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Short communication

Use of post-mortem computed tomography in disaster victim identification. Updated positional statement of the members of the disaster victim identification working group of the *International Society of Forensic Radiology and Imaging*; July 2019

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1. Introduction

Post-Mortem Computed Tomography (PMCT) has an established role in the forensic investigation of death. Its use has also been proposed for mass fatalities and it has been applied in several incidents [1–10]. PMCT is applicable to human, animal and environmental material and PMCT may be used as an adjunct to or, in some cases, instead of internal autopsy. Indications for its use include:

- Identifying of potential hazardous materials within the body
- Disaster Victim Identification (DVI)
- Identifying the cause of, and contributory factors to death
- Gathering evidence for a criminal investigation

The computed tomography (CT) scanner can be mobile (lorry-based) or at a fixed site, thus can be used at the scene of incident or within a permanent or temporary mortuary, or in a medical facility. If there is no power supply available, mobile scanners will need an electricity generator. The imaging protocol(s) used will be dependent and determined by the incident and radiological modality available.

2. Body handling

The safe handling of bodies or other material is beyond the scope of this document. However, the CT scanner and staff must be integrated into the appropriate body handling protocols for a particular incident [11,12]. When the body is delivered to the scanner it must be placed on the scan table, ideally as close to the anatomic supine 'facing-upwards' position. The body should be fixed in place using straps. In order to ensure the correct orientation during the examination of the human remains, a self-adhesive radiographic marker can be applied to the body bag.

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It is recommended to start the examination with imaging of the closed body bag as PMCT may be performed without breaking the seal of a body bag. If additional procedures are required to enhance the CT scan, direct access to the body will be necessary. Manipulation of the body may be required, including pulling the arms into the side of the body, breakdown of rigor mortis or performing soft tissue or even bone release in cases of burning, to allow the body to fit through the scan aperture. Opening of the body bag or manipulation of the body should only be done if safe to do so and if authorised by the lead investigator. All manipulations of the body should be recorded.

Care should be taken to prevent damage to the scanner due to exceeding the weight limit or to leakage of body fluids or preservatives and placing the body on a watertight rescue stretcher free of metal may be necessary.

2.1. The PMCT scan

All staff entering the imaging room (controlled area) must comply with local radiation protection requirements (local rules) and every effort must be made to ensure the safest level of radiation protection that can be reasonably achieved. The person undertaking the imaging procedures should ideally be a forensic or DVI trained radiography specialist, or at least have had appropriate training in radiography. The trained radiography specialist may be assisted by other staff for the handling of bodies.

The position of the body on the CT-table should be entered into the scan set-up information (default supine). If the position of the body is not apparent then a 'scout' localiser image can be acquired. If the position is suboptimal then the body can be repositioned or its actual orientation should be entered into the set-up information. The entire body bag should be scanned in every case as evidence may have become detached from the palpable body or body parts. On some scanners, this may require body repositioning if the bag length is greater than the possible table movement.

The imaging protocol needs to be tailored to the particular needs of the investigation and data handling capabilities. However, considering the hardware and software needs and the capability of all current CT scanners it should be possible to perform an optimal CT study in all instances. Generally, choice of reconstructed slice thickness depends on a compromise between desired spatial resolution, quality of multi-plane reconstructions and the difficulty of data handling for large file sizes. Reducing slice thickness whilst maintaining image quality (signal-to-noise ratio) requires higher x-ray exposure, increasing x-ray tube heating (tube-loading), which may be a problem for older generation CT scanners.

For an optimal protocol reconstruction thickness should be 1 mm for all body regions allowing for detailed multi-plane reformats and 3D reconstructions. A high kilovolt (kV) approach (e.g. 120 kV) is generally used and a high tube current (mAs) is preferred, except for small body parts and infants. Auto-mA is not required. Matrix, pitch, gantry rotation speed and other parameters should be set as for standard clinical use and must take tube-loading into account. If tube-loading alerts prevent setting the required scan thickness, do not scan at lower resolution but consider: reducing individual scan lengths, increasing scan time, higher kV and lower mAs, apply "auto-mA, etc. in accordance with technical experience.

Scan data can be reconstructed in different algorithms depending on the tissue of interest e.g. bone, lung or soft tissue algorithms. These are sometimes called hard or soft algorithms. We would recommend that a minimum of two reconstructions are performed; a soft tissue and a hard (bone) algorithm (preferably) with metal artefact reduction and extended grey scale if available). Using too many reconstruction algorithms increases the scan file size, placing strain on image archiving and transmission where required.

2.2. Head and neck

Consider scanning the brain and neck twice with and without gantry tilt. Scanning at various gantry tilt angles has the advantage of displacing artefacts from dental mercury amalgam and allowing better visualisation of the posterior fossa and upper cervical spine. Another option is to rescanning after repositioning the head. Specific dental reconstructions can be performed for detailed dental analysis, especially for identification purposes [13]. Scanning the head and cervical spine separately also allows for a smaller FoV, increasing the spatial resolution.

2.3. Chest, abdomen, pelvis and limbs

Consider scanning the chest abdomen and pelvis in one run to include the upper femurs and scanning the lower limbs separately. If scanning the limbs separately consider including the pelvis (overlap with the body series) as this allows 3D reconstructions for assessment of mechanism of trauma.

2.4. Upper limbs

It may not be possible to scan the upper limbs satisfactorily as they may lie outside the effective field of view. If there is important DVI information required from the upper limbs this needs to be identified at the point of scanning and body positioning/strapping may need to be altered to allow for this.

If it is possible to scan the whole body in one run, this data-set can be used for 3D reconstructions to illustrate the location and extent of injuries. This does, however, create a large data file and may cause delays in transmission.

2.5. Additional procedures

If it is appropriate to open the body bag it is possible to obtain tissue and fluid samples using CT image navigation. This can be done in two ways i.e. markers on the skin or CT fluoroscopy, depending on local expertise. A robotic tissue sampling technology has been developed but is not widely available [14].

To reduce metal artefacts and to arrive at a better material characterisation dual-energy CT may be used [15]. This may, for example, be valuable for the characterisation of dental filling material [16].

Contrast enhancement (including angiography) and pulmonary ventilation are not directly related to DVI but may be performed for other indications separately, depending on local expertise [17].

For identification purposes it can be valuable to de-flesh parts of the body such as the pubic symphysis, medial ends of clavicles, femur, and skull, in order to assess ethnicity, age, sex and stature. However, the use of radiology, especially CT scanning, may obviate the need for this process, and the CT data can be used to perform a digital or virtual anthropological examination [18,19].

In some situations, it is helpful to rescan a body after removal of large metal objects from the body bag or after repositioning body part in an anatomic position. PMCT can also be used to document the body after a full internal and external examination as well as produce files suitable for 3D printing of body parts. These may be used for identification purposes, for example the printing of the teeth for comparison against ant-mortem smile images [20].

2.6. Image data handling

Images can be produced in digital and/or film format. The quantity of data available from multi-detector CT, and the requirement for multiplanar reconstruction for image analysis, effectively make hard copy image printing unsatisfactory for full image analysis. Hard copy printing of selected images to show specific points (after image analysis) may be useful. Provision must be made for the secure storage of images which complies with the incident criminal justice standard. This may require an 'authenticated' master copy being produced and handed to the authorities at the time of scanning. Data transfer can be made to anywhere in the world for image analysis. Depending on image data size and internet bandwidth this may take a varying amount of time.

2.7. Image interpretation

All imaging undertaken should be reported [21]. Preferably the reporting is done on the site of the DVI to make optimal use of the imaging data although the combination of mobile CT scanner and remote reporting has been successfully used as exampled by the Grenfell Tower Disaster, United Kingdom [22].

For DVI a quick-scan report form can be used with information on the state of the body, if it is intact, if the face may be recognisable, the estimate of age and sex, the presence of identifiable objects, the location of teeth and the presence of restorations, and further biological and medical profiling. This report can be accompanied by one or two annotated illustrations that should be understandable for the non-medical personnel responsible for the DVI. In combination with the markers on the body bag this information can speed-up the DVI process. The CT scan may make the requirement for dedicated dental X-rays, as well as fluoroscopy unnecessary. Information on the presence of forensic traces and safety risk should be conveyed as well.

Ideally, information provided by the CT scan can be used to complete the INTERPOL DVI (pink) form [23,24,25]. A more comprehensive report can be written in a later phase, depending on the investigation. The reporting should be undertaken by an appropriately trained professional with both a clinical and a forensic background in imaging, preferably a radiologist experienced in postmortem imaging although, depending upon local practice and PMCT interpretation experience, other specialists such as forensic pathologists, dentists and anthropologists may, under the governance of a forensic radiologist, author or be involved in the authorship of the report. Ante-mortem (clinical) radiological images (for example but not limited to radiographs, fluoroscopy, computed tomography or dental radiology) should be sought as part of the clinical data gathering process as they can be used as a part of the comparative, identification process.

3. Summary

This positional statement updates the previous 2014 ISFRI positional statement regarding the use of CT for mass fatalities investigations [8]. It takes into account the increasing global use of CT in Disaster Victim Identification including the introduction by INTERPOL and adoption by other countries of the INTERPOL DVI Radiology Reporting Form [24].

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jofri.2019.100346.

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