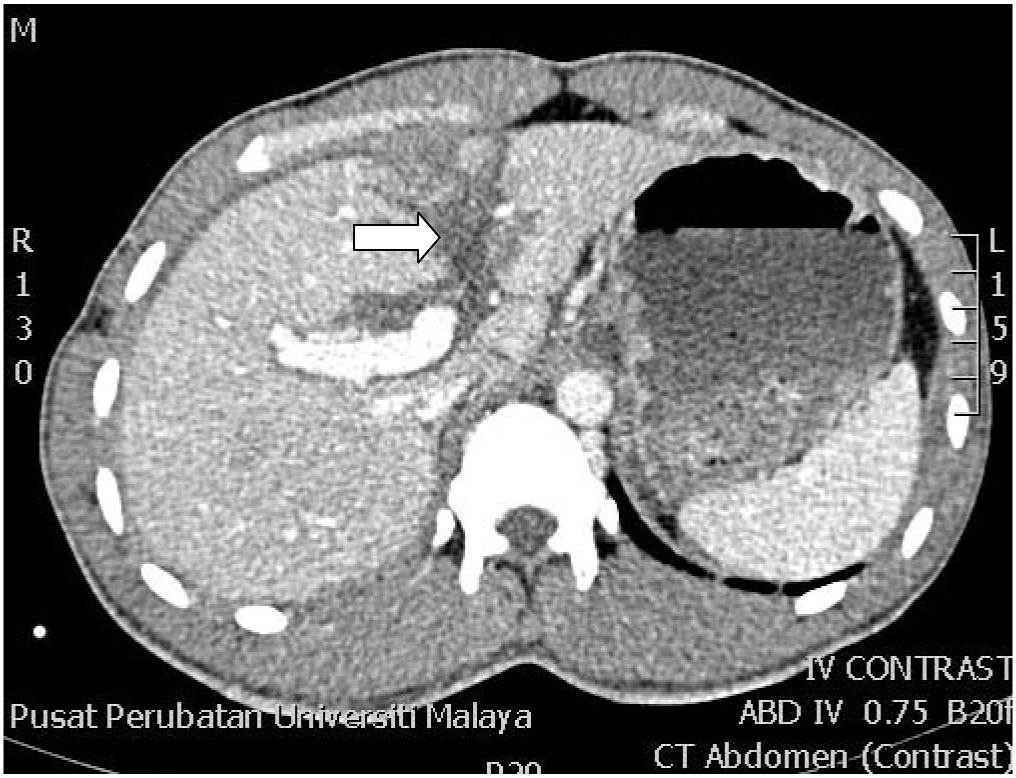


Figure 1: Axial computed tomography scan of the abdomen shows a hypodense laceration of the liver (arrow).

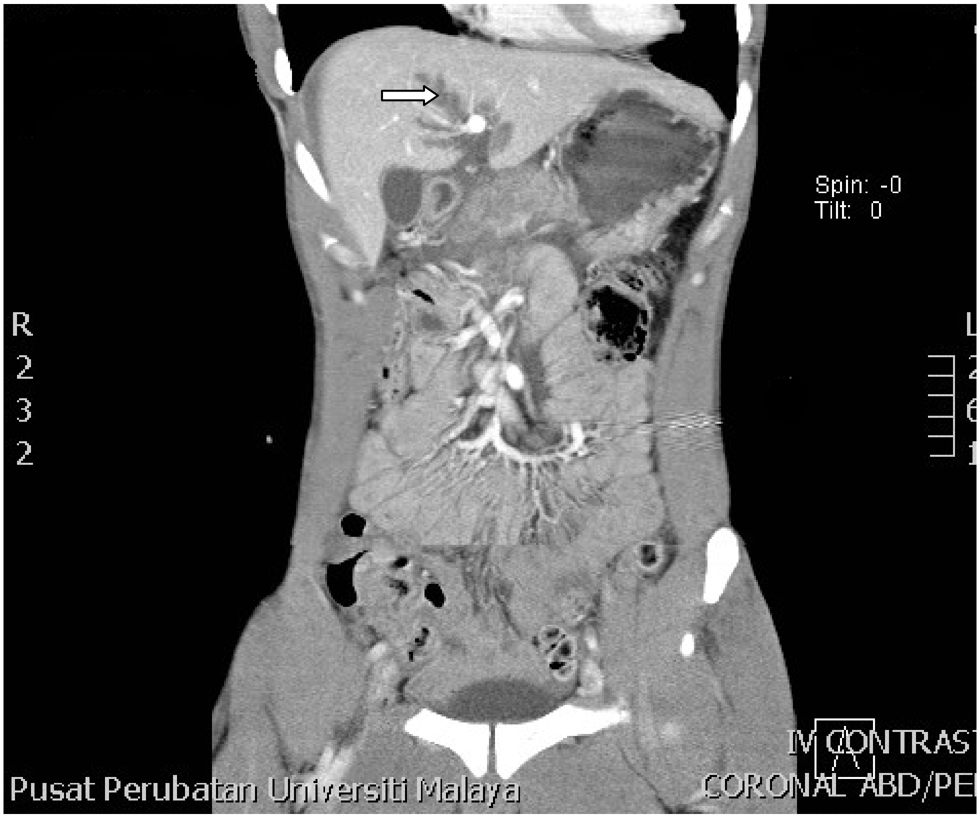
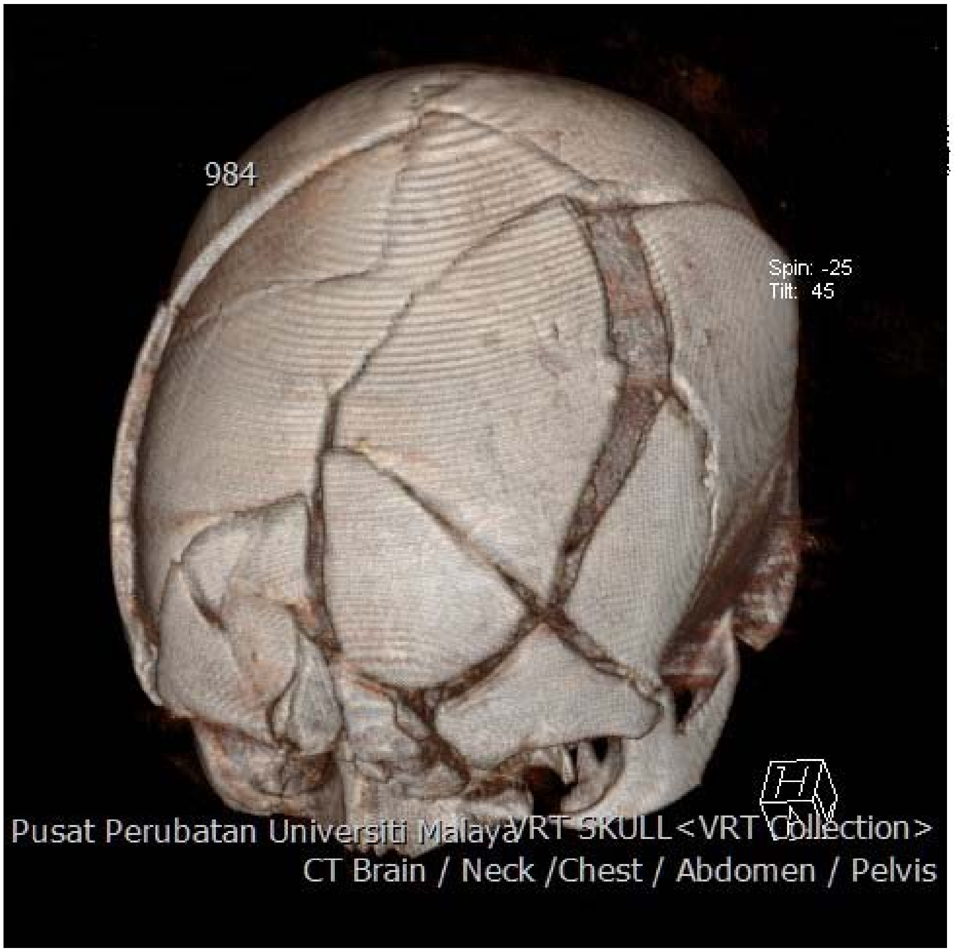


Figure 2: A coronal CT scan of the abdomen showing laceration of the liver post trauma (arrow)

Figure 3: Extensive head injury sustained due to fall from height. Subarachnoid bleed, multiple contusions and cerebral oedema are seen in this axial computed tomography of the brain. There are also multiple skull fractures seen. The patient succumbed after 2 hours.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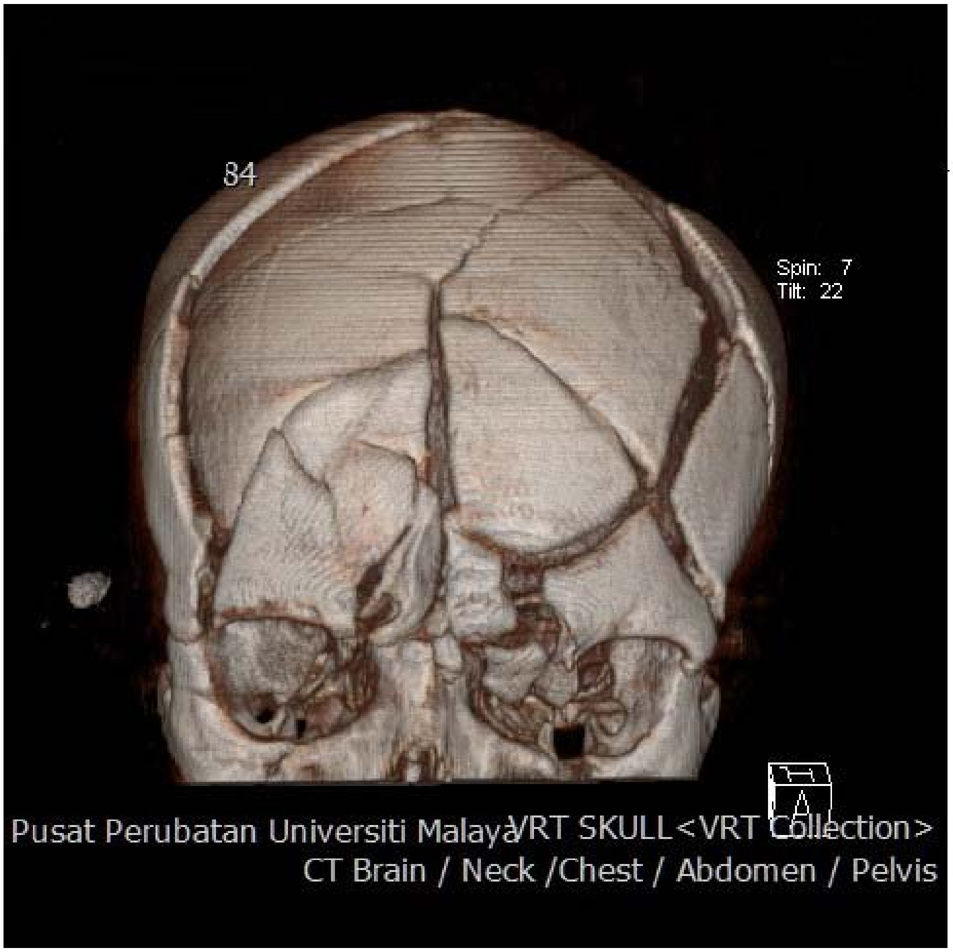
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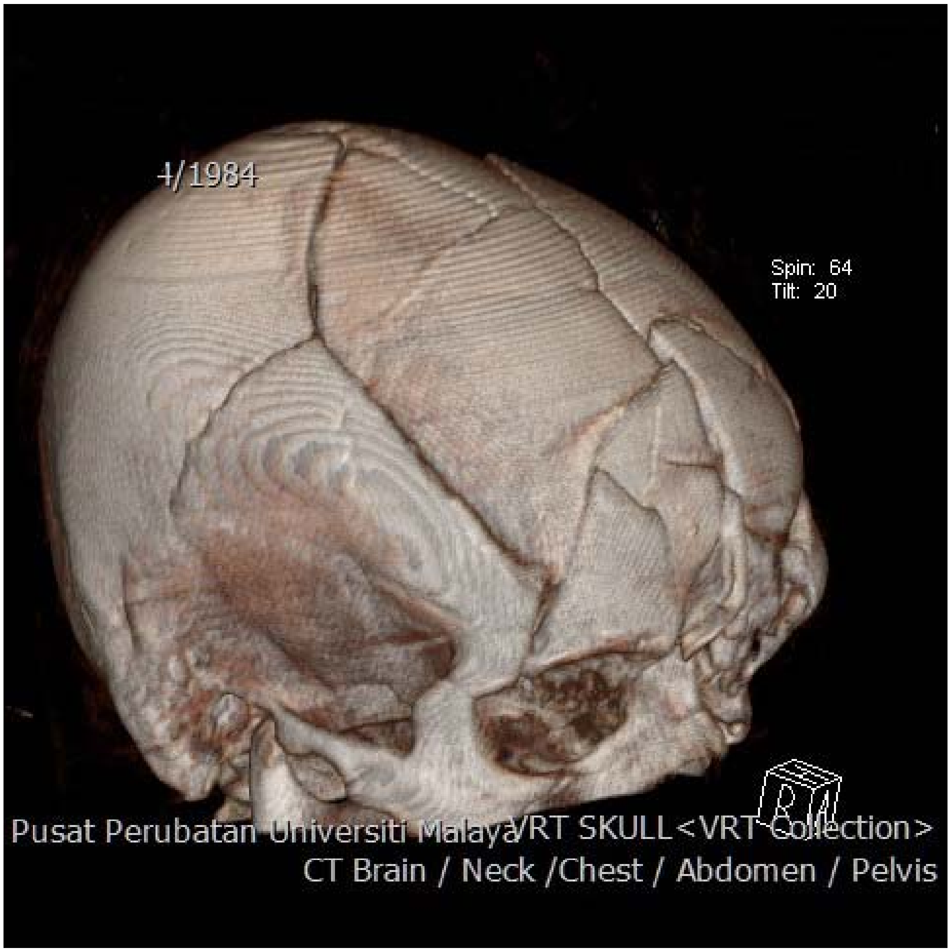

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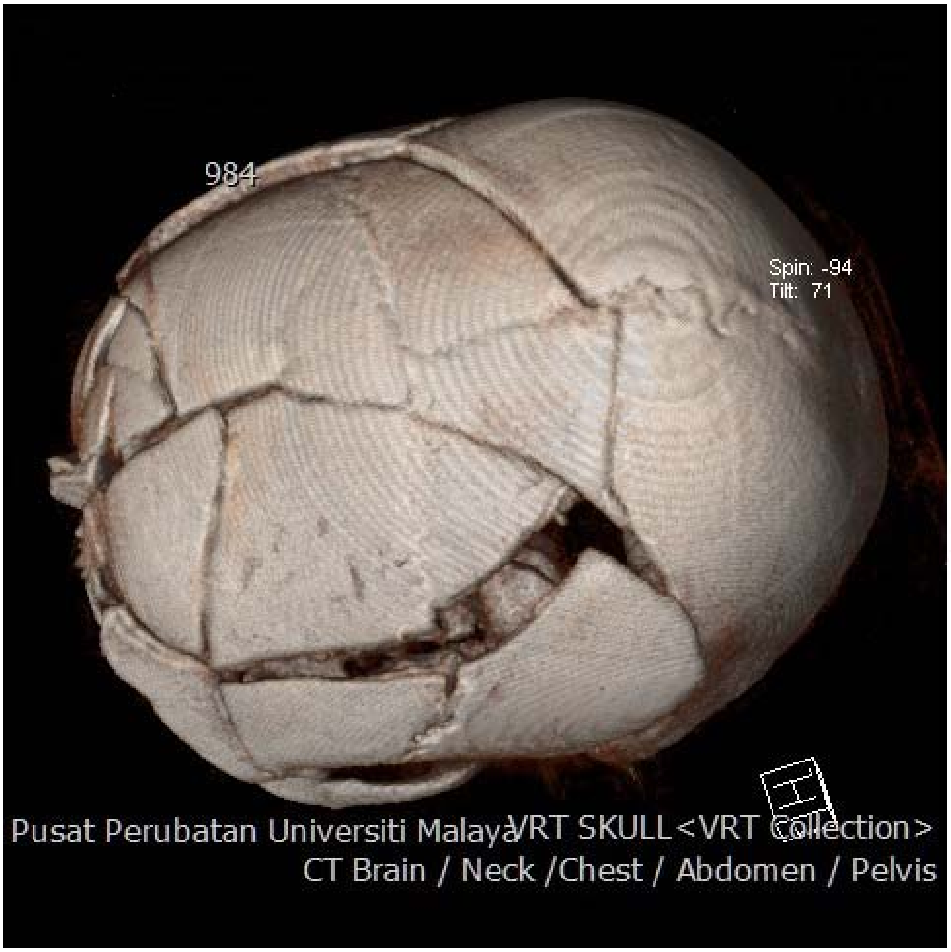
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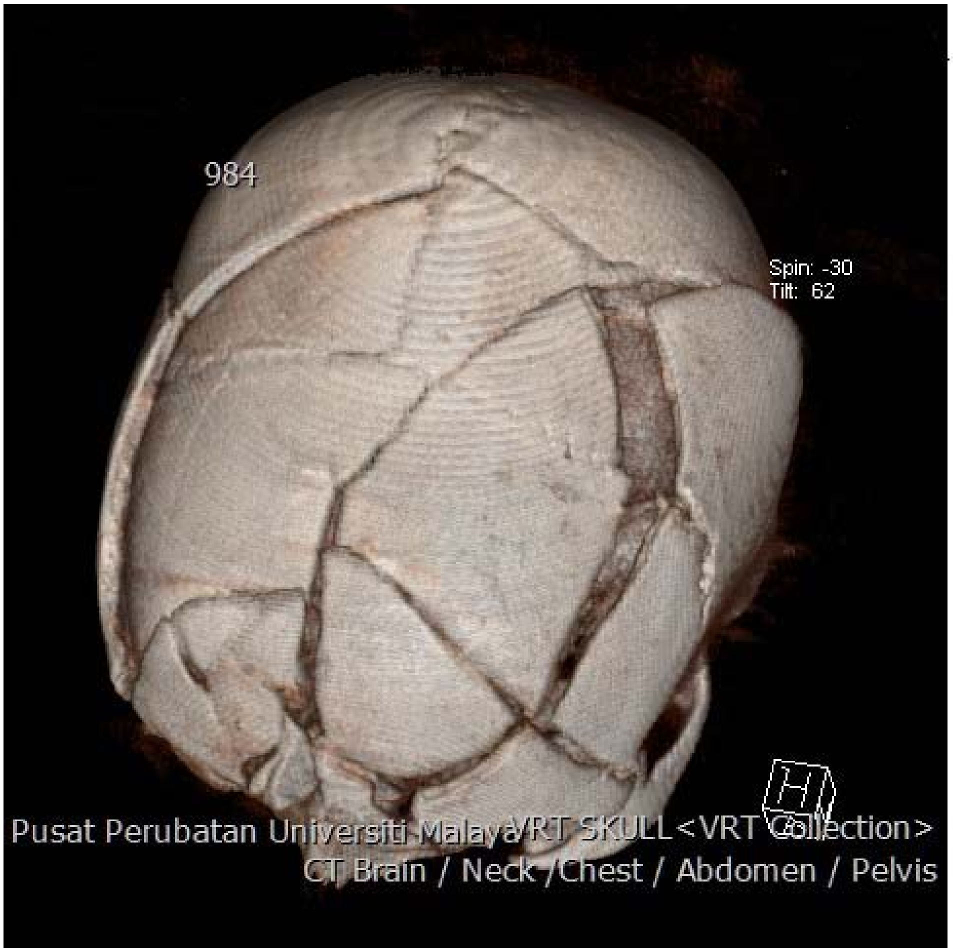

Figure 4: A 3D reconstructed image of the skull showing extensive fractures due to a fall from height