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Seminars in
ULTRASOUND
CT and MRI

Virtopsy and Living Individuals Evaluation Using Computed Tomography in Forensic Diagnostic Imaging

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The applications of forensic radiology involve both Virtopsy both studies on living people – to demonstrate bone age, search for foreign bodies, such as voluntary injection of drug ovules or surgical sponges accidentally forgotten, to assess gunshot wounds, to evaluate injuries by road accidents, and cases of violence or abuse (both in adults and in children). Computed tomography is the most used imaging tool used in forensic pathology and its indications are mainly focused on cases of unnatural deaths or when a crime is suspected. It is preferred over the standard autopsy in selected cases, such as in putrefied, carbonized or badly damaged bodies; or as a preliminary evaluation in mass disasters.
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Introduction

The applications of forensic radiology (FR) involve both studies on living people and cadavers – to demonstrate bone age, search for foreign bodies, such as voluntary injection of drug ovules or surgical sponges accidentally forgotten, to assess gunshot wounds, to evaluating injuries by road accidents and cases of violence or abuse (both in adults and in children).[1-3]

FR-computed tomography (FR-CT) is the most used imaging tool in forensic pathology, and its indications are mainly focused on cases of unnatural deaths or when a crime is suspected. These cases include traumatic events, gunshot injuries, hanging, strangulation and drowning, cases of suspected abuse, age estimation, battered child and body packing, and can be applied even in putrefied, carbonized, or badly damaged bodies.[4-15]

Moreover, diagnostic imaging is used for mass disasters, reducing the time consuming use of conventional autopsies in selected cases, for the identification of human corpses with clothing and personal effects, thus also preserving evidence in an undisturbed state. Diagnostic imaging plays a pivotal role in the preliminary evaluation in the "safety screening" prior to forensic assessment of the remains; thus, preventing dangers to the workers who handle the corpses, or in case of infection surveillance, such as pulmonary tuberculosis, confirmed by CT examination before autopsy.[16-18]

Although the costs and availability of CT scanners and personnel are the most important limitations of FR-CT screening before conventional autopsy, especially considering that not all the forensic departments have its own FR department, it is an excellent complementary technique, due to its speed and ease of use and noninvasiveness. Acquired data remain unmodified and virtually indefinitely stored and easily accessible.[1,15,19] The major advantage of FR-CT is that it allows the study of body parts or areas that are not routinely dissected during a standard autopsy, such as the viscero-cranium, shoulder girdle, extremities, outer pelvis, craniocervical junction, larynx, and soft tissue of the back, as well as allowing for the detection of gas and fluid accumulations – such as blood – and it is particularly useful for evaluating the presence of fractures (even very small ones) in poorly accessible skeletal parts.[7,20,21]

Moreover, FR-CT is the most suitable technique for putrefied, carbonized or otherwise highly damaged bodies, sustaining the pathologist in his activity, or in very particular cases, for example in communities where autopsy is not

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Figure 1 CT virtopsy imaging. Gas appears in the intracranial vessels (A and B).

Figure 2 CT virtopsy imaging. The brain starts to liquefy.

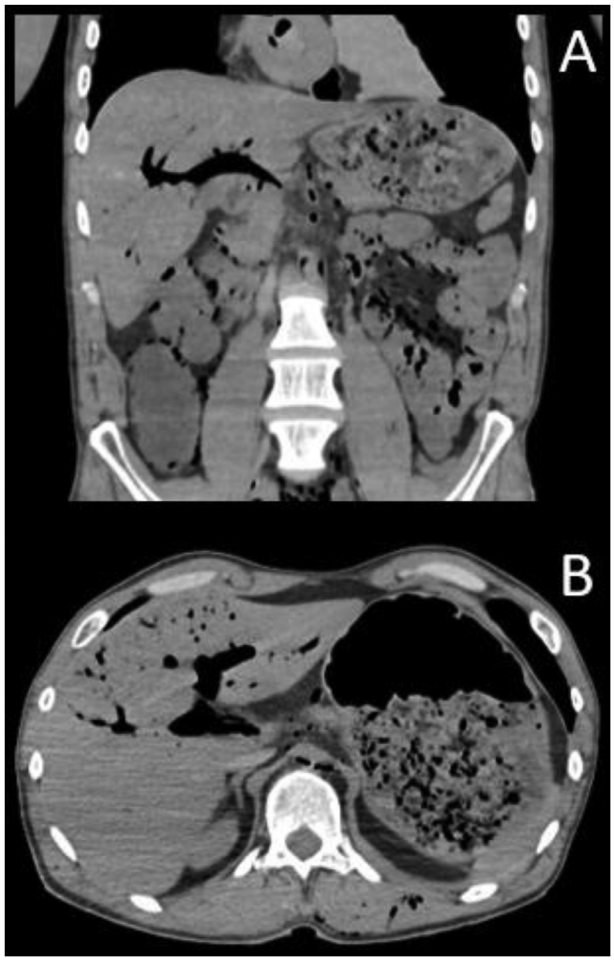

Figure 3 CT virtopsy imaging. Gas in the portal system (A and B).

widely accepted for religious or social reasons, such as Buddhists, Muslims, or Orthodox Jews.[12,13]

Nevertheless, the main weakness of this method is the limited value for parenchymal organ visualization for which forensic examination using MRI (FR-MR) is preferred, but not often performed.

Although the availability of equipment and dedicated radiographers and radiologists vary widely worldwide, protocols tend to be quite similar in different institutions.

In our institution, for corpses we perform basal scans of each body bag. First a 5-mm thick slice sequential scan of the head is performed, than a spiral single scan is performed including all body volume (1.25 mm or 0.6 mm thick slice acquisition, depending if a more detailed representation of bones is required).

If a single acquisition is not possible because of body positioning due to rigor mortis, the scan is repeated after repositioning.[22,23]

Images are then evaluated on dedicated workstation where 3D and multiplanar reconstruction are available.

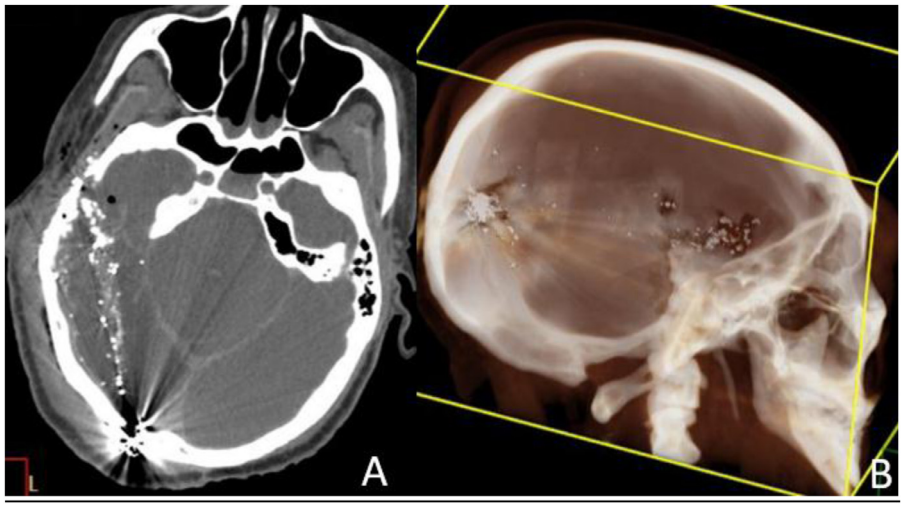

Figure 4 CT virtopsy imaging of a gunshot victim with bullet trespassing skull bone from temporal right side to occipital fossa, axial (A) and 3D VR images (B).

Indications of FR-CT in Cadavers

Identification

The identification of an unknown decedent is crucial both from a juridical point of view, concerning criminal, civil, insurance issues, and for ethical reasons as well, not the least providing closure to relatives.

This is particularly important nowadays, in the scenario of mass migrations, where the personal identification of dead migrants may provide some relief to relatives in the countries of origin or of destination who do not know if their loved ones are dead or alive.[25]

Odontological identification is one of the most used and reliable manners of identification, widely accepted by all scientific communities, and relies on the comparison between a missing person's past radiographic images from a dental clinic and radiographs performed on an unknown corpse, especially evaluating root canal therapies, endodontic posts, crowns, bridges and filling, which are all handcrafted and their morphology is unique by definition.[24,25]

In the head, evaluation the frontal sinuses are the most standardised due to their variability of shape and size and individuality of sinus profile (even homozygotic twins have different frontal sinuses).[25]

Also trunk and limbs can be evaluated when searching for single morphological characteristics, keeping in mind that the individuality increases with the number of pathological, deformative, and therapeutical characteristics.

Time and Cause of Death

The use of computed tomography and magnetic resonance imaging has recently become a potential tool to investigate the early and later postmortem changes in internal organs.[12]

Among the early postmortem changes, livor mortis is the earliest to set in and can be detected on imaging, especially in the lungs, which show diffuse ground-glass opacity in the dependent posterior lower lobes with a horizontal demarcation line to the anterior nonaffected lung. In the head, the

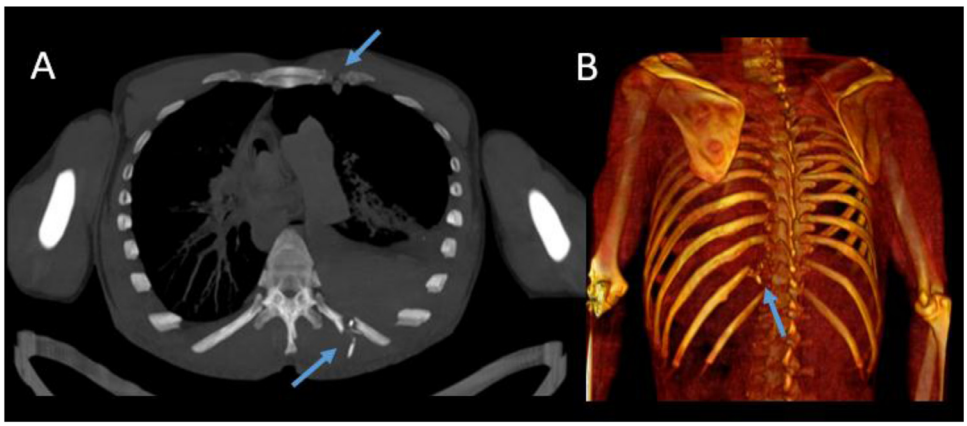

Figure 5 Axial (A) and 3D VR (B) images. CT virtopsy imaging of a gunshot victim with bullet causing rib fractures (arrows). Metallic bullet fragments can be visualized within the posterior rib.

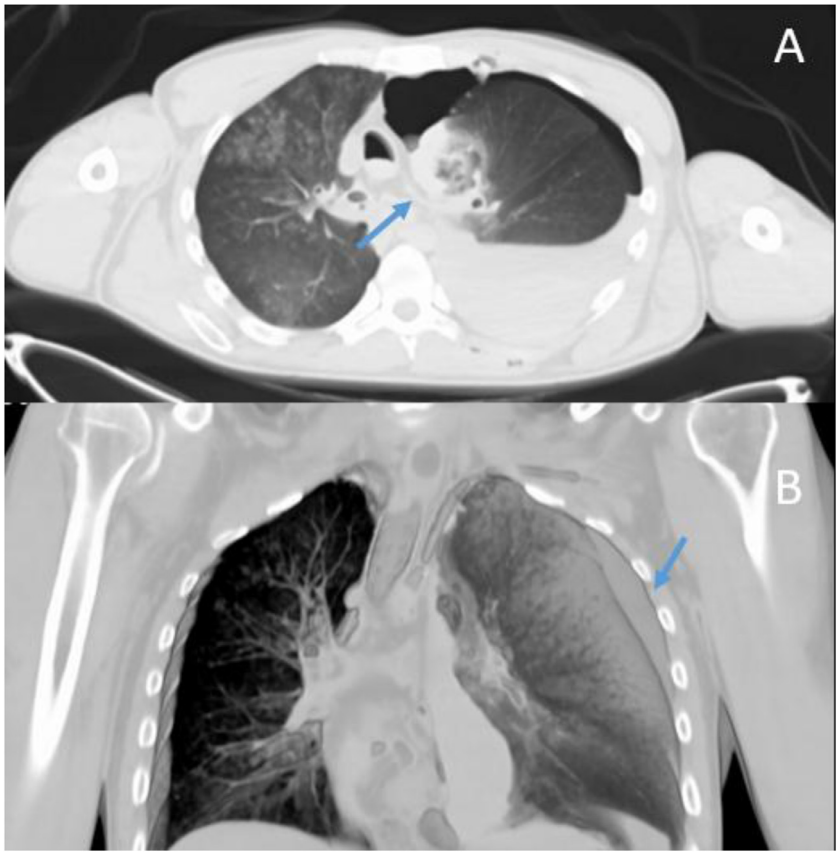

Figure 6 CT virtopsy imaging of the gunshot victim in Fig. 5. Axial and MIP coronal images show lung consolidation due to heat injury from bullet trespassing (arrow, A) and pneumothorax (arrow, B).

earliest changes due to decomposition are the loss of grey−white matter differentiation and decreased attenuation and loss of sulcal definition. Then gas appears in the intracranial vessels and finally the brain liquefies and becomes water in attenuation (Figs. 1 and 2). The intra-abdominal compartment is the first region to exhibit putrefactive changes of decomposition with gas evident in the intestinal wall and the mesenteric vessels and portal venous system (Fig. 3).[26-31]

Although standard autopsy is the technique of choice in cases of unnatural death, the use of radiological tools can be

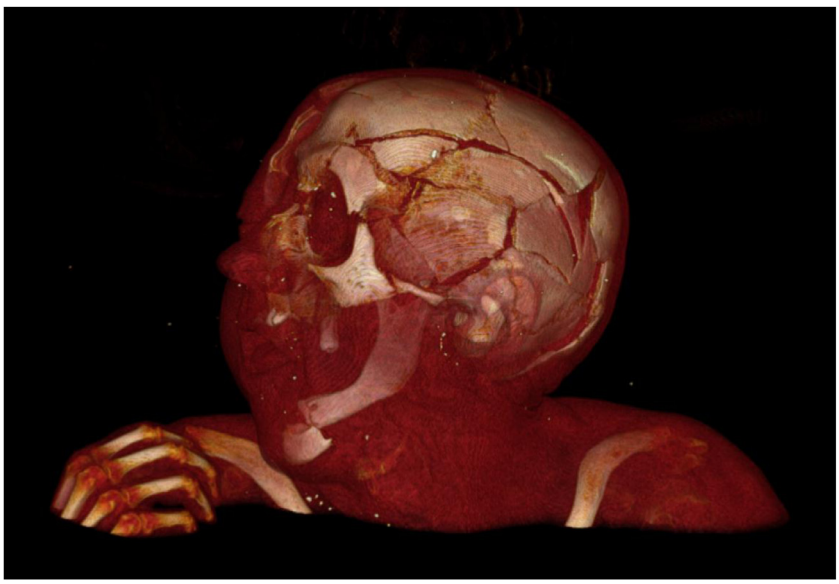

Figure 7 CT virtopsy imaging of a man with multiple skull and jaw fractures.

Figure 8 CT virtopsy imaging of man in Fig. 7. Multiple views (A-C): 3D VR.

Figure 9 CT virtopsy images of a subject who died because of a building collapse. The images taken in the place of accident (A). 3D VR of the corpse (B), and coronal MPR (C) that shows spine fracture and diastasis.

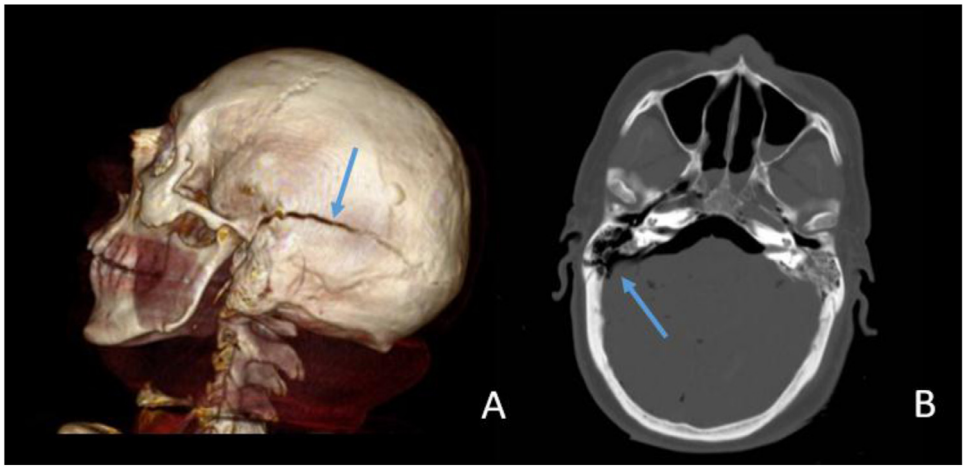

Figure 10 CT virtopsy imaging of a man who died in a car accident. Fracture of the mastoid – visible both in 3D VR (arrow, A) and in axial plane (arrow, B).

quite feasible in cases of traumatic events such as bone fractures and nonaccidental injury in children; gunshot injuries; hanging, strangulation, and drowning cases; putrefied, carbonized, and badly damaged bodies.

Traumatic Events and Ballistic Trauma

FR-CT is the method of choice for investigating cases of traumatic death, providing information concerning the biomechanical origins of fractures, thereby contributing to the forensic reconstruction of a case (Figs. 4-6). Its sensitivity for osseous findings is higher than that of conventional autopsy (though poorer for the soft tissues), and is useful in determining whether the injury is accidental or inflicted. The data include the location and type of fracture (considered with reference to the age and expected level of activity of the individual), the configuration and direction of fractures which may locate the impact point and direction of impact (Figs. 7-14), as well as the shape of the wounding object or weapon.[32-40]

Moreover, FR-CT is a useful tool for gunshot wounds because it may reveal the presence or absence of bullet(s), the caliber, the presence and the number of entrance and exit wounds, its/their track, fragments (cloud of minute metallic fragments detached from the projectile, a phenomenon called "lead snowstorm" and associated injuries, thus indicating angle and direction of fire (Figs. 4 and 5).[36-40]

Due to its high resolution for bones, it is able to reveal bones beveling from bullet's impact. This technique is reliable also for living individuals.

Violent Mechanic Asphyxia

Hanging and strangulation events can be evaluated by FR-CT, showing the typical findings of cutaneous/subcutaneous/intramuscular hemorrhage (usually sternocleidomastoid and platysma muscle), glottic edema, perilaryngeal bleeding, and laryngohyoid fracture or vessel disruption. In drowning victims, fluid or froth in the airways from central aspiration into

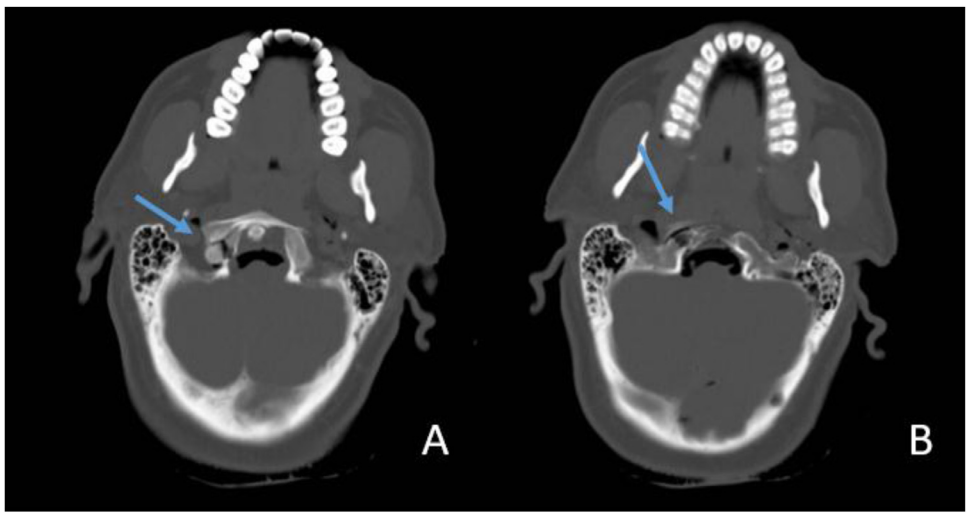

Figure 11 CT virtopsy imaging of the same man of Fig. 10 shows fracture of the anterior arch of C1 (arrow, A) and clivus (arrow, B).

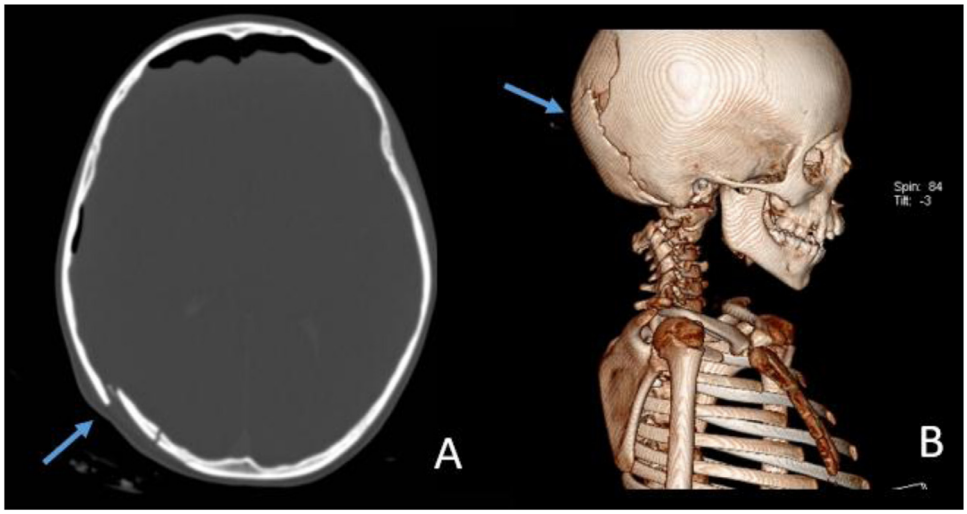

Figure 12 CT virtopsy imaging of a 10-years-old female who died in a car accident. Fracture of the parietal bones — visible both in axial plane (arrow, A) and 3D VR (arrow, B).

trachea or main bronchi, with emphysema aquosum and low standing diaphragm can be observed (Figs. 15-19). In these cases, aspiration and swallowing of water or high-density materials (sand, mud, or silt) can lead to pulmonary edema, or may fill the paranasal sinuses and may distend stomach and duodenum.[41-49] These findings are better detected at FR-CT than in classic autopsy.

Mass Disasters

Tragic *e*vents may determine the need to perform a large number of autopsy exams in a short time. The typology of disaster may be various, resulting in the necessity of analyzing a huge number of corpses, sometimes mutilated and particularly difficult to identify. Different kinds of disasters require processing and identification of multiple victims. Mass casualties are unfortunately not restricted to natural occurring or accidental causes; terrorist attacks are recent examples in which radiology plays a significant role in both identification of the victims and investigations of the accidents. The availability of mobile trailer-mounted CT-scanners provided with control area, reporting room, on-board generator, and cooling system, is likely to be considered the gold standard in "mass casualties."[14-19]

Decomposed, Carbonized, and Badly Damaged Bodies

Because of its noninvasive nature, FR-CT should be considered also in all cases where body is found in advanced state of decomposition or its been subjected to massive alterations, such as burning at high temperatures. Preliminary FR-CT

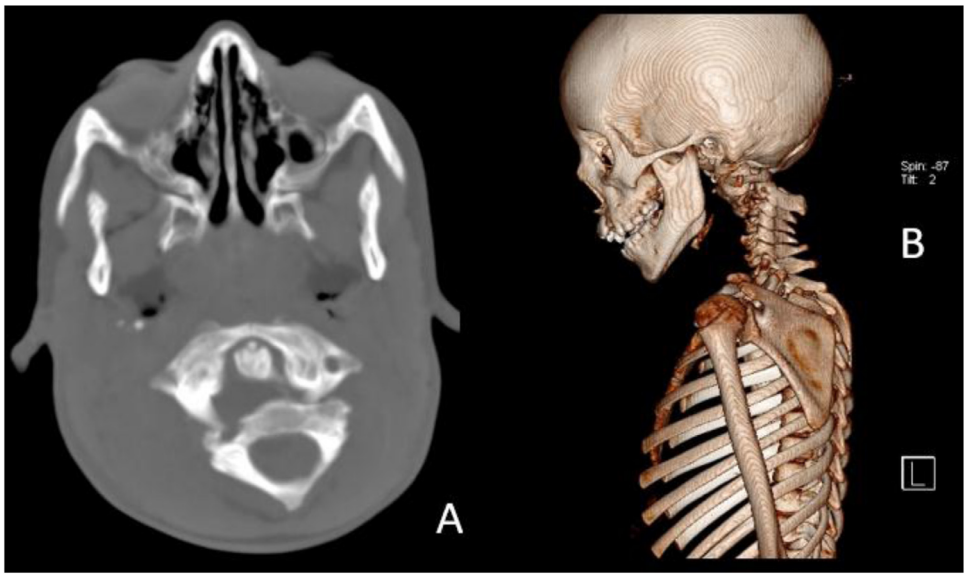

Figure 13 CT virtopsy imaging of the same child as in Fig. 12 showing anteroposterior dislocation of the first two cervical vertebrae — visible both in in axial plane (A) and 3D VR (B).

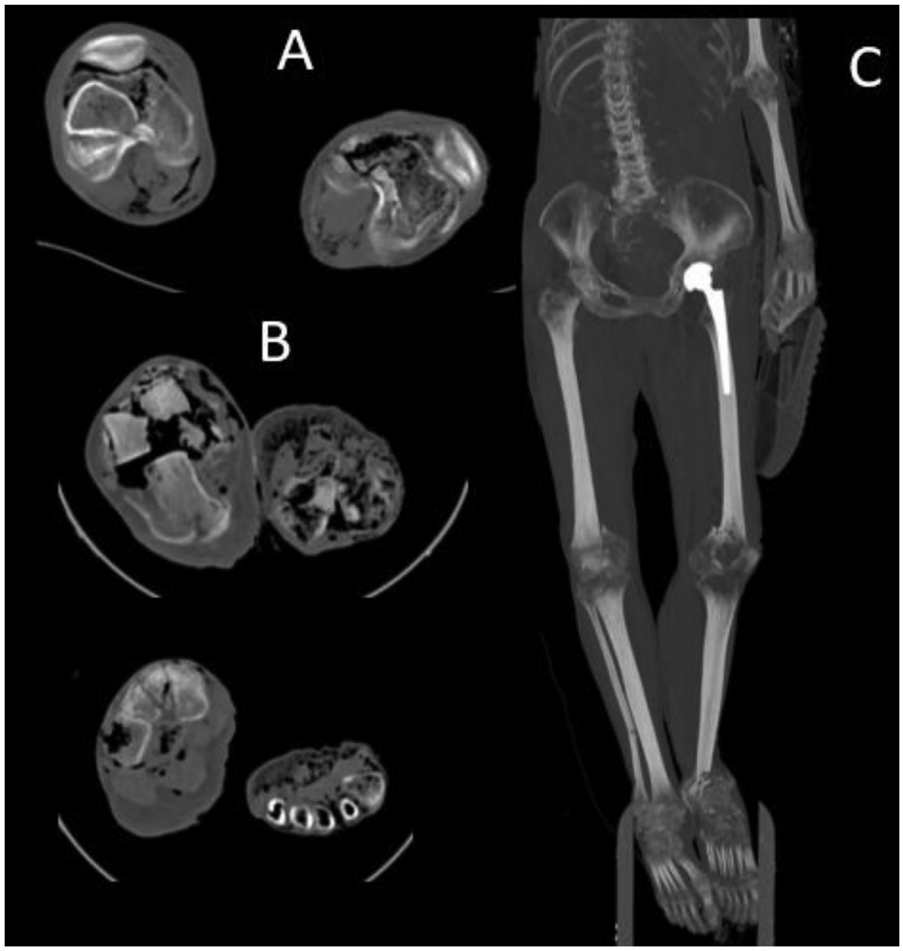

Figure 14 CT virtopsy imaging of a woman who died from self-defenestration showing multiple fractures of the lower limb bones and hip prosthesis (axial A-B images, and coronal view C).

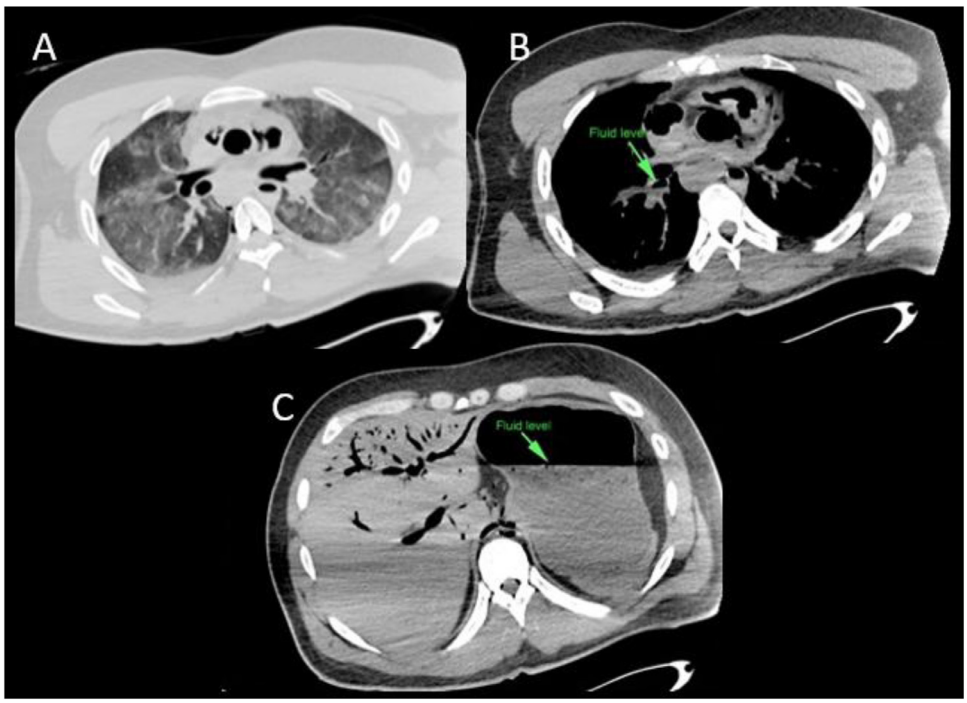

Figure 15 CT virtopsy imaging shows typical findings in drowning victims. Lung pattern is characterized by diffuse ground glass opacities (A). Fluid levels are seen in the trachea and main bronchi (arrow, B) as well as in the stomach (arrow, C). Is it also possible to notice gas in the portal venous system due to initial decomposition (C).

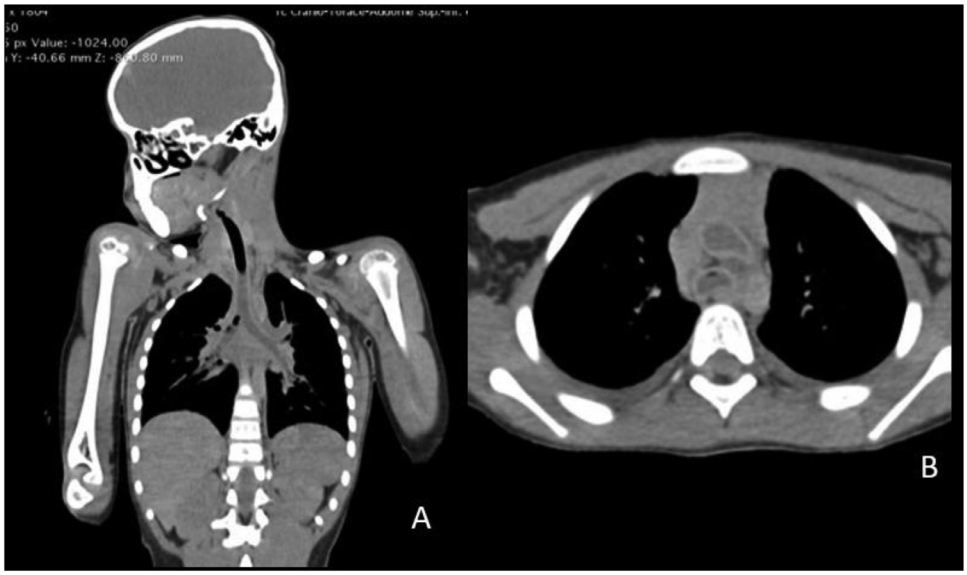

Figure 16 CT virtopsy imaging of a drowned young boy. Coronal MPR (A) and axial view (B) show the trachea and main bronchi filled with water.

may be used when evaluating decomposed corpses, helping to evaluate, better than conventional autopsy, hidden injuries, and pathological findings. The most well-known and commonly observed feature of decomposition on FR-CT is the presences of gases in all anatomic spaces and loss of density in soft tissues. In advanced putrefaction, the texture can be completely dissolved, leading to a liquefaction of entire organs (Fig. 20).[12,13]

Indications of FR-CT in Living Individuals

Foreign Bodies Identification and Body Packing

From a gauze left in surgical site to detection of drug-filled packets, FR-CT plays a role of pivotal importance in living individuals, to detect foreign objects and complications.

"Body packers" either swallow drug-filled packets or introduce drug-filled packets into their bodies rectally or vaginally, with the purpose of concealing them. Nevertheless, current protocols recommend the use of radiography first to confirm packet retention and, in case of doubt, the use of abdominal CT scan with reduced mAs. The highest frequently involved drug is cocaine.[50-54] Every of these small cocaine-filled packets measures 8-10 mm and consists of around 2-6 g of cocaine powder of variable cleanliness, mostly badly encased in several layers of packing material of changeable type, including glassine crack, plastic bags, cellophane paper, plastic wraps, aluminum foil, glassine crack, and condoms.[51] These ingested packets appear on CT examination as oval dense foreign bodies located within the gastrointestinal tract, with characteristic appearance: "tic-tac sign," the "double condom sign," defined as a clear crescent of air bordering an ovoid opacity may be visible and the "rosette sign" (air within the knot of the tied condom containing the drug in a manually wrapped packet).[50-54]

Abuse and Battered Child

Postmortem imaging is also particularly useful when child abuse is suspected. In these cases, characteristic

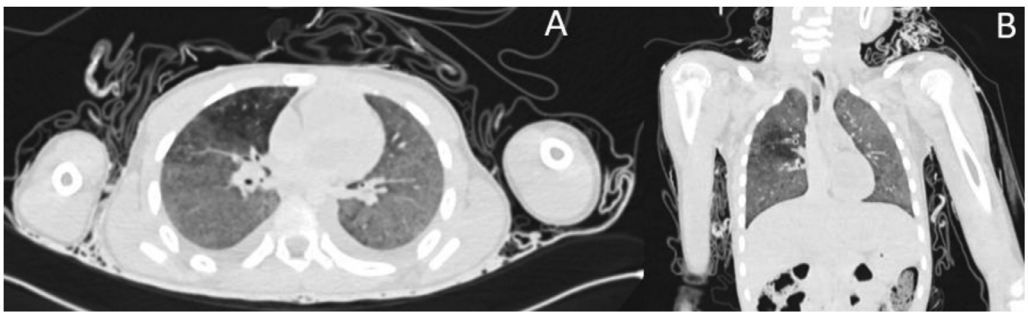

Figure 17 CT virtopsy image of a drowned young female. Axial (A) and coronal (B) MPR images. Diffuse ground glass opacities and water in trachea.

Figure 18 CT virtopsy imaging of advanced decomposed hanged man. Coronal MPR image with lung window (A) and 3D VR image of whole body with enhanced visualization of a rope around neck and wrists (B).

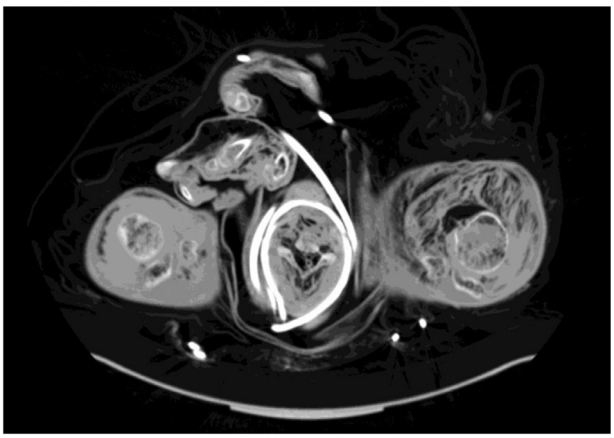

Figure 19 CT virtopsy imaging of the same man of Fig. 18, better depicts the rope around his neck.

nonaccidental injuries include multiple posterior rib fractures, long bone metaphyseal fractures, vertebral body compression fractures, small bowel hematomas, and shearing-type brain injuries. Head findings can be detected in cases of battered child, and often deaths due to child abuse can occur as a consequence of intracranial or extracranial injuries. The names applied to the syndromes of inflicted head injury in infancy reflect the actions necessary to cause the types of injuries seen, such as shaking an infant held by the arms or trunk or forcefully striking an infant's head against a surface.[55-59]

Nevertheless, in living children, FR-MR should be preferred, for radiation protection issues: The use of diffusion-weighted magnetic resonance imaging allows the evaluation of the role of hypoxic-ischemic injury in traumatic pediatric head injuries.[59-61]

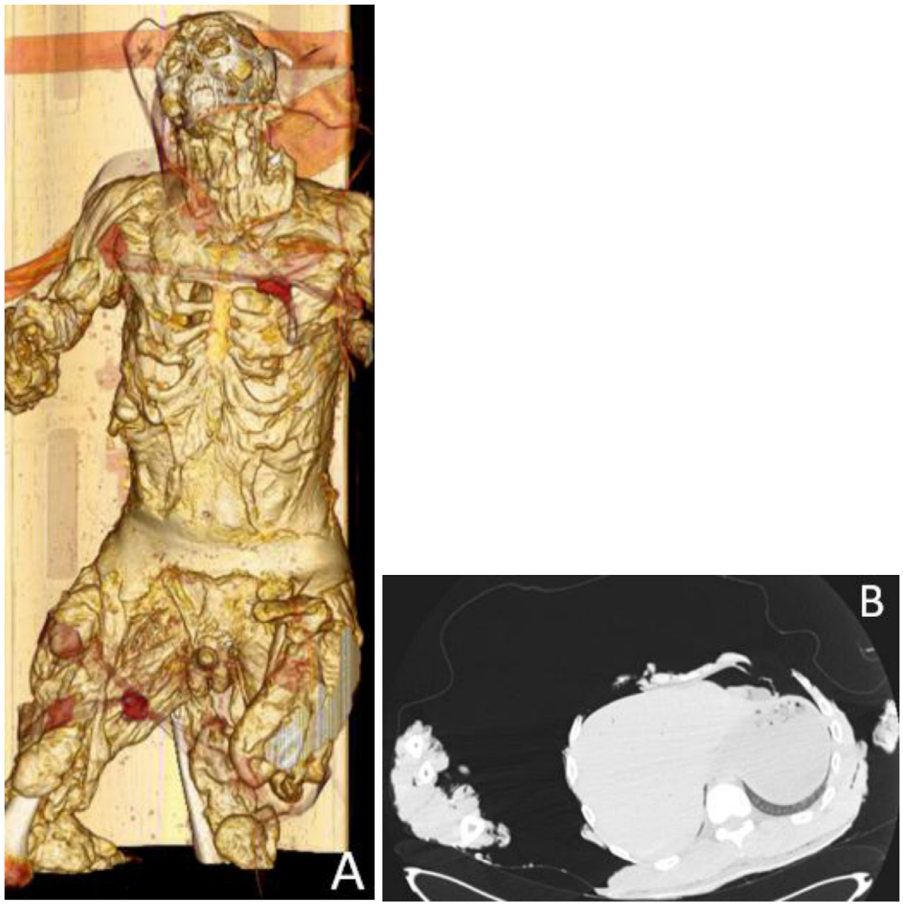

Figure 20 CT virtopsy imaging of a charred decomposed corps: 3D VR image of whole body (A) and axial imaging that shows the loss of superficial tissues (B).

Conclusions

In conclusion, the indication for FR-CT imaging strongly depends on the applied technique, each of which has its advantages and disadvantages. Sensitivities and specificities of imaging versus autopsy or forensic clinical examination depend on the modality used and the case itself.

For these reasons FR-CT and FR-MR, especially in post-mortem imaging, are a double-edged knives, with clear superiority in specific diagnostic areas but also with definite shortcomings compared with autopsy in other areas. As a result, the gold standard for post-mortem forensic assessment is still the forensic autopsy, but post-mortem imaging is of pivotal importance as complementary technique, becoming crucial in selected cases and situations.

References

1. Baglivo M, Winklhofer S, Hatch GM, et al: The rise of forensic and post-mortem radiology—Analysis of the literature between the year 2000 and 2011. J Forensic Radiol Imaging 1:3-9, 2013
2. Aalders MCG, Decker SJ, Ford J, et al: Research in forensic radiology and imaging; identifying the most important issues. J Forensic Radiol Imaging 8:1-8, 2017
3. De Bakker HM, Soerdjbalie-Maikoe V, Kubat B, et al: Forensic imaging in legal medicine in the Netherlands: Retrospective analysis of over 1700 cases in 15 years' experience. J Forensic Radiol Imaging 6:1-7, 2016
4. Wilemann Y, Thali MJ, Kneubuehl BP, et al: Correlation between skeletal trauma and energy in falls from great height detected by post-mortem multislice computed tomography (MSCT). Forensic Sci Int 180:81-85, 2008
5. Leth PM, Struckmann H, Lauritsen J: Interobserver agreement of the injury diagnoses obtained by postmortem computed tomography of traffic fatality victims and a comparison with autopsy results. Forensic Sci Int 225:15-19, 2013
6. Schnider J, Thali MJ, Ross S, et al: Injuries due to sharp trauma detected by post-mortem multislice computed tomography (MSCT): A feasibility study. Leg Med 11:4-9, 2009
7. Kirchhoff SM, Scaparra EF, Grimm J, et al: Postmortem computed tomography (PMCT) in deadly gunshot wounds. Int J Legal Med 130:819, 2016. https://doi.org/10.1007/s00414-015-1225-z
8. Plaetsen SV, De Letter E, Piette M, et al: Post-mortem evaluation of drowning with whole body CT. Forensic Sci Int 249:35-41, 2015
9. Leth PM, Madsen BH: Drowning investigated by post mortem computed tomography and autopsy. J Forensic Radiol Imaging 9:28-30, 2017
10. Aquila I, Falcone C, Di Nunzio C, et al: Virtopsy versus autopsy in unsual case of asphyxia: Case report. Forensic Sci Int 229:e1-e5, 2013
11. Ruder TD, Thali Y, Schindera ST, et al: How reliable are Hounsfield units measurements in forensic radiology? Forensic Sci Int 220:219-223, 2012
12. Thali MJ, Yen K, Schweizer W, et al: Into the decomposed body—forensic digital autopsy using multilice-computed tomography. Forensic Sci Int 134:109-114, 2003
13. Murakami T, Akashi S, Uetani M, et al: Burned bodies: How do we evaluate the death in a fire on CT?. EPOS Electronic Presentation Online System (105) ECR.
14. O'Donnell C, Iino M, Mansharan K, et al: 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 205:15-28, 2011
15. Ruder TD, Kneubuehl BP, Gotsmy WF, et al: Radiologic identification of disaster victims: A simple and reliable method using CT of the paranasal sinuses. Eur J Radiol 81:e132-e138, 2012
16. Young VS, Eggesbù HB, Gaarder C, et al: Radiology response in the emergency department during a mass casualty incident: A retrospective study of the two terrorist attacks on 22 July 2011 in Norway. Eur Radiol 27(7):2828-2834, 2017
17. Bolster F, Linnau K, Mitchell S, et al: Emergency radiology and mass casualty incidents-report of a mass casualty incident at a level 1 trauma center. Emerg Radiol 24:47-53, 2017
18. Brunner J, Rocha TC, Chudgar AA, et al: The Boston Marathon bombing: After-action review of the Brigham and Women's Hospital emergency radiology response. Radiology 273:78-87, 2014
19. Sidlerr M, Jackowski C, Dirnhoefer R, et al: Use of multislice computed tomography in disaster victim identification—Advantages and limitations. Forensic Sci Int 169:118-128, 2007
20. Zerbo S, Di Piazza A, Re GL, et al: Utility of post mortem computed tomography in clivus fracture diagnosis. Case illustration and literature review. Leg Med 30:42-45, 2018. Jan 1
21. Pfaeffli M, Vock P, Dirhofer R, et al: Post-mortem radiological CT identification based on classical ante-mortem X-ray examinations. Forensic Sci Int 171:111-117, 2007
22. Flach PM, Gascho D, Schweitzer W, et al: Imaging in forensic radiology: An illustrated guide for postmortem computed tomography technique and protocols. Forensic Sci Med Pathol DOI 10.1007/s12024-014-9555-6.
23. Ampanozi G, Zimmermann D, Hatch GM, et al: Format preferences of district attorneys for post-mortem medical imaging reports: Understandability, cost effectiveness, and suitability for the courtroom: A questionnaire based study. Leg Med 14:116-120, 2012
24. Cattaneo C, Tidball Binz M, Penados L, et al: The forgotten tragedy of unidentified in the Mediterranean, Forensic Sci Int 2015;250:e1-e2.
25. Christensen AM: Testing the reliability of frontal sinuses in positive identification. J Forensic Sci 50:18-22, 2005
26. O'Donnell C: An image of sudden death: utility of routine postmortem computed tomography scanning in medico-legal autopsy practice. Diagn Histopathol 16:552, 2010
27. Thali MJ, Yen K, Schweitzer W, et al: Virtopsy, a new imaging horizon in forensic pathology: Virtual autopsy by postmortem multisclice computed tomography (MSCT) and magnetic resonance imaging (MRI)—a feasibility study. J Forensic Sci 48:386-403, 2003.)
28. Christe A, Flach P, Ross S, et al: Clinical radiology and postmortem imaging (Virtopsy) are not the same: Specific and unspecific postmortem signs. Leg Med 12:215-222, 2010
29. Levy AD, Harck HT, Mallak CT: Postmortem imaging: MDCT features of postmortem change and decomposition. Am J Forensic Med Pathol 31:12-17, 2010
30. Offiah CE, Dean J: Post-mortem CT and MRI: Appropriate post-mortem imaging appearances and changes related to cardiopulmonary resuscitation. Br J Radiol 89, 2016
31. Yamazaki K, Shiotani S, Ohashi N, et al: Hepatic portal venous gas and hyperdense aortic wall as post-mortem computed tomography findings. Leg Med 5:338-341, 2003
32. Andenmatten MA, Thali MJ, Kneubuehl BP, et al: Gunshot injuries detected by post-mortem multi-slice computed tomography (MSCT): A feasibility study. Leg Med (Tokyo) 10:287-292, 2008. Nov
33. DiMaio VJM: Gunshot wounds. Practical Aspects of Firearms, Ballistics, and Forensic Techniques. Boca Raton, FL: CRC Press, 1999
34. Donchin Y, Rivkind AI, Barziv J, et al: Utility of postmortem computed tomography in trauma victims. J Trauma Inj Infect Crit Care 37:552e6, 1994
35. Harcke HT, Levy AD, Abbott RM, et al: Autopsy radiography: Digital radiographs (DR) vs multidetector computed tomography (MDCT) in high-velocity gunshot wound victims. Am J Forensic Med Pathol: 28:13e9, 2007
36. Hollerman JJ, Fackler ML, Coldwell DM, et al: Gunshot wounds: 1. Bullets, ballistics, and mechanisms of injury. AJR Am J Roentgenol 155:685-690, 1990
37. Hollerman JJ, Fackler ML, Coldwell DM, et al: Gunshot wounds: 2. Radiology. AJR Am J Roentgenol 155:691e702, 1990
38. Jeffery A, Rutty GN, Robinson C, et al: Computed tomography of projectile injuries. Clin Radiol 2008
39. Levy AD, Abbott RM, Mallak CT, et al: Virtual autopsy: Preliminary experience in high-velocity gunshot wound victims. Radiology 240:522e8, 2006
40. Maiese A, Gitto L, De Matteis A, et al: Post mortem computed tomography: useful or unnecessary in gunshot wounds deaths? Two case reports. Leg Med (Tokyo) 16:357-363, 2014. Nov
41. Lo Re G, Vernuccio F, Galfano MC, et al: Role of virtopsy in the postmortem diagnosis of drowning. Radiol Med 120:304-308, 2015
42. Biljardta S, Brummela A, Tijhuisa R, et al: Post-mortem fluid stasis in the sinus, trachea and mainstem bronchi; a computed tomography study in adults and children. J Forensic Radiol Imaging 3:162-166, 2015
43. Kawasumi Y, Kawabata T, Sugai Y, et al: Diagnosis of drowning using post-mortem computed tomography based on the volume and density of fluid accumulation in the maxillary and sphenoid sinuses. Eur J Radiol 82:e562-e566, 2013
44. Lundermose SB, Jacobsen C, Jakobsen LS, et al: Exact volumetric determination of fluid in the paranasal sinuses after drowning. J Forensic Radiol Imaging 3:111-116, 2015
45. Vander Plaetsen S, De Letter E, Piette M, et al: Post-mortem evaluation of drowning with whole body CT. Forensic Sci Int 249:35-41, 2015
46. Christe A, Aghayev E, Jackowski C, et al: Drowning—post-mortem imaging findings by computed tomography. Eur Radiol 18:283-290, 2008
47. Usui A, Kawasumi Y, Funayama M, et al: Postmortem lung features in drowning cases on computed tomography. Jpn J Radiol 32:414-420, 2014
48. Shiotani S, Kobayashi T, Hayakawa H, et al: Postmortem pulmonary edema: a comparison between immediate and delayed postmortem computed tomography. Leg Med (Tokyo) 13:151-155, 2011
49. Shahnazi M, Sanei Taheri M, Pourghorban R: Body packing and its radiologic manifestations: A review article. Iran J Radiol 8:205-210, 2011
50. Kucukmetin NT, Gucyetmez B, Poyraz T, et al: Foreign material in the gastrointestinal tract: Cocaine packets. Case Rep Gastroenterol 8:56-60, 2014. (eCollection 2014)
51. Hergan K, Kofler K, Oser W: Drug smuggling by body packing: What radiologists should know about it. Eur Radiol 14:736-742, 2004
52. Pinto A, Reginelli A, Pinto F, et al: Radiological and practical aspects of body packing. Br J Radiol 87:20130500, 2014
53. Poletti PA, Canel L, Becker CD, et al: Screening of illegal intracorporeal containers ("body packing"): Is abdominal radiography sufficiently accurate? A comparative study with low-dose CT. Radiology 265:772-779, 2012
54. Offiah AC, Hall CM: Radiological Atlas of Child Abuse. Oxford and New York: Radcliffe Publishing, 2009
55. American Academy of Pediatrics. Section on Radiology. Diagnostic imaging of child abuse. Pediatrics. 105:1345-1348, 2000
56. American Academy of Pediatrics; Section on Radiology. Diagnostic imaging of child abuse. Pediatrics 123:1430-1435, 2009
57. Piteau SJ, Ward MG, Barrowman NJ, et al: Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: A systematic review. Pediatrics 130:315-323, 2012
58. van Rijn RR, Spevak MR: Imaging of neonatal child abuse with an emphasis on abusive head trauma. Magn Reson Imaging Clin N Am 19:791-812, 2011
59. Binenbaum G, Christian CW, Ichord RN, et al: Retinal hemorrhage and brain injury patterns on diffusion-weighted magnetic resonance imaging in children with head trauma. J AAPOS 17:603-608, 2013
60. Biousse V, Suh DY, Newman NJ, et al: Diffusion-weighted magnetic resonance imaging in shaken baby syndrome. Am J Ophthalmol 133:249-255, 2002
61. Parizel PM, Ceulemans B, Laridon A, et al: Cortical hypoxicischemic brain damage in shaken-baby (shaken impact) syndrome: Value of diffusion-weighted MRI. Pediatr Radiol 33:868-871, 2003