Postmortem Imaging: A Transdisciplinary Approach for Objectified Knowledge

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The development of postmortem imaging and its introduction into forensic medicine, especially modern cross-sectional imaging techniques, have led to the emergence of new specialties and subspecialties. As with other transdisciplinary projects, the need to become familiar with some characteristics of the respective other disciplines is both a challenge and an opportunity. The forensic pathologist has to learn to deal with the possibility of investigating the inside of a body without opening it, the radiologist has to learn to manage forensic questions and postmortem artifacts, and the radiographer has to learn how to cope with dead bodies instead of living patients and adapt examination protocols. This chapter will give the reader the perspective of each of these three practitioners.

3.1 The Forensic Pathologist and Postmortem Imaging

Postmortem imaging has been in routine use in forensic medicine for decades [1, 2]. Standard radiography (x-ray) was the first modality employed. More recently, however, we have seen the emergence and increasing use of modern cross-sectional imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI). Radiologic facilities, including trained staff and equipment, vary widely from one institute to another. Many do not possess their own equipment and benefit from the devices and staff at the nearest hospital.

Preautopsy postmortem imaging examinations provide many advantages for the forensic pathologist, in particular pushing the limits of conventional autopsy. Those minimally invasive examinations offer the possibility of quickly obtaining an overview of the inside of a body before opening it, allowing the forensic pathologist to prepare the autopsy. According to the radiologic findings, the dissection technique can be anticipated and adapted more precisely, and protection measures can be adjusted toward a potential danger, such as tuberculosis or an intracorporeal sharp foreign body.

While MRI is the technique of choice for investigating soft tissue and the parenchyma of organs, CT is a wonderful tool for investigating the skeletal system [3–6]. It enables the detection and detailed documentation of the morphology of bone fractures anywhere in the body, even small fractures, which is very important and useful for the forensic pathologist in trauma cases. Moreover, when fractures are in regions that are not easily accessible for autopsy, such as the face, CT allows viewing them noninvasively, without the need for dissection and excessive damage to body parts visible to the family. The exact morphology of fractures is important for determining the mechanism involved, but manipulations during autopsy may dislodge the bony fragments of complex fractures and change their initial position and characteristics. Postmortem CT (PMCT) images can show the initial position of fragments before any modification is induced during external or internal examinations. In some cases, three-dimensional reconstructions are helpful for understanding and explaining the mechanism of injury. They can be performed through CT or a three-dimensional surface scanning device. The latter is rarely used outside research programs.

Postmortem imaging is also of major interest for the localization of intracorporeal foreign bodies, such as gunshot projectiles or implanted medical devices like prostheses, stents, or catheters. It gives the forensic pathologist the opportunity to look for projectiles or fragments of projectiles that could have been hard to find or to reach with standard CT-blinded dissection [3, 7]. Concerning medical implants, it is crucial to be able to determine if the material is correctly

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implanted, which can be very difficult through traditional medico-legal dissection but important in cases of suspected or known medical malpractice. In another context, the presence of a medical device can be useful when an identification of the body is required [3].

The assessment of gas inside a body is essential for the determination of the vitality of a traumatism. It can be very tricky when only a few small bubbles are present; this can be missed with conventional autopsy. CT is very sensitive and can allow detection of even a few small gas bubbles for the identification of gaseous isolated bubbles or collections, which is important in cases of vital air embolism (as a vitality sign or cause of death) and barotrauma [8]. One caveat when dealing with a dead body is that those gas bubbles may be cadaveric putrefaction gas [9, 10].

Natural death is an important part of the daily routine in legal medicine, in particular with sudden cardiac deaths, and forensic pathologists must continue to implement postmortem diagnostic techniques in the field of cardiovascular deaths. One major problem with postmortem cases is the flattened vessels, making it impossible to visualize the vascular lumina. In the last 15 years, research groups at institutes of legal medicine around the world have developed and continued to improve PMCT or MRI in association with contrast agent [11–17]. The aim is to detect a source of hemorrhage, quantify blood loss, and detect anatomic variations and pathologic modifications of the vascular system. Indeed, with conventional autopsy, the visualization of vessels is extremely difficult and time-consuming. Sometimes, it is even impossible, especially when small vessels are involved.

Traditionally, the forensic pathologist provides the description of the structures of interest with words, drawings, or two-dimensional photographs. Postmortem imaging offers a new documentation means with three-dimensional data. Three-dimensional reconstructions of fractures or a firearm projectile trajectory provide images that are easy to understand for people without medical knowledge.

Conventional autopsy is operator-dependent and destructive to internal body structures. A second autopsy is possible and sometimes requested, but is very difficult to perform because of the postdissection status. In contrast, the quick overview of the body that is permitted with postmortem imaging is objective and reproducible. Images of the intact whole body, acquired before any autopsy-induced changes, are digitized to allow their conservation and the possibility of asking for a second opinion if needed.

The concept of noninvasive postmortem examinations of corpses is very attractive, in particular in cases of religious prohibitions or child death. Today, forensic pathologists fear that postmortem imaging has become an alternative to conventional autopsy. The authors strongly believe that the combination of conventional autopsy and proper use of postmortem imaging—meaning an adequate indication with the appropriate technique applied—can lead to increased quality of the postmortem investigations. Post-processing techniques and modalities can supply strong forensic evidence in some complex medico-legal cases, such as three-dimensional reconstructions of bone fractures in the case of a car accident or gunshot injury. Postmortem imaging alone is not sufficient, however, especially in cases of natural death. The forensic pathologist needs to assess the internal organs and structures focusing on the colors, consistency, and texture, which are not reflected in radiologic images. Furthermore, complementary analyses requiring sampling of tissue or body fluids (histology, toxicology, and chemistry) are often required in forensic medicine. Although these issues can be partially resolved with imaging-guided sampling, they cannot be interpreted on their own; in many cases, a full autopsy is required anyway, not only to confirm radiologic diagnosis but also to rule out any other findings that may have escaped the imaging modality. The trend is not to replace conventional autopsy with postmortem imaging but rather to consider imaging as an added value to traditional forensic investigations, such as toxicology and histology. It is the responsibility of the forensic pathologist to know the advantages and limitations of the different examinations (radiologic or morphologic) and to choose the best investigation modality for the case to be solved.

The increasing use of postmortem imaging in medico-legal routines is leading more and more forensic pathologists to learn about the different techniques and modalities, image interpretation, and relevance of the indication to perform these kinds of examinations. The help of a radiologist is usually required, but interpretation of postmortem radiologic data made for medico-legal purposes is quite different from a clinical interpretation made for a therapeutic purpose, especially because of the existence of postmortem artefacts [18]. Today, only a few specialists have the knowledge to interpret postmortem images. Until a recognized specialty or subspecialty of forensic radiology is created, the collaboration between the forensic pathologist and a trained radiologist is crucial to establishing a proper and accurate medico-legal interpretation of the images.

3.2 The Forensic Radiologist

From the perspective of a clinical radiologist, forensic imaging may look fascinating, intimidating, or anything in between. Many radiologists are reluctant to get involved with forensic radiology for various reasons, including administrative, medical, financial, and ethical concerns. Furthermore, not every radiologist likes to be confronted with dead bodies or even forensic questions concerning death. However, if this discomfort is overcome, forensic radiology can be greatly rewarding and instructive.

Forensic radiology is a young discipline with a bright future. Especially in recent times, institutes are beginning to apply the potential of modern imaging modalities to their routine forensic or pathologic case work. This trend opens promising fields of research and practice for interested radiologists. Already, many forensic pathology departments are cooperating with radiologists, and it seems only a matter of time until dedicated centers of forensic imaging will be established across the world.

The radiologist is an important member of any forensic radiology team. Correct interpretation of cross-sectional images requires extensive professional experience because inexperienced readers regularly overlook subtle findings. Technical knowledge about modern imaging equipment and its optimal application in a specific case is a prerequisite for high image quality and reliable diagnosis, which is an expertise rarely found outside the circle of experienced radiologists and radiographers.

Although radiologists in general are familiar with modern cross-sectional imaging techniques, forensic radiologic examinations differ from the clinical routine in a number of important ways. Thus, experience is as indispensable as interdisciplinary communication among radiologists, radiographers, and forensic pathologists.

3.2.1 Image Quality

Radiation protection of the "patient" is not a major issue in postmortem imaging; therefore examinations can be performed with settings that guarantee optimal image quality. The contrast agents used in postmortem imaging can also be optimized to deliver contrast that is superior to clinically used products. Finally, no motion artefacts occur, which further increases the image quality of motion-sensitive examinations like CT and MRI.

These factors combine to elevate the image quality of PMCT and especially PMCT angiography (PMCTA) over their respective clinical counterparts and counterbalance the fact that forensic institutes often have access only to older imaging equipment. The image quality with conventional radiography is less affected by the forensic setting and does not differ significantly from the clinical situation. Postmortem MRI (PMMRI) has the benefit of a lack of motion of artefacts but involves numerous other challenges, e.g., temperature-dependent contrast agents [10].

3.2.2 Indications

The indication for postmortem imaging in general and PMCT with or without contrast agent in particular is to detect and characterize external and internal lesions, evaluate foreign bodies, and ultimately ascertain the manner and cause of death. Among the questions encountered in forensic radiology are the search for signs of medical error, identification of a body, determination of the intracorporal localization and trajectory of a projectile or knife, or correlation of a lesion pattern with possible injury mechanisms.

PMCT is excellently suited and superior to autopsy in the detection and documentation of skeletal lesions [11]. As in clinical CT, acute intracranial hemorrhage can readily be diagnosed by unenhanced PMCT.

Multiphase PMCTA (MPMCTA) is currently the best-evaluated postmortem imaging method to precisely localize hemorrhages even from very small vessels. Vascular occlusions in cases of cardiac or brain infarction can be detected with high diagnostic confidence. MPMCTA is also a very good method for diagnosing lesions of parenchymatous organs such as the liver, kidneys, and spleen. In addition, it is excellently suited for evaluating intracorporal trajectories of projectiles or stab wounds [11].

Conventional radiographs or fluoroscopy combine the advantages of a relatively inexpensive, easy-to-use, and widely available machine with the disadvantages of two-dimensional projection images and low soft tissue contrast. Their main applications are detection of bone lesions and radiopaque foreign bodies.

PMMRI currently cannot be considered a routine postmortem imaging method. Its limited availability has hindered the development of standardized PMMRI protocols; however, active research in the field carries the promise of changing this situation [12–16]. Because of its excellent soft tissue contrast, PMMRI can be expected to play a role in cases in which subtle soft tissue lesions are important, e.g., acute cardiac infarctions or acute stroke. Possible other applications might arise for determining the postmortem interval, for example subtle bone lesions as in child abuse, age estimation, imaging of decomposed bodies, hematoma age assessment, differentiation of vital and postmortem thrombus, and MRI spectroscopy, among others.

3.2.3 Interpretation

The possibility of correlating radiologic findings with autopsy is an opportunity to improve the diagnostic accuracy of the reporting radiologist, who immediately receives feedback about the accuracy of a diagnosis. Ambiguous radiologic findings can be resolved at autopsy by the forensic pathologist performing the autopsy or even by a forensic radiologist who is willing and allowed to be present in the autopsy room.

In general, postmortem changes to the body, such as autolytic processes or the formation of putrefactive gas, must be taken into account when interpreting postmortem images. For skeletal lesions, the interpretation of PMCT or postmortem radiographs is comparable to that of clinical imaging. More challenging are pulmonary pathologies, because these may be obscured by frequently encountered postmortem accumulation of fluid in the alveolar and interstitial spaces.

In postmortem angiography, intravascular formation of postmortem clots may mimic vital embolism, notably in the cerebral, pulmonary, or coronary arteries. Various contrast agent–related artefacts may also appear, and different types of contrast agents produce different kinds of artefacts.

3.2.4 Reporting

Radiologic reporting basically follows clinical standards and needs to answer the diagnostic issues. In forensic imaging, this question is usually a forensic one, so the report needs to focus on giving forensically important answers. Thus, although skin lesions, for example, are usually less important in clinical imaging, they may be essential as defense lesions in cases of stabbing. Hepatic cirrhosis with portal hypertension may be clinically interesting but will be unimportant in a shotgun victim. The report should be useful to the forensic pathologists and other relevant participants in the local judicial system. Again, interdisciplinary communication is necessary to determine the formal needs for the report to be incorporated into the forensic case work.

3.3 The Forensic Radiographer

The cause of death can be revealed in the vast majority of cases when radiologic imaging is combined with external examination and autopsy.

Because of the increased use of radiologic devices in postmortem investigations [17], the world of forensics seems to have an opportune moment to introduce the skills of the radiographer into forensic imaging [18]. For images to be used in court and trials as well as in autopsy reports, the image quality needs to be as good as possible.

In Lausanne, at the University Centre of Legal Medicine, the employment of a radiographer began with the installation of an eight-row multi-detector CT unit in November 2008 in association with the University of Health Sciences (HESAV) and its radiography department. The main activity was scanning every corpse admitted to the forensic institute regardless of the need for external examination and/or autopsy.

This new dedicated CT scanner was used for a research project called “Postmortem Dynamic Angiography” (Grabherr and coworkers, 2009) during which it formed the basis for a new practice in conjunction with the development of the Virtangio contrast agent injection device.

In some institutes, standardized basic scans can be performed by the medical staff or by the autopsy technicians after a short training course on handling the CT device. Most cases, however, are not “standard cases.” In nonstandard cases, the CT examination protocol must be adapted to the specific properties of the case, e.g., in corpses presenting a high body mass index or when detailed visualization of a specific body region is important. These protocol modifications are the most important determinants of the obtained image quality. For this reason, forensic CT data should be acquired by the trained specialists: the radiographers.

With the development of MPMCTA [4], the role of the forensic radiographer appears obvious. At the beginning of the MPMCTA research project, several specialists were needed to prepare the body for injection (forensic pathologist), take biopsies and liquid samples under CT guidance (radiologist), work the modified heart–lung machine (cardiotechnician), and perform the CT scan (radiographer). With the development of the dedicated injection device Virtangio, all of these tasks can be performed by only one trained specialist: the forensic radiographer.

3.3.1 Duties

The main activities of the radiographer are duties linked with the imaging techniques and the preparation of the body. In our center, this means:

- Realization of the unenhanced CT scan
- Denudation of the femoral vessels (artery and vein)
- Cannulation of the femoral vessels
- Sampling of peripheral blood and peripheral muscle if needed
- CT-guided biopsy and puncture of the lungs, gallbladder, and urinary bladder
- Preparation of the Virtangio device
- Injection of contrast agent for the different phases: arterial, venous, and dynamic
- Postprocessing of images
- Archiving data

With the development of this specific activity for radiographers in forensic imaging, training is now available at different levels of professional experience, from bachelor-level students to certified radiographers. To obtain a certificate in forensic radiography, students work on a large variety of subjects, such as quantification of hemorrhages with MPMCTA, forensic anthropology, ballistics, or postmortem angiography of the upper limbs.

An international bachelor's training under the ERASMUS program (European Action Scheme for the Mobility of University Students) has been offered by the HESAV (University of Health Sciences) in collaboration with the University Centre of Legal Medicine Lausanne-Geneva since 2013. This module, including an internship of two months, has been validated with 15 European Credits Transfer System (ECTS) and allows students to discover the main activity of the forensic radiographer through theoretical lessons and practice.

For trained radiographers, internships are always possible in our center and a dedicated training ITRaFoR (International Training for Radiographers in Forensic Radiology) was set up in 2013 to introduce colleagues to legal medicine, forensic science, and especially forensic imaging, such as PMCT, MPMCTA, and three-dimensional surface scanning.

Thus, the forensic radiographer is an important member of any forensic imaging team, someone who can perform the technical tasks associated with forensic imaging and MPMCTA. This contribution not only guarantees optimal image quality but also reduces the time other specialists need to dedicate to the case.

3.4 Key Points

If the initial discomfort is overcome, forensic radiology is greatly rewarding and instructive for forensic pathologists, radiologists, and radiographers.

Forensic imaging is already an important part of routine forensic casework with an impact that can be expected to continue its rapid growth.

The differences between clinical and forensic imaging require experience and interdisciplinary communication.

The forensic pathologist, radiographer, and radiologist are all indispensable members of any forensic imaging team because of their specific respective professional experience.

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