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CT-Scanning in Forensic Medicine

Peter Mygind Leth
University of Southern Denmark
Denmark

1. Introduction

The forensic community has in general been slow to implement the modern diagnostic imagining modalities, partly due to unawareness of its potentials and probably also for financial reasons. Now CT and other imagining techniques such as magnetic resonance imaging are however gaining access to forensic medicine, as an increasing number of forensic institutes install CT-and even MR-scanners (1-6). A research group from the University of Bern and their international partners in the socalled *virtopsy-project* has been leading in this development (7, 8).

Investigation of deseased is of importance for several different reasons, including jurisprudence, science, education and quality control. The traditional methods of investigation have been an external examination of the body at the inquest, often followed by an autopsy. The autopsy techniques have been developed to a high standard during many hundred years, but have some obvious limitations: certain parts of the body are not always investigated, especially in the limbs, the back and the neck, and the autopsy procedure disturbs the normal anatomy. Some may have ethical or religious objections (9). The number of autopsies seems to be declining in many countries (10) and have long since ceased to be the main focus for pathological departments.

Modern diagnostic imaging techniques will therefore be of increasing importance in the investigation of the dead in the future. There are important differences between clinical and forensic postmortem radiology (11). Movement artefacts or radiation overdose is not a problem in the latter. Contrast administration requires specialized techniques (12, 13) and are not yet routinely used. Internal lividity, intravascular clots and gasformation from decomposition may cause interpretational problems (figure 1 – 2) (14). Furthermore, knowdledge of forensic pathology, especially forensic traumatology, is needed for the interpretation. The focus of the forensic investigation is different from clinical practise and includes consideration of the injury mechanism. A forensic radiologist must thus be educated in both radiology and forensic pathology and preferrably work in co-operation with the pathologist who performs the autopsy (15).

CT may be used before the medicolegal inquest to broaden the basis for decision about autopsy, or it may be used as an adjunct to autopsy in all cases or in selected cases. If available, CT should be performed in trauma cases, including gunshots, in battered child cases and in identifications. Postmortem CT has some obvious limitations compared to autopsy. The visual sensations are of inferior quality with less resolutions and no colour, and other senses such as touch and smell are not used. It is difficult to obtain material for microscopy or microbiology. CT-guided biopsies of organs or mass lesions may however be obtained when autopsy is not consented (16).

Fig. 1. Transversal CT-image of thorax with internal lividity in the lungs.

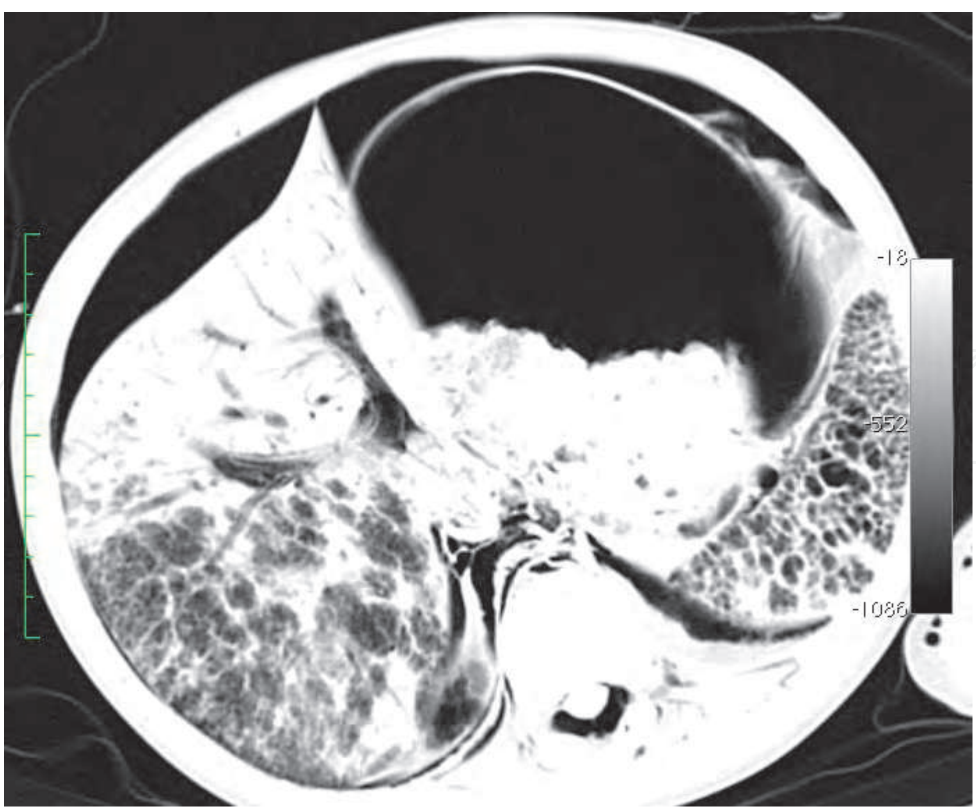


Fig. 2. Transversal CT-image of abdomen with gas formation caused by decomposition.

2. Equipment

Forensic facilities with a large wordload will need an efficient multislice helical scanner. In smaller institutions a less expensive CT-scanner may suffice if the equipment is used primarily as an adjunct to autopsy.
The scanoperator should preferably be a fulltime radiographer, but in our experience it is possible for a forensic technician to operate the equipment in routine cases after appropriate training and supervision.
The equipment should be installed next to the morgue and the workstation in or next to the autopsy room, for easy access to the CT images. CT images can also be sent to a smartphone or an iPad. Some forensic centers coorperate with clinical radiological centers and utilize their staff and equipment.
The CT-images may be stored on a variety of storage media, such as an external harddisk or on CDs. The CT diagnoses may be registered according to standardised systems. We use ICD-diagnoses for non-trauma diagnoses and AIS for trauma diagnoses (17-19).

3. Determination of identity

Bodies may be unrecognizeable due to external factors such as fire, severe trauma or putrefaction. In these cases, CT may be of great help in establishing the identity. The identification process is based on a comparison of postmortem and antemortem descriptions and may be registered on Interpol identification forms. These contain general characteristics of the deseased such as sex, age estimate, height and hair colour, and some specific characteristics such as tatoos, scars and implants. Of particular importance are odonthology, fingerprints and DNA-profile. Most of the relevant sections in the Interpol forms can be filled out from the CT investigation (20) which has the additional benefit of providing a permanent objective record of the findings. Some characteristics such as the shape of the nose or ears may be even better appreciated from CT-images because of their "neutral" apperance (figure 3). Superimposition on portrait photos in photoshop is also possible. CT makes an anthropological assessment of the bones possible without defleshing, providing information of height from the length of the long bones, of age and of sex. Implants, such as prosthetic implants or artificial heart valves are easily found (figure 4). Sometimes antemortem X-rays may yield important clues to the identity, but are often not available until after the autopsy. If a volume of digitalized X-ray information from a post mortem CT-scanning is available, then it is easy to reconstruct an X-ray in the correct projection for comparison (21). The individual unique shape of the frontal sinus is among the features that may be used for identification based on X-ray-photos (22).
CT has been used for disaster victim identification. In Great Britain mobile CT-units have been deployed to the autopsy area for a major road traffic accident (23, 24), and in Australia CT has been used with great success in the Victoria bushfire disaster (25). CT substitutes the three traditionally used types of X-ray imaging: plain X-rays, fluoroscopy, and dental radiographs. Special software is needed for the latter.

4. Traffic fatalities

Postmortem examination of traffic fatalities serves as a quality check of treatment and diagnosis and provides information for accident profylaksis. A combination of CT and

Fig. 3. Face eyes, nose and mouth of unidentified man seen in profile. 3D CT reconstruction.

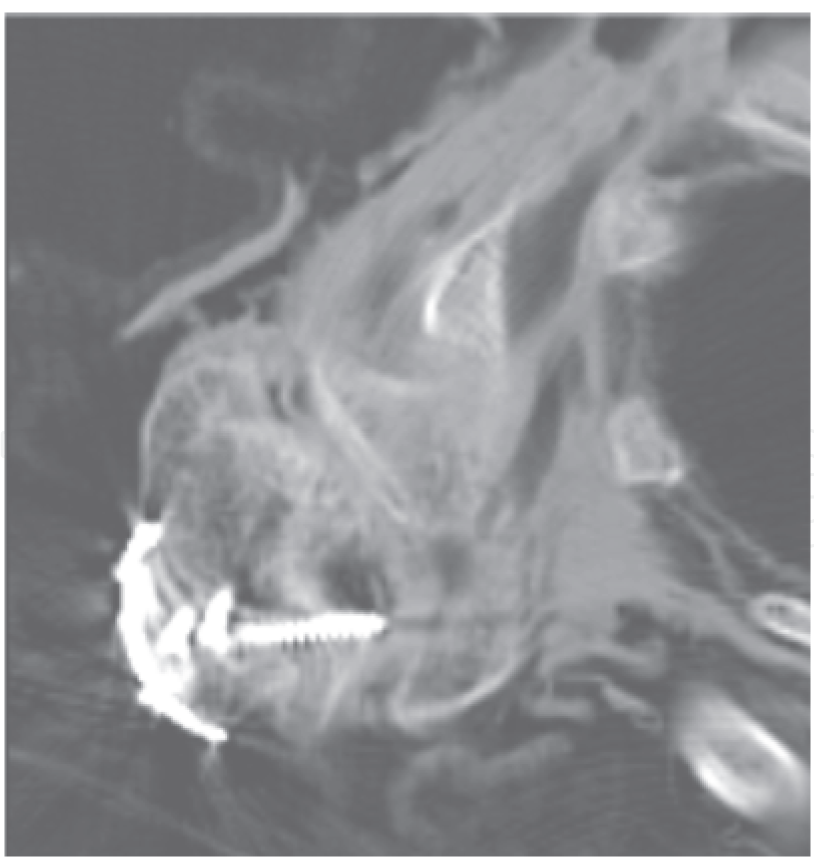


Fig. 4. Implant in humerus. Such CT finding may be of importance in the identification process. Unidentified man found in ditch.

autopsy gives the most accurate information, but if an autopsy is not possible for legal or ethical reasons a CT scanning should be performed. The trauma diagnoses could be registered according to the abbreviated injury scale for easy comparison among trauma centers (19).

Fig. 5. Tibia with intermediary fragment caused by anterior impact. 3D CT reconstruction. Pedestrian hit by car.

It is possible to identify injury patterns characteristic of specific accident scenarios (figure 5). Frontal car chrashes, which are the most common type of motor vehicle accidents, will for example cause the unrestrained driver or front seat passenger to be propeled forward causing first an extension of the lumbar spine and a slide forward with knee impact against the fascia, and then a move upwards and forwards of the body with impact of the crown against the roof frame and of the chest against the steering wheel/dashboard, and finally a foreward flexion of the cervical or thoracic spine with a final strike of the head against the windshield or the pillars. The resulting lesions appear from table 1. A more exhaustive text should be sought for a detailed description of the various accident types and their characteristic injury patterns (26). Many factors will contribute to modify the classical injury patterns. Airbags may cause severe head, neck and chest injuries in the unrestrained driver or front seat passenger (27). If the victim is ejected from the car, all kinds of injuries can be seen. In selected cases it may therefore be advisable to confer the case with the car inspector, and if possible to inspect the wreckage and the accident scene in order to make the proper clinico-pathological correlations.

Hit-and-run cases present a special challenge. In such cases it is of particular importance to obtain a volume of digitalized CT-data as this permits later comparisons with characteristics of the vehicle. The virtopsy group has applied photogrammetry for such comparisons (28).

Region	Injuries
Head and neck	Skull fractures, pneumoencephalon intracranial hematoma, cerebral contusion and laceration, brainstem damage, fractures of cervical vertebrae, atlanto-occipital dislocation, transection of cervical cord
Chest	Fracture of sternum and ribs, haemopneumothorax, lung laceration, heart laceration, aorta rupture
Abdomen	Laceration of liver, spleen, mesentery/omentum,
Extremities	Fractures of pelvis, femur with dislocation of hip joints, patella, tibia, fibula and metatarsal bones

Table 1. Injuries found in driver and front seat passenger in frontal crashes

5. Gunshot cases

The use of radiology in the investigation of firearm fatalities has been a standard practice since the discovery of X-rays. However CT offers significant advantages over plain film X-rays (29, 30). CT cannot replace all the information that an autopsy can provide, and at present CT should be considered an adjunct to the forensic autopsy.

This chapter contains information about CT used in cases of firearm fatalities, but a more detailed description of weapon types and ammunition should be sought in a more comprehensive text (31).

The primary aim of the radiological examination is to localize the projectiles and fragments, to determine the bullet tracks and to evaluate extent of damage caused, with the ultimate aim to reconstruct the event. The absence of foreign material suggests that the projectile may have traversed the body and exited. The evaluation is much easier done in 3D CT-images than in 2D plain radiographs. It is easy to create an overview of the distribution of pellets in shotgun lesions and to localize projectiles or fragments from single projectile gunshot lesions. It is also possible to localize the entrance and exit wounds, to determine the bullet tracts, fracture patterns and other major lesions, and in contrast to dissection this may be obtained without disturbing the normal anatomy. Gunshot residues in and around the entrance wound can be detected by routine clinical CT which is of use in the forensic investigation of surviving victims where an inspection of the bandaged entrance wound is not possible (32). When a projectile passes a flat bone, typically the cranium, a conical shaped injury with socalled “bevelling” is seen to the inside of the entrance wound and outside to the exit wound, easily identifiable on CT. Sometimes a projectile strikes the skull and deflects away without entering the cranial cavity. This may result in a socalled “keyhole” injury with both internal and external bevelling.

When a projectile penetrates the body, it delivers energy to the tissues. The amount of destruction is proportional to the amount of energy delivered. A projectile produces a permanent channel in its path (figure 6) and produces a temporary radial displacement of tissues. High velocity projectiles produce a very large temporary cavity that may cause tissue damage at a distance from the the permanent wound track. The resultant radiological picture depends on the elasticity of the tissue in question. In liver and brain there will be considerable organ disruption whereas lung tissue better tolerates the lateral displacement.

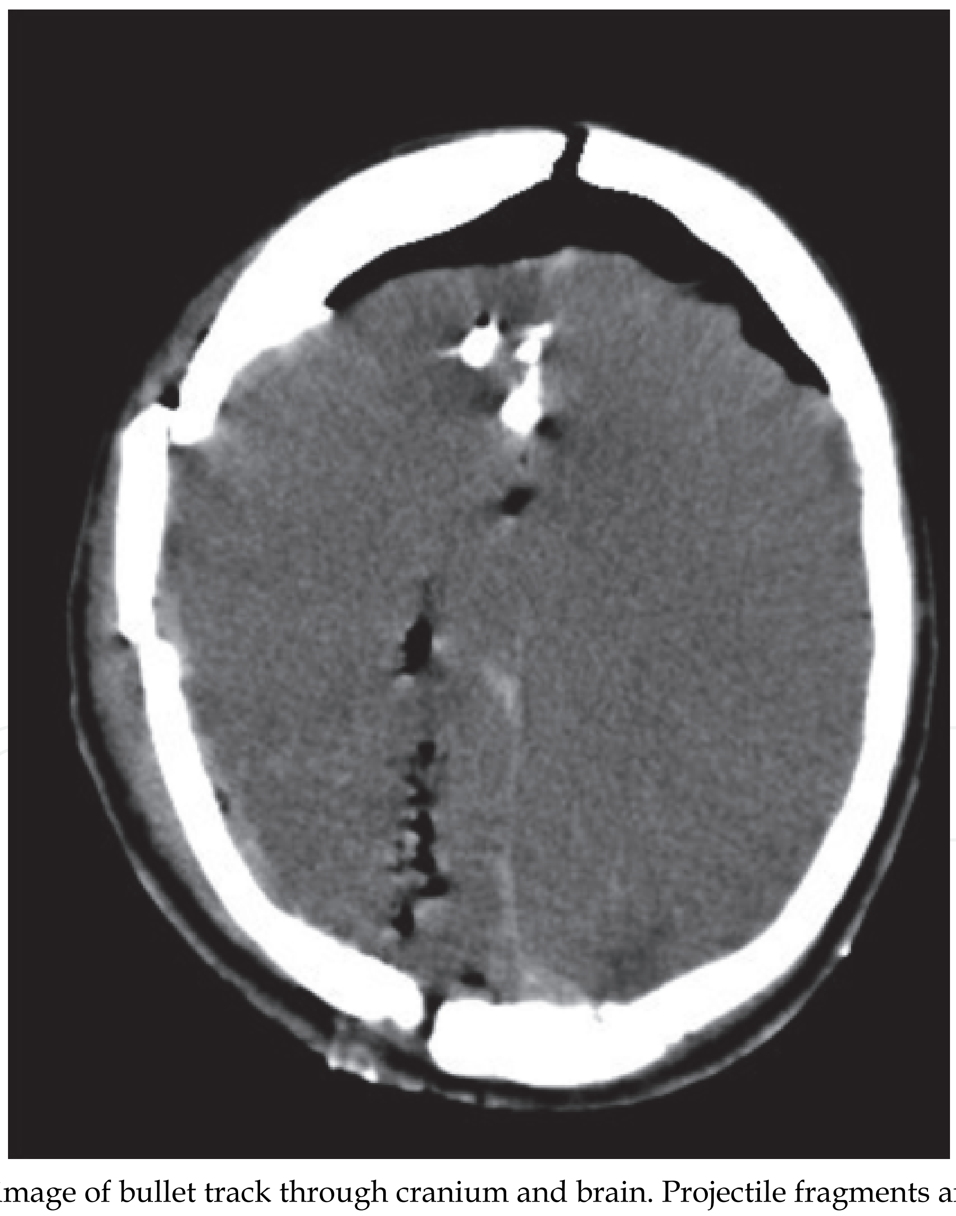


Fig. 6. CT-image of bullet track through cranium and brain. Projectile fragments are seen. Suicide.

Projectiles may cause injury to vessels resulting in haemothorax, haemopericardium (figure 7) or intraperitoneal bleeding. Pellets may enter the bloodstream and travel to a distant site – a socalled projectile embolus. The vascular injuries are not easily visualized by post-mortem CT since contrast medium is not used routinely.

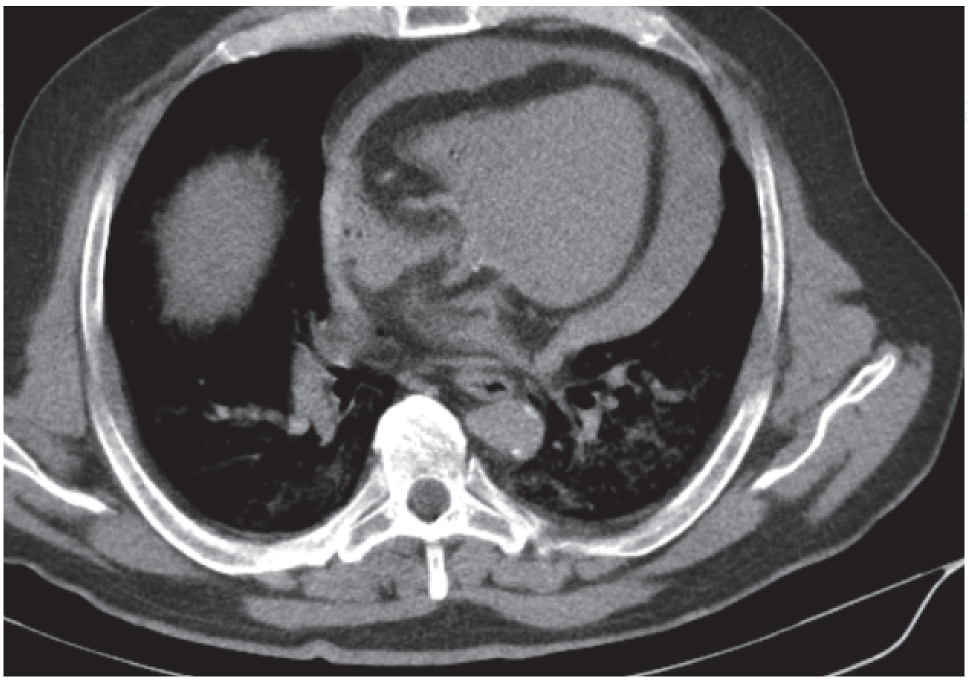


Fig. 7. CT-image displaying haemopericardium caused by a lesion of a coronary artery by a projectile track through the thorax

A shotgun produces a conical stream of pellets that disperse over an ever widening area at increasing distance. Close range shotgun lesions may contain pieces of wadding in addition to the pellets, but the wadding is not identifiable on CT. In shotgun lesions the shot angle can be illustrated by marking the entrance wounds and the pellets in different colours.

CT allows discrimination between foreign objects that differ in radio absorption, such as glass fragments from a shot fired through a window or metal fragments from passage through the door of a vehicle. Retrieval and analysis of such fragments may be of importance in reconstructing the event and in determining the location of the crime scene (29).

CT may provide important additional information in cases where the visual evaluation is difficult due to severe decomposition or charring.

The high-quality, neutral CT-images reduce the need for autopsy photographs in court.

6. Terror bombs

The types of explosives involved in terror attacks are remotely controlled explosives and suicide bombers. The explosives often contain multiple shrapnel fragments such as nails, bolts, small metal balls and other components to increase the damage. These fragments can easily be found by CT, and subsequently secured for technical investigation. The injuries are classified into three catagories. Primary blast injuries are caused by the shock wave (blast wind) and include pulmonary hemorrhage, gastrointestinal hemorrhage and perforation of the eardrums. Secondary injuries are caused by objects propelled outward by the explosion. They include penetrating injuries and orthopedic impact injuries. Tertiary injuries occur when the victims are thrown against solid objects by the blast wind. CT allows a quick overview of the fracture systems and injuries to internal organs. Information about the scene is essential for the evaluation of the CT and autopsy findings. In terror-bombing caused by a suicide terrorist, it is often possible to identify the suicide bomber based on the pattern of lesions which of course is of great importance to the police investigation (33, 34).

7. Stab wounds

Stab wounds are often encountered in forensic practice. The main forensic issues are number and location of wounds, stab channel depth and direction, wound morphology and indicators of thrust force. The ultimate issues are reconstruction of the event, type of weapon used and estimation of permanent injury and life danger. CT can detect a high percentage of stab wounds, and it is often possible to determine the depth and direction of the wound channel (35). The information gained from CT is often more reliable than can be obtained from dissection or probing. These invasive techniques change the anatomy whereas CT shows the undisturbed anatomy. However, caution should be exerted when measuring the channel depth in soft tissues since the channel may collapse, resulting in too short a measurement. It must also be emphasized that not all stab wound can be visualized on CT, especially if there are many closely grouped wounds and if the wounds are superficial. It is therefore important to correlate CT findings with the findings at the external examination. These problems may be overcome with scanners with better resolution or by optimizing the scanning technique (35). CT can easily detect skeletal injuries. These are important since they are indicators of thrust force. Instillation of contrast medium in the stab wound tract has been investigated experimentally (figure 8) (36).

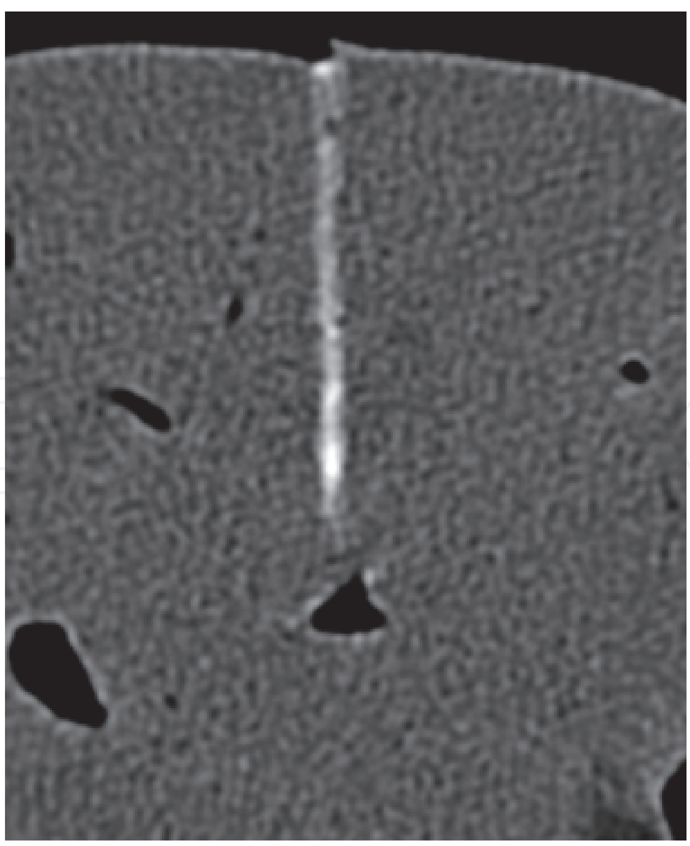


Fig. 8. Stab channel in liver tissue filled with contrast medium.

8. Blunt trauma to the head and neck

Facial fractures are very common in forensic pathology, but are often overlooked at autopsy if the soft tissues of the face are not dissected. Fractures of the cranial vault and base can usually be visualized on CT, although not with the same degree of precision as can be obtained by autopsy (37). CT allows massive cranial fractures to be viewed in situ (figure 9) which can be of importance in homicide cases where a comparison with a blunt weapon may be needed. With dissection the cranial fragments tend to fall apart. Intracranial haemorrhages are easily detected by CT and the volume measured. Figure 10 illustrates a cerebral haemorrhage in a severly decomposed body. At the autopsy the brain was completely liquified and it was impossible to localize and measure the haemorrhage.

Fig. 9. CT-image displaying extensive fractures of cranium and facial bones. Car driver, traffic accident.

Fig. 10. Transversal CT-image of the head. An intracerebral haemorrhage is clearly visible. Severely decomposed body scanned inside the body bag.

Fractures in the cranio-cervical region are relatively common, but are sometimes overlooked at autopsy, and it may be difficult to evaluate the degree of spinal stenosis. CT makes this evaluation much easier, but does not depict small hemorrhages, contusions or necroses of the spinal cord or brain (38, 39).

Hanging, ligature strangulation and manual strangulation are of great forensic importance. Strangulation marks on the neck are detectable by CT and provide a permanent record of the shape that can not be obtained by any other means. Some soft tissue lesions such as subcutaneus, lymph node and intramuscular haemorrhage can be detected by CT, but minor bleedings are not found (40, 41). Hyoid, thyroid and cricoid fractures are usually found. Pneumomediastinum and cervical emphysema have been described in hanging cases and are probably a vital reaction caused by attempted breathing (42).

9. Drowning

In wet drownings aspiration of water to the lungs is seen in 60 % of cases, and more fluid is found in the main bronchi and trachea than normally seen postmortem. Pleural effusion and fluid in ventricle, duodenum and paranasal sinuses are also common findings. A reduced bronchial-arterial coefficient is a sign of bronchospasm (43). Reduction of the blood density (Houndsfield Units) in the right heart chamber is indicative of haemodilution (44). The body fat of cadavers that have been in the water for a long time becomes transformed to an insoluble soap called adipocire. The extent of adipocire formation can be determined by CT and can be used to give a crude estimate of the postmortem interval (45).

10. Burnt bodies

Bodies damaged by fire must be investigated in order to secure the identity and to establish the cause and mode of death. It is important to determine if the deceased was alive when the fire started, to find injuries and secure samples for toxicology (including CO and cyanide from fire smoke). CT is of help in determining the identity and to detect projectiles in victims shot and then torched. CT can not detect soot in the airways (an important vital sign). A socalled pseudohaematoma, which is a postmortem heath-caused epidural hematoma, is easily identified by CT. It transverses the cranial suture lines in contrast to a true epidural hematoma.
CT are very useful in determining the number of individuals and getting an overview in cases of multiple fire deaths (25).

11. Child abuse

Radiology has played a significant role in the forensic investigation of physical abuse of children since John Caffey's landmark paper of 1946 (46). Abusive head trauma is the leading cause of death from child abuse. Skeletal injuries are important markers of trauma mechanism and frequency.
The injuries should as a general rule be evaluated in connection with the presenting story, which in cases of child abuse is inconsistent with the injuries found. Multiple fractures and fractures of varying age are highly suspicious of child abuse. Relevant differential diagnoses should be considered (47). In cases of fatal child abuse, a thorough radiological examination should be performed (48). CT raw data should be kept permanently.
Cranial fractures are not in themselves highly suggestive of child abuse, but the level of suspicion should increase with complex skull fractures. Child abuse with intracranial injury includes subarachnoid and subdural hemorrhage, intracerebral and intracerebellar haemorrhage, and brain edema. It has been discussed whether intracranial injuries can be caused by shaking alone or if an impact of the head is also needed (49).
Smaller children subjected to abuse are sometimes grabbed around the chest and shaken resulting in posterior fractures of the ribs whereas older children are held by the extremities. Rib fractures are rarely seen as a result of resuscitation. Socalled bucket handle metafysal fractures are virtually pathognomonic of child abuse. These injuries are usually seen in nonambulatory small children and are located at the distal humerus, knee or ankle. Twisting

and pulling may cause subperiostal haemorrhage which subsequently calcifies and shows up on radigraphs as either a subtle thin line or of more massive proportion depending on the degree of bleeding. Diaphyseal spiral fractures caused by a twisting force are highly suggestive of abuse, especially in children who do not yet walk, but transverse long bone fracture may also be seen. Hand fractures are highly suspicious, except for fractures of the distal phalanx of the fingers from closing doors. Scapular fractures are also suspicious. They involve the acromion or less commenly the blade. Clavicle fractures may be seen as a perinatal fracture, but rarely as a result of child abuse.

12. Various other CT findings

Postmortem CT can document the position of catheters, tubes or drains prior to the autopsy which can be of great importance in medical malpractise cases.

CT is well suited to detect abnormal gas collections such as pnemothorax, pneumomediastinum, pneumoencephalon and air embolism (figure 11). Air embolism may occur in various forensic settings such as head trauma (50), diving accidents, stab wounds, gunshot wounds and traumatic pneumothorax. In cases of massive airembolism right heart failure may occur. Hypoxic brain death is also possible due to vascular obstruction in the cerebral vessels. Diagnosing air embolism at autopsy is difficult. One method involves aspiration of air from the right heart chamber, a method that allows a chemical analysis of the aspired air. Postmortem CT readely displays the amount and distribution of gas in the vascular system and in the cardiac chambers, but does not allow a chemical characterization of the gas. The distribution of the gas may indicate if the presence of gas is caused by air embolism or putrefaction.

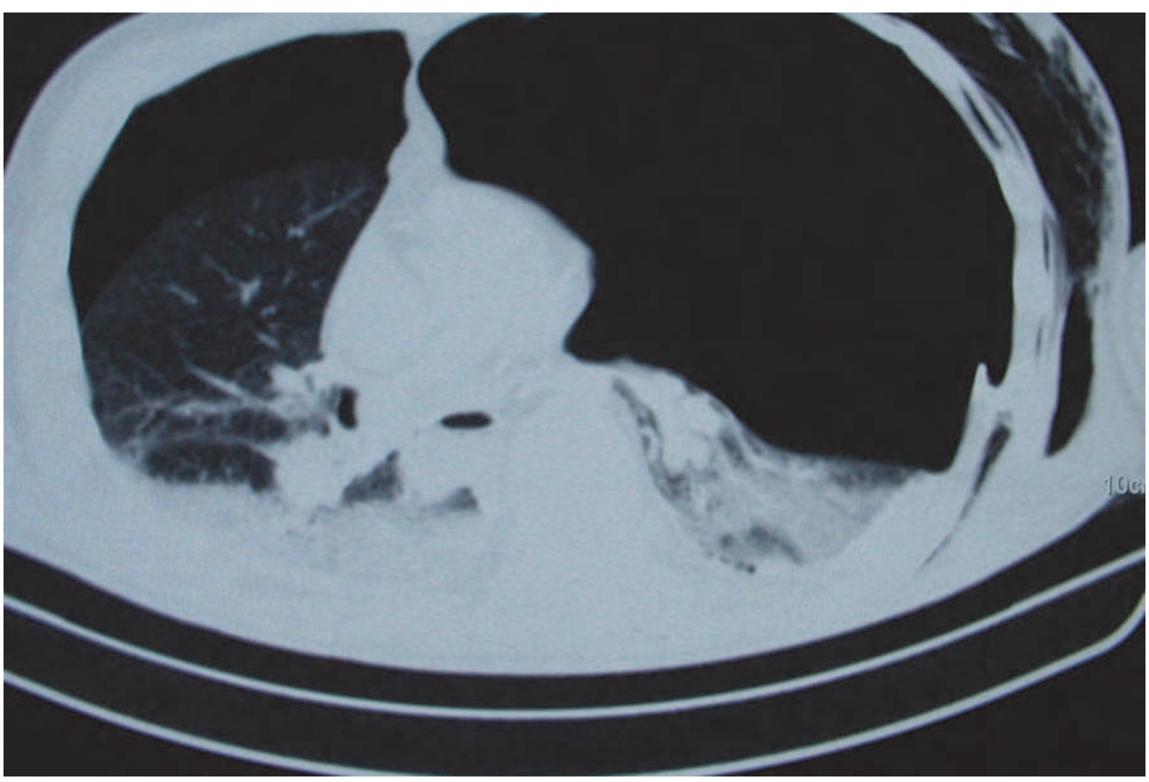


Fig. 11. Transversal CT-image of a pressure pneumothorax with displacement of the heart, rib fractures and subcutaneous emphysema. Man trampled by Icelandic horse.

Autopsy determination of fatal hemorrhage as the cause of death depends on sparsity of lividity and on the amount of blood in the vessels. This is a highly subjective method. It has been suggested that a quantitative estimation of blood loss may be possible by CT measurement of the diameter of major vessels (51).

13. Natural deaths

A large proportion of medico-legal deaths are of natural origin. At our department natural deaths comprise a third of the autopsy workload. These cases include sudden unexpected deaths, suspected malpractice cases, individuals found dead under suspicious circumstances and others. The findings are not in principle different from similar cases known from clinical radiology, but there are as already mentioned, some important differences in technique (no contrast medium), post-mortem changes of the body and not least the purpose of the investigation. In most cases it is not possible to replace the autopsy with a CT-scanning. Too many diagnoses will be missed without autopsy, and it is much easier to obtain sufficient and suitable material for histology and microbiology at an autopsy. However CT provides important additional information. Internal fluid collections such as hydrothorax and ascites (5) are easily found and quantified. It is possible to evaluate degree of displacement of internal structures which is not so easily done at autopsy (figure 12).

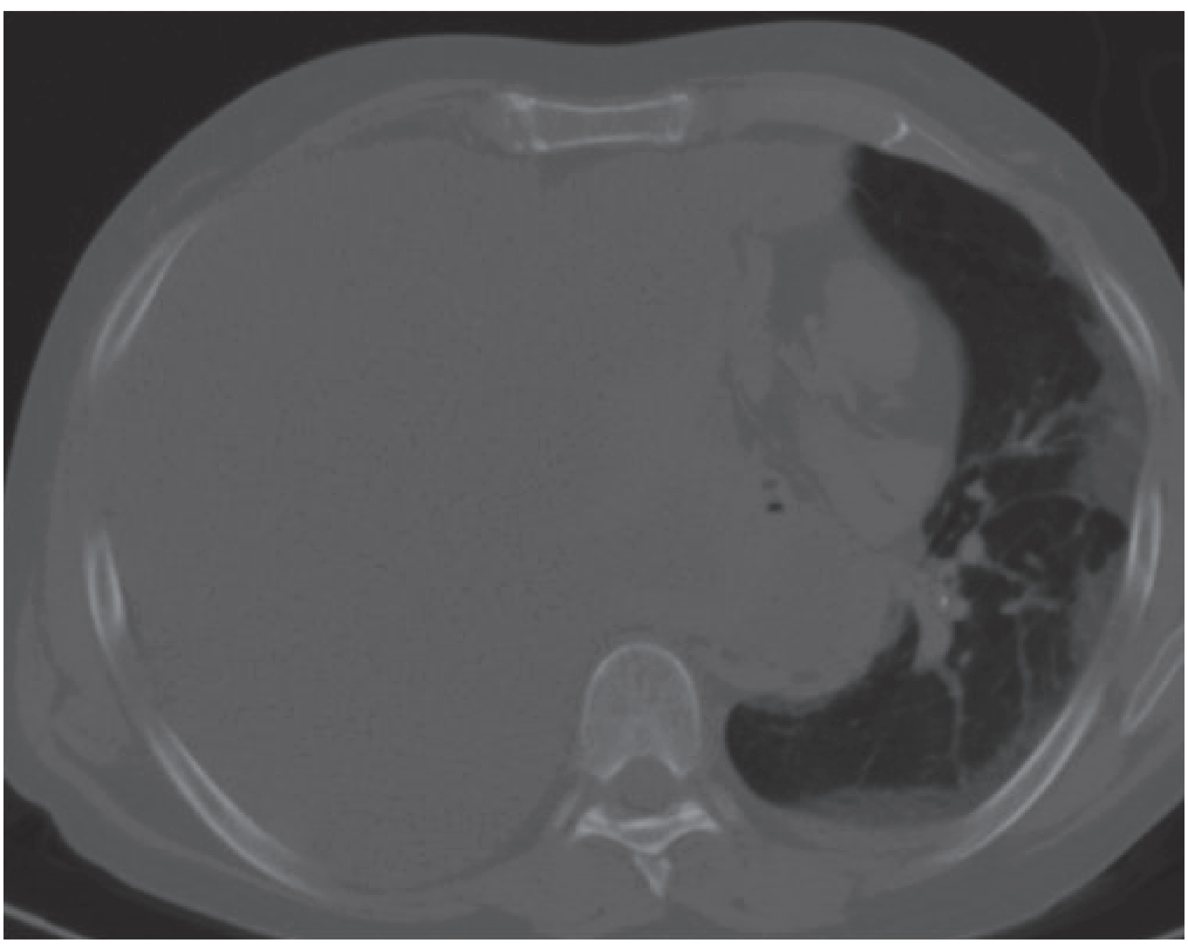


Fig. 12. Transversal CT-image of thorax with severe hydrothorax in the right pleural cavity causing displacement of the heart to the left.

14. Future developments

A Swiss group has developed a method for post-mortem angiography based on an oily contrast agent (52) introduced through the femoral artery and vein. Samples for toxicology must be taken before the angiography is performed, but since the oily contrast agent remains in the vessels biopsies for histology can be taken later. It is also possible to perform an autopsy, although the organs become somewhat slippery. The method seems to be particular useful for detection of postsurgical bleeding, and it is likely that it will become an important tool in the future.

Jacobsen et al (53) have suggested using finite element analysis on the volume of digitalized data from a fractured skull for biomechanical approximation of the injury mechanism and involved forces. The idea is to remove the fracture digitally and then perform digital simulations of various blunt impacts. Such experiment has hitherto used standard cranial models, but the CT data allow an individualized model to be used. The calculations are very demanding, and not yet practically possible without a supercomputer, but it is certainly an original idea to use CT-data for other purposes than imaging.

Another future application could be cinematographic analysis of a whole body and its surroundings for reconstruction of a crime or an accident. Various scenarios could be tested to see if certain bullet paths or fracture systems could be recreated under different conditions. This would be very useful, not least in analysis of trauma mechanisms in traffic accidents.

Computerized tomography and other methods for acquisition of a digitalized data volume from bodies will undoubtedly play an increasing role in forensic medicine in the future.

15. References

[1] Leth PM. Computerized tomography used as a routine procedure at postmortem investigations. Am J Forensic Med Pathol. 2009 Sep;30(3):219-22.

[2] Poulsen K, Simonsen J. Computed tomography as routine in connection with medico-legal autopsies. Forensic Sci Int. 2007 Sep 13;171(2-3):190-7.

[3] Rutty GN, Morgan B, O'Donnell C, Leth PM, Thali M. Forensic institutes across the world place CT or MRI scanners or both into their mortuaries. J Trauma. 2008 Aug;65(2):493-4.

[4] O'Donnell C, Rotman A, Collett S, Woodford N. Current status of routine post.mortem CT in Melbourne, Australia. Forensic Sci Med Pathol. 2007;3:226-32.

[5] Yamazaki K, Shiotani S, Ohashi N, Doi M, Kikuchi K, Nagata C, et al. Comparison between computed tomography (CT) and autopsy findings in cases of abdominal injury and disease. Forensic Sci Int. 2006 Oct 16;162(1-3):163-6.

[6] Thomsen AH, Jurik AG, Uhrenholt L, Vesterby A. An alternative approach to Computerized Tomography (CT) in forensic pathology. Forensic Sci Int. 2009;183:87 - 90.

[7] Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, et al. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)--a feasibility study. J Forensic Sci. 2003 Mar;48(2):386-403.

[8] The Virtopsy Approach. Thali MJ, Dirnhofer R, Vock P, editors: CRC Press; 2009.

[9] Davis GJ, Peterson BR. Dilemmas and solutions for the pathologist and clinician encountering religious views of the autopsy. South Med J. 1996 Nov;89(11):1041-4.
[10] Ayoub T, Chow J. The conventional autopsy in modern medicine. J R Soc Med. 2008 Apr;101(4):177-81.
[11] Christe A, Flach P, Ross S, Spendlove D, Bolliger S, Vock P, et al. Clinical radiology and postmortem imaging (Virtopsy) are not the same: Specific and unspecific postmortem signs. Leg Med (Tokyo). 2010 Sep;12(5):215-22.
[12] Pøhlsgaard C, Leth PM. Post-mortem CT-coronary angiography. Scandinavian Journal of Forensic Science. 2007;13:8-9.
[13] Ross S, Spendlove D, Bolliger S, Christe A, Oesterhelweg L, Grabherr S, et al. Postmortem whole-body CT angiography: evaluation of two contrast media solutions. AJR Am J Roentgenol. 2008 May;190(5):1380-9.
[14] Jackowski C, Thali M, Aghayev E, Yen K, Sonnenschein M, Zwygart K, et al. Postmortem imaging of blood and its characteristics using MSCT and MRI. Int J Legal Med. 2006 Jul;120(4):233-40.
[15] O'Donnell C, Woodford N. Post-mortem radiology--a new sub-speciality? Clin Radiol. 2008 Nov;63(11):1189-94.
[16] Aghayev E, Thali MJ, Sonnenschein M, Jackowski C, Dirnhofer R, Vock P. Post-mortem tissue sampling using computed tomography guidance. Forensic Sci Int. 2007 Mar 2;166(2-3):199-203.
[17] International Statistical Classification of Diseases and Related Health Problems 10th Revision : WHO.
[18] Abbreviated Injury Scale 2005: Association for the Advancement of Automotive Medicine.
[19] Leth PM, Ibsen M. Abbreviated Injury Scale Scoring in Traffic Fatalities: Comparison of Computerized Tomography and Autopsy. J Trauma. 2010;68(6):1413-6.
[20] Sidler M, Jackowski C, Dirnhofer R, Vock P, Thali M. Use of multislice computed tomography in disaster victim identification--advantages and limitations. Forensic Sci Int. 2007 Jul 4;169(2-3):118-28.
[21] Pfaeffli M, Vock P, Dirnhofer R, Braun M, Bolliger SA, Thali MJ. Post-mortem radiological CT identification based on classical ante-mortem X-ray examinations. Forensic Sci Int. 2007 Sep 13;171(2-3):111-7.
[22] Reichs KJ. Quantified comparison of frontal sinus patterns by means of computed tomography. Forensic Sci Int. 1993 Oct;61(2-3):141-68.
[23] Rutty GN, Robinson CE, BouHaidar R, Jeffery AJ, Morgan B. The role of mobile computed tomography in mass fatality incidents. J Forensic Sci. 2007 Nov;52(6):1343-9.
[24] Rutty GN, Robinson C, Morgan B, Black S, Adams C, Webster P. Fimag: the United Kingdom disaster victim/forensic identification imaging system. J Forensic Sci. 2009 Nov;54(6):1438-42.
[25] O'Donnell C, Iino M, Mansharan K, Leditscke J, Woodford N. Contribution of postmortem multidetector CT scanning to identification of the deceased in a mass disaster: Experience gained from the 2009 Victorian bushfires. Forensic Sci Int. 2010 Aug 4.
[26] Saukko P, Knight B. Tranportation Injuries. Knight's Forensic Pathology. London: Arnold; 2004.

[27] Sato Y, Ohshima T, Kondo T. Air bag injuries--a literature review in consideration of demands in forensic autopsies. Forensic Sci Int. 2002 Aug 28;128(3):162-7.
[28] Thali MJ, Braun M, Buck U, Aghayev E, Jackowski C, Vock P, et al. VIRTOPSY--scientific documentation, reconstruction and animation in forensic: individual and real 3D data based geo-metric approach including optical body/object surface and radiological CT/MRI scanning. J Forensic Sci. 2005 Mar;50(2):428-42.
[29] Andenmatten MA, Thali MJ, Kneubuehl BP, Oesterhelweg L, Ross S, Spendlove D, et al. Gunshot injuries detected by post-mortem multislice computed tomography (MSCT): a feasibility study. Leg Med (Tokyo). 2008 Nov;10(6):287-92.
[30] Jeffery AJ, Rutty GN, Robinson C, Morgan B. Computed tomography of projectile injuries. Clin Radiol. 2008 Oct;63(10):1160-6.
[31] Di Maio VJM. Gunshot Wounds: Practical Aspects of Firearms, Ballistics, and Forensic Techniques1999.
[32] Stein KM, Bahner ML, Merkel J, Ain S, Mattern R. Detection of gunshot residues in routine CTs. Int J Legal Med. 2000;114(1-2):15-8.
[33] Shaham D, Sella T, Makori A, Appelbum L, Rivkind AI, Bar-Ziv J. The role of radiology in terror injuries. Isr Med Assoc J. 2002 Jul;4(7):564-7.
[34] Benjaminov O, Sklair-Levy M, Rivkind A, Cohen M, Bar-Tal G, Stein M. Role of radiology in evaluation of terror attack victims. AJR Am J Roentgenol. 2006 Sep;187(3):609-16.
[35] Schnider J, Thali MJ, Ross S, Oesterhelweg L, Spendlove D, Bolliger SA. Injuries due to sharp trauma detected by post-mortem multislice computed tomography (MSCT): a feasibility study. Leg Med (Tokyo). 2009 Jan;11(1):4-9.
[36] Bolliger SA, Preiss U, Glaeser N, Thali MJ, Ross S. Radiological stab wound channel depiction with instillation of contrast medium. Legal Medicine. 2010;12(1):39-41.
[37] Jacobsen C, Lynnerup N. Craniocerebral trauma - Congruence between post-mortem computed tomography diagnoses and autopsy results A 2-year retrospective study. Forensic Sci Int. 2010 Jan 30;194(1-3):9-14.
[38] Yen K, Sonnenschein M, Thali MJ, Ozdoba C, Weis J, Zwygart K, et al. Postmortem multislice computed tomography and magnetic resonance imaging of odontoid fractures, atlantoaxial distractions and ascending medullary edema. Int J Legal Med. 2005 May;119(3):129-36.
[39] Fenger-Gron J, Kock K, Nielsen RG, Leth PM, Illum N. Spinal cord injury at birth: a hidden causative factor. Acta Paediatr. 2008 Jun;97(6):824-6.
[40] Yen K, Thali MJ, Aghayev E, Jackowski C, Schweitzer W, Boesch C, et al. Strangulation signs: initial correlation of MRI, MSCT, and forensic neck findings. J Magn Reson Imaging. 2005 Oct;22(4):501-10.
[41] Leth PM, Christensen MR. Computerized tomography used for investigation of homicide victims. Scandinavian Journal of Forensic Science. 2010;in print.
[42] Aghayev E, Yen K, Sonnenschein M, Jackowski C, Thali M, Vock P, et al. Pneumomediastinum and soft tissue emphysema of the neck in postmortem CT and MRI; a new vital sign in hanging? Forensic Sci Int. 2005 Oct 29;153(2-3):181-8.
[43] Christe A, Aghayev E, Jackowski C, Thali MJ, Vock P. Drowning--post-mortem imaging findings by computed tomography. Eur Radiol. 2008 Feb;18(2):283-90.

[44] Levy AD, Harcke HT, Getz JM, Mallak CT, Caruso JL, Pearse L, et al. Virtual autopsy: two- and three-dimensional multidetector CT findings in drowning with autopsy comparison. Radiology. 2007 Jun;243(3):862-8.

[45] Jackowski C, Thali M, Sonnenschein M, Aghayev E, Yen K, Dirnhofer R. Adipocere in postmortem imaging using multislice computed tomography (MSCT) and magnetic resonance imaging (MRI). Am J Forensic Med Pathol. 2005 Dec;26(4):360-4.

[46] Caffey J. Multiple fractures in the long bones of infants suffering from chronic subdural hematoma. Am J Roentgenol Radium Ther. 1946 Aug;56(2):163-73.

[47] Pandya NK, Baldwin K, Kamath AF, Wenger DR, Hosalkar HS. Unexplained fractures: child abuse or bone disease? A systematic review. Clin Orthop Relat Res. 2011;469(3):805-12.

[48] Adamsbaum C, Mejean N, Merzoug V, Rey-Salmon C. How to explore and report children with suspected non-accidental trauma. Pediatr Radiol. 2010 Jun;40(6):932-8.

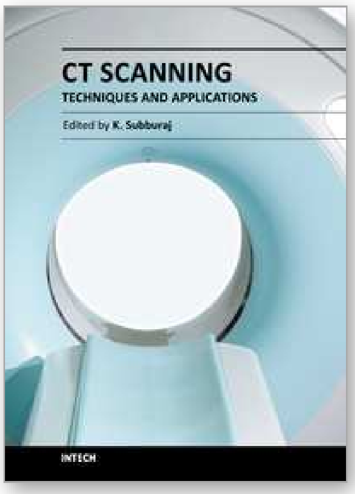
[49] Christian CW, Block R, Neglect CCA. Abusive Head Trauma in Infants and Children. Pediatrics. 2009 May;123(5):1409-11.

[50] Adams V, Guidi C. Venous air embolism in homicidal blunt impact head trauma. Case reports. Am J Forensic Med Pathol. 2001 Sep;22(3):322-6.

[51] Aghayev E, Sonnenschein M, Jackowski C, Thali M, Buck U, Yen K, et al. Postmortem radiology of fatal hemorrhage: measurements of cross-sectional areas of major blood vessels and volumes of aorta and spleen on MDCT and volumes of heart chambers on MRI. AJR Am J Roentgenol. 2006 Jul;187(1):209-15.

[52] Grabherr S Fau - Djonov V, Djonov V Fau - Yen K, Yen K Fau - Thali MJ, Thali Mj Fau - Dirnhofer R, R D. - Postmortem angiography: review of former and current methods. AJR Am J Roentgenol. 2007;188(3):832-8.

[53] Jacobsen C, Bech BH, Lynnerup N. A comparative study of cranial, blunt trauma fractures as seen at medicolegal autopsy and by computed tomography. BMC Med Imaging. [Comparative Study Evaluation Studies]. 2009;9:18.



CT Scanning - Techniques and Applications
Edited by Dr. Karupppasamy Subburaj

ISBN 978-953-307-943-1
Hard cover, 348 pages
Publisher InTech
Published online 30, September, 2011
Published in print edition September, 2011

Since its introduction in 1972, X-ray computed tomography (CT) has evolved into an essential diagnostic imaging tool for a continually increasing variety of clinical applications. The goal of this book was not simply to summarize currently available CT imaging techniques but also to provide clinical perspectives, advances in hybrid technologies, new applications other than medicine and an outlook on future developments. Major experts in this growing field contributed to this book, which is geared to radiologists, orthopedic surgeons, engineers, and clinical and basic researchers. We believe that CT scanning is an effective and essential tools in treatment planning, basic understanding of physiology, and and tackling the ever-increasing challenge of diagnosis in our society.