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ScienceDirect
Forensic Science International 169 (2007) 118–128
Forensic Science International
www.elsevier.com/locate/forsciint

Use of multislice computed tomography in disaster victim identification—Advantages and limitations

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Received 18 January 2006; received in revised form 4 June 2006; accepted 7 August 2006
Available online 25 September 2006

Abstract

After a mass fatality incident (MFI), all victims have to be rapidly and accurately identified for juridical reasons as well as for the relatives' sake. Since MFIs are often international in scope, Interpol has proposed standard disaster victim identification (DVI) procedures, which have been widely adopted by authorities and forensic experts. This study investigates how postmortem multislice computed tomography (MSCT) can contribute to the DVI process as proposed by Interpol. The Interpol postmortem (PM) form has been analyzed, and a number of items in sections D and E thereof have been postulated to be suitable for documentation by CT data. CT scans have then been performed on forensic cases. Interpretation of the reconstructed images showed that indeed much of the postmortem information required for identification can be gathered from CT data. Further advantages of the proposed approach concern the observer independent documentation, the possibility to reconstruct a variety of images a long time after the event, the possibility to distribute the work by transmitting CT data digitally, and the reduction of time and specialists needed at the disaster site. We conclude that MSCT may be used as a valuable screening tool in DVI in the future.

Keywords: Forensic science; Forensic radiology; Multislice computed tomography; Mass fatality; Disaster; Identification; Interpol; Virtual autopsy

1. Introduction

In case of mass fatality incidents (MFIs), it is very important to identify the victims rapidly and accurately, both for juridical reasons and for the relatives to be able to mourn. The International Committee of the Red Cross's contribution to the 2004 16th meeting of Interpol's Standing Committee on Disaster Victim Identification states that "identification represents the fulfilment of the right of human beings not to lose their identities after death and, overall, the right of families to know what has happened to their relatives in all circumstances" [1].

MFIs, whether natural disasters (such as floods), accidents (such as aircraft crashes) or outbreaks of violence (such as armed conflicts or acts of terrorism), are often international in scope, so that authorities and experts from several countries are involved in the actions taken in the aftermath. Fortunately, an internationally agreed upon standard exists about how to proceed to identify victims of MFIs: Interpol's Disaster Victim Identification Guide [2], which is useful in any type of disaster, regardless of its cause and the dimension of the death toll. It "describes the three major stages in victim identification, namely: search for antemortem information for possible victims; recovery and examination of bodies to establish postmortem evidence from the deceased; comparison of antemortem and postmortem data" [3] and it "is the only international instrument found that specifically addresses concrete disaster victim identification techniques in disaster conditions" [3]. To facilitate the aforementioned third stage in DVI – comparison of antemortem (AM) and postmortem (PM) data – Interpol has devised a DVI form set, consisting of a yellow AM form, a pink PM form, and a Comparison Report (to be filled in when an identification has been established based on the match between one AM and one PM form). All three forms are available for download from Interpol's website [4] in several languages as both a plain paper-and-pencil version (to be first printed, then filled in) and an electronic version (to be

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0379-0738/$ – see front matter
doi:10.1016/j.forsciint.2006.08.004

filled in electronically and printed later). What makes the use of these forms so recommendable is the fact that all versions share an identical layout and numbering of items, many of which are simply boxes that can be marked with a cross, allowing the handling of reports compiled in foreign languages. Furthermore, database software has been developed specifically for searching and matching AM and PM cases compiled with the electronic versions of the forms.

After every MFI, the decision has to be made whether autopsies should be performed on all victims. While this is undoubtedly advisable at least in all cases in which a criminal or terrorist background to the incident is suspected, it may not always be necessary for the sake of establishing a victim's identity and cause of death. Nevertheless, Interpol, considering DVI "an integral and essential part of the overall investigation of the disaster" [2; p. 20], recommends performing autopsies on all victims "not only for the identification and cause of death aspects, but also to assist in preventing or minimizing the effects of similar incidents in the future" [2; p. 20]. Indeed this appears to be considered standard practice by DVI experts in many countries where MFIs have occurred since the mid-1980s [5–9]. However, national law may not deem autopsy of all disaster victims mandatory, and thus even Interpol member states do not always adhere to that recommendation, as illustrated by the SAS SK 686 aircraft accident at the Milan Linate airport on 8 October 2001, where the prosecutor in charge ordered judicial autopsies of only 10 of the 118 victims [10]. This example shows that the decision made on this question after a given MFI is not simply a matter of the number of victims. It must though be noted that all of [5–9] relate to MFIs in which no more than 155 dead bodies were found. So far, to the authors' knowledge, no single MFI in which Interpol's recommended DVI procedures have been adhered to has even remotely approached the dimensions of the 26 December 2004 Tsunami disaster in south Asia.

For almost as long as they exist, imaging methods have not only been used for diagnostic but also for identification purposes [11]. Routinely used are the dental status, evidence of surgical implants and bony findings such as the sinus frontales or vascular sulci of the cranium [12]. The comparison of antemortem and postmortem roentgenograms is a well-established method. The advent of computed tomography has given us more imaging modalities to work with. Identification has become possible by comparing antemortem CT scans with postmortem X-ray images [13] and by comparing antemortem and postmortem CT scans [14,15]. More recent advances in CT technology have made the tedious work of producing postmortem X-ray images whose projections match those of given antmortem images unnecessary by allowing to rotate three-dimensional image data in virtual space and to calculate simulated X-ray images [12,16–18].

Recently, CT technology has developed to the point where a CT scanner mounted on a trailer can be operated in the field. The practicality of such mobile CT Equipment has already been proved in a research project by the Egyptian Supreme Council of Antiquities, in which the mummies from the Valley of the Kings near Luxor are scanned in a truck outfitted with a mobile Siemens Somatom Emotion 6 MSCT scanner donated by Siemens Medical Solutions [19] and the National Geographic Society [20].

In a research project termed "Virtopsy®" [21,22], the Institute of Forensic Medicine of the University of Berne, Switzerland has been gathering increasing experience in the field of postmortem multislice computed tomography (MSCT) examination since 2000. It has been shown that postmortem CT images are interpretable even if the body is badly destroyed, e.g. in advanced stages of decomposition [23]. In the view of the experiences gained so far, the apparent increase of both frequency and scope of MFIs, and the increasing availability, affordability and ease-of-use of MSCT equipment, one may consider introducing CT into the DVI process as a screening tool. The aim of the present study is thus to investigate how postmortem MSCT examinations can contribute to the DVI process as proposed by Interpol, particularly to which extent it can be used to gather and objectively document the data to be filled in a victim's PM Form, facilitating the whole process especially in cases where full autopsies are not performed on all victims for whatever reasons or where the number of victims and specific circumstances (such as the climate) threaten to prevent timely examination of all dead bodies.

2. Materials and methods

We analyzed Interpol's pink PM form to identify parts which can possibly be filled in with information gathered from the victim's CT data rather than from direct observation of the victim's dead body itself. The AM and PM forms are divided into seven sections A–G as follows:

(A) Personal data of the missing person (not present in the PM form).
(B) Recovery of the body from the site (not present in the AM form).
(C) Description of effects: (1) clothing and shoes; (2) personal effects; (3) jewellery.
(D) Physical description of the body, distinguishing marks (such as, e.g. tattoos).
(E) Medical information about the missing person (AM); data obtained by internal examination of the body (PM).
(F) Dental information (AM); dental data (PM).
(G) Any further information that may assist in identification.

In the PM form, these sections are usually filled in by the following persons:

(B) Police, fire brigade, civil protection, military, other.
(C) Police, fire brigade, civil protection, military, other.
(D) Forensic pathologist.
(E) Forensic pathologist.
(F) Forensic odontologist.
(G) Various persons.

We concentrated on sections D and E of the PM form, as these are the ones to be filled in by the forensic pathologist and, together with section F, the ones most likely to accept data obtained from CT scans. Table 1 gives a more detailed overview of their contents.

A list of those Items from sections D and E postulated to be suitable for documentation by CT data was compiled. Postmortem CT scans were then performed on 32 forensic cases at the Institute of Forensic Medicine of the University of Berne, Switzerland on a multislice CT scanner (Siemens Somatom Emotion 6—the same model as used for scanning the Egyptian mummies on a truck) with a slice thickness of 1.25 mm, and the resulting data were processed on a workstation (Leonardo, Siemens Medical Solutions, Germany).

Table 1
Relevant items of sections D and E of the Interpol DVI PM form

PM form page and item	CT documentation possible		
	Yes	Partially	No
D1–D3			
Physical description (at mortuary)			
31 State of the body		X[a]	
31A Estimated age		X[b]	
32 Height	X		
33 Weight		X[c]	
34 Build	X		
35 Race		X	
36 Hair of the head			X
37 Forehead	X		
38 Eyebrows			X
39 Eyes			X
40 Nose		X[d]	
41 Facial hair			X
42 Ears	X		
43 Mouth	X		
44 Lips		X[e]	
45 Teeth		X[f]	
46 Smoking habits			X
47 Chin	X		
48 Neck	X		
49 Hands		X[g,h]	
50 Feet		X[g]	
51 Body hair			X
52 Pubic hair			X
53 Specific details		X[i]	
54 Circumcision			X
E1			
Internal examination—full autopsy			
60 Head		X	
61 Chest		X	
62 Abdomen		X	
63 Other internal organs		X	
64 Skeleton/soft tissue		X	
65 Various		X	
E2			
Medical conclusions			
71 Sex	X		
72 Estimated age		X[b]	
73 Samples taken		X[j]	
74 Other clues for identification	X		

[a] It must be recorded whether the body is visually identifiable or not.
[b] Age estimation based on CT data is possible but not the preferred method.
[c] Weight can only be estimated from the body volume measured by CT.
[d] Spectacle marks, if shallow, may not be visible in CT.
[e] Lip make-up is not visible in CT.
[f] Denture ID number is not visible in CT.
[g] Nail paint is not visible in CT.
[h] Nicotine stains are not visible in CT.
[i] Tattoos are not visible in CT.
[j] Samples may be taken as CT-guided postmortem biopsies.

We investigated whether the informations required for the proposed items of the Interpol PM form can be gained from the CT data.

3. Results and discussion

All items asking about color (e.g. skin or eyes) were excluded, as CT images do not give such information. Equally, all items concerning hair (even if not asking about its color) were excluded because the diameter of a hair is less than 0.625 mm, which is the resolution limit of our CT scanner. We postulated all other items except circumcision status (item D3-54) to be suitable for documentation by CT. Table 1 gives the results in brief. Beyond what is listed in Table 1, pages D4 and E3 can also be completed with CT findings. They consist of a body sketch and a skeleton sketch which are completed with details already documented in items D1-31 (‘State of the body’), D3-53 (‘Specific details’), and El-64 (‘Skeleton/Soft tissue’ under the heading ‘Internal examination—Full autopsy’).

In *item D1-31*, which describes the *state of the body*, the forensic pathologist first has to record whether the body is visually identifiable or not. The actual description that follows can then be based on CT images. Twelve body regions (head, neck/throat, right arm, left arm, right hand, left hand, body front, body back, right leg, left leg, right foot, and left foot) are separately described as damaged, burned, decomposed, skeletonized, missing, or loose; CT has been proved to be useful for doing so. It has turned out to be particularly good at localizing both intensity and direction of heat in burnt bodies [24].

It is worth noting that a body’s age appears three times in the PM form. *Item D1-31A* means the *estimated age* based on the body’s physical description (at the mortuary). The method of age estimation should be stated. We will discuss age estimation in the context of item E2-72.

To establish the *height* of the body (*item D1-32*), one of several methods may be used. With a continuous set of CT data, virtual sections at arbitrary angles through the volume can be calculated; then the distance between two points, such as both ends of a bone, within such a plane can be measured. If the body can be laid outstretched on the examination table, its full length can even be determined from the CT data in one single measurement. If this is not possible due to contractures, e.g. in burnt victims, the body height can still be determined by adding the measured lengths of a number of skeleton segments. Finally, if the body is not complete, one of several anthropological methods can be applied [25–28]. These are expressed as formulas which have the lengths of several of the long bones of the extremities as parameters [29,30]. Fig. 1 shows measurements of a victim’s humerus, radius, femur, and tibia in reformatted CT images.

The *weight* of a body (*item D1-33*) is best established by weighing the body, but since body volume, which can be measured from the data of a full body CT scan, is correlated with body weight (Verma et al. [31], who measured body volume with a water displacement technique, found the correlation coefficient to be $r = 0.9966$ in a sample of soldiers), it is possible to at least estimate the body weight using CT data—this may prove helpful for control if doubt arises later concerning the documented weight or if weighing has been missed altogether.

In items Dl-34–D3-54, the forensic pathologist is asked for physical descriptions of various parts of the body based on external inspection. Among these, about 60% can, at least

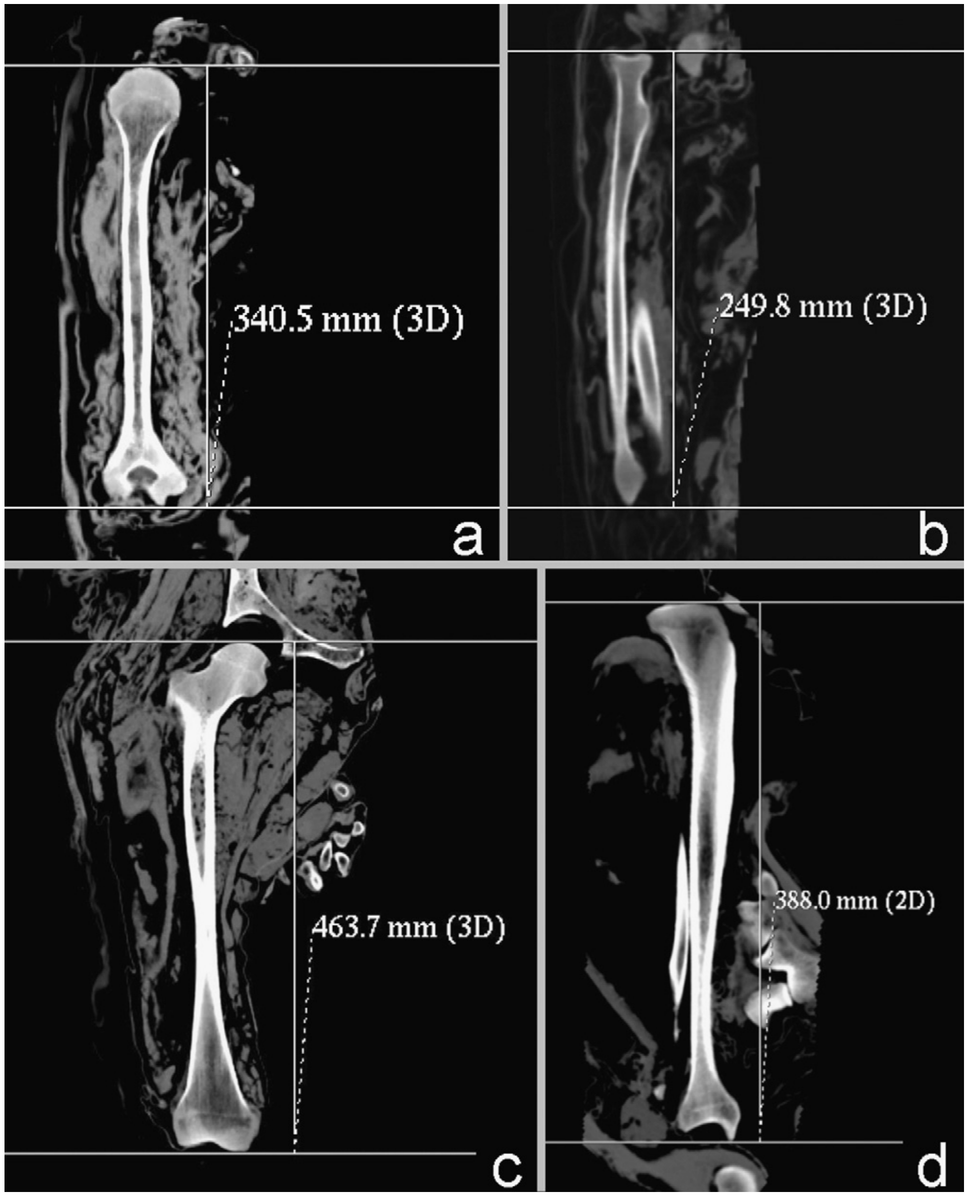

Fig. 1. Distance measurements within reformatted images that have been chosen to contain both end points of a selected bone; these measures are used for stature estimation in a decomposed corpse. (a) Humerus, (b) radius, (c) femur and (d) tibia.

partially, be described using three-dimensional reconstructions of soft tissues. A relatively small number of reconstructed images can be used for many different items.

In *item D1-34* (*Build*), the forensic pathologist is asked for a description of a victim's bodily constitution (light, medium, or heavy; item 34.01), head form in the frontal view (oval, pointheaded, pyramidal, circular, rectangular, or quadrangular; item 34.02) and head form in the profile (shallow, medium, or deep; item 34.03). While even unaltered CT slices allow to establish item 34.01, the bodily constitution, three-dimensional reconstructions of the soft tissues of the head must be calculated so as to establish items 34.02 and 34.03 (the head form) as if by looking at the actual body. Fig. 2 shows the head of one of our forensic cases, both in the frontal view and in profile, in three-dimensional CT data reconstructions and in photographic pictures for comparison. When deciding on items 34.02 and 34.03, it is advisable to consult the silhouette sketches which are provided (at the end of the comparison report form) and which are shown in Fig. 3a. Fig. 3b shows the corresponding item of the Interpol PM form.

In *item D1-35* (*Race*), one is asked to determine a victim's race as caucasoid, mongoloid or negroid and the complexion as light, medium or dark. Since there are various skeletal features that are used by anthropologists for race determination [25–28], we expect that three-dimensional reconstructions of bones may allow to complete this task without the need to prepare bones.

In *item D2-37* a body's *forehead* has to be described in terms of height/width (low, medium, or high; narrow, medium or wide; item 37.01) and inclination (protruding, vertical, slightly receding or clearly receding; item 37.02). This can be done with the help of the reconstructed images that have already been calculated for item D1-34. In *item D2-40*, the *nose* is to be

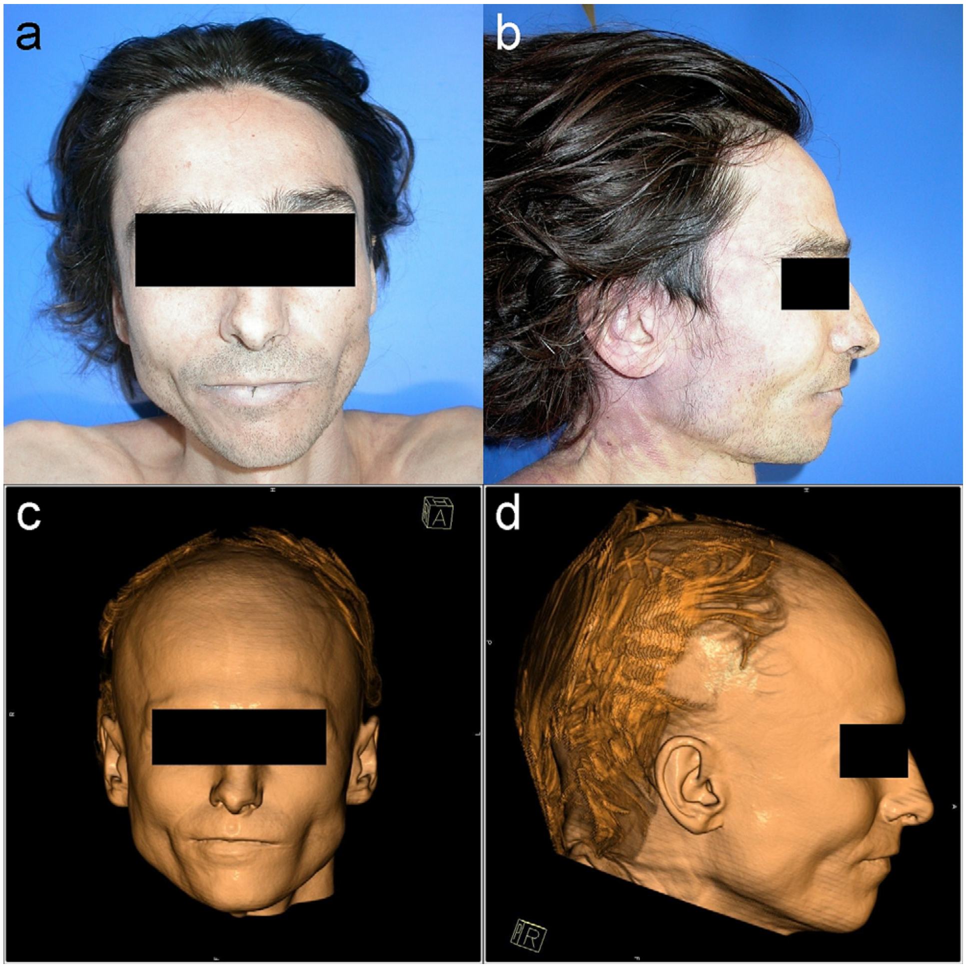

Fig. 2. Comparison between three-dimensional soft tissue reconstruction from CT data and photography. (a and b) Photographs. Note that the only features not also visible in the 3D reconstructions are single hair and color of hair and skin. (c) 3D reconstruction of skin surface, frontal view. Useful for compilation of Interpol PM form items Dl-34.02 (head form, front), D2-37.01 (forehead: height/width), D2-42.01 (ears: size/angle), D2-43 (mouth), D2-44 (lips), D2-47.02 (chin: shape). (d) 3D reconstruction of skin surface, lateral view. Useful for compilation of Interpol PM form items Dl-34.03 (head form, profile), D2-37.02 (forehead: inclination), D2-40 (nose), D2-42.01 (ears: size/angle), D2-74.01 (chin: size/inclination).

described in terms of size/shape (small, medium or large; pointed, roman (i.e. with a prominent bridge), or alcoholic; item 40.01), presence or absence of spectacle marks (and other peculiarities; item 40.02), and curve/angle (concave, straight, or convex; turned down, horizontal, or turned up; item 40.03). With the possible exception of spectacle marks – namely if they are too shallow – these descriptions too are feasible using the same images as before. As a help to decide on item 40.03 (curve/angle of the nose), silhouette sketches similar to those of the head form are provided.

Item D2-42 asks for a description of the *ears* in terms of size/ angle (small, medium, or large; close-set, medium, or protruding; item 42.01) and of ear lobe attachment and piercing (item 42.02). Silhouette sketches of ear lobe attachment are provided.

Items D2-43 and D2-44 describe the *mouth* in terms of size (small, medium, or large) and the *lips* in terms of shape (thin, medium, or thick). The presence of lip make-up, which cannot be seen in any kind of CT images, is recorded in item 43 also.

Items D3-47 and D3-48 describe the *chin* in terms of size/ inclination (small, medium, or large; receding, medium, or protruding; item 47.01) and shape (pointed, round, angular, cleft chin, or groove; item 47.02) and the *neck* in terms of length/shape (short, medium, or long; thin, medium, or thick; item 48.01) and peculiarities (goiter, prominent Adams apple, collar/shirt no., circumference in cm). No new images need to be computed for item 47, as the needed informations are to be found in the ones used for items 34.02 and 34.03 (the head form).

In *items D3-49 and D3-50*, the *hands* and *feet* are described in terms of shape/size, nails, and peculiarities. While it is impossible to perceive nail paint or nicotine stains in any kind of CT images, width and length of hand and feet and length of nails can be described with the help of three-dimensional reconstructions.

It is evident that the descriptions given in the above-mentioned items are of a subjective character; different examiners might describe the same person differently. Figs. 2 and 3 illustrate this difficulty; the reader may try to decide whether the head in this given case is oval or pointheaded and whether it is medium or deep in profile. Such decisions are even more difficult in those items where no

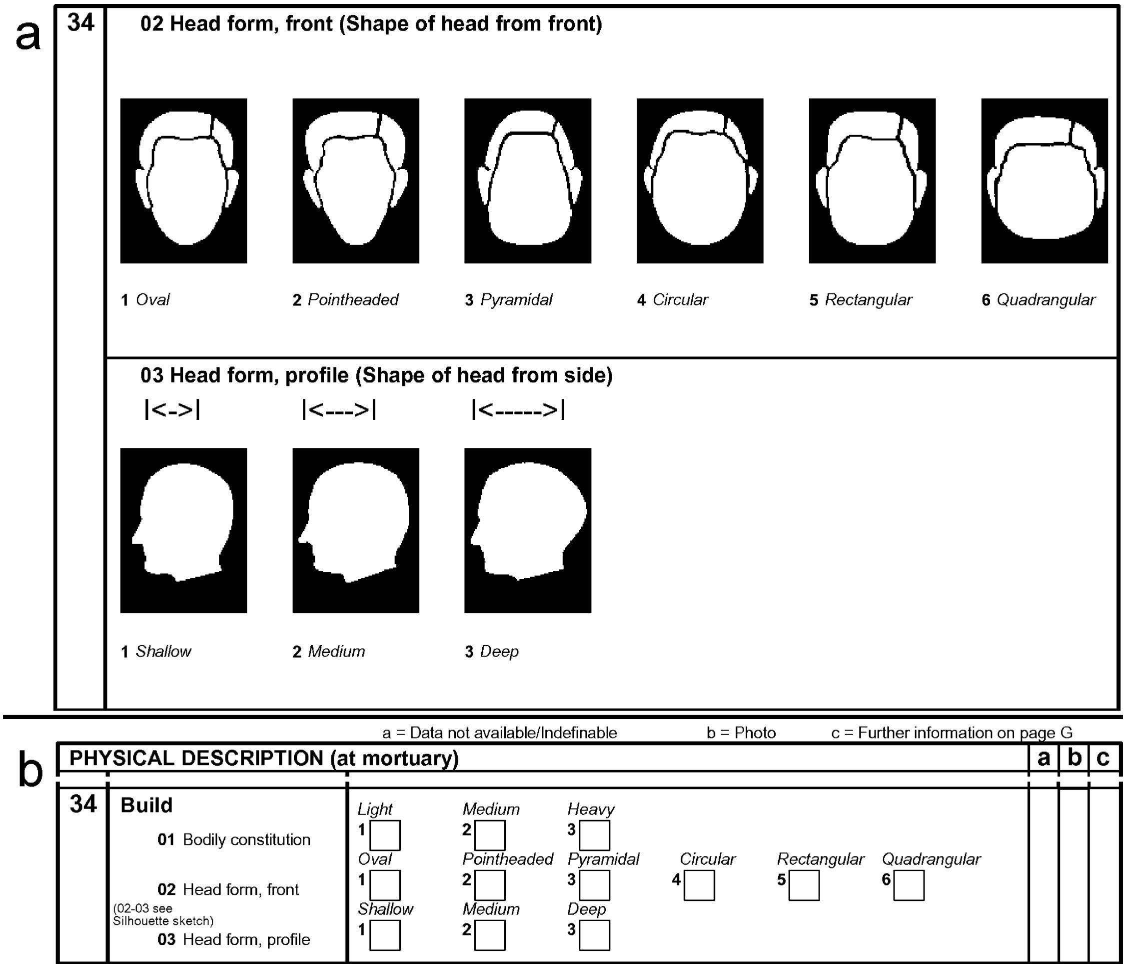

Fig. 3. Excerpt from the Interpol Comparison Report and PM form: (a) Silhouette sketch provided at the end of the comparison report. Use this to decide on an individual's head form. The reader may try to classify the individual in Fig. 2c and d and (b) item Dl-34 (build) of the Interpol PM form.

sketch is provided, such as nose or ear size. There is always the risk that an examiner thinks those noses and ears to be of medium size that are similar to his own, which can make matching AM and PM forms difficult, as they are virtually never compiled by the same person. It must be noted, though, that these difficulties are the same whether one inspects an actual dead body or three-dimensional CT reconstructions. The advantage of the CT approach lies in documentation. Whereas photographic documentation limits the views of a deceased to a number of angles, from a CT data set reconstructed views from different angles can be calculated in an infinite number, at any time. If, e.g. no picture has been taken showing the ears' angle, what the examiner wrote down in item D2-42.01 can still be controlled later if CT data of the head are available. It may also be seen as an advantage that reconstructed images do not have the same emotional impact on viewers as photographs.

Using *item D2-45*, the forensic pathologist has to roughly describe a victim's *teeth* in terms of condition (natural, untreated, treated, crowns, bridges, or implants; item 45.01), gaps and missing teeth (item 45.02), and dentures (part, upper, part, lower, full upper, full lower, ID-number; item 45.03). A much more thorough listing of dental findings will be asked for in section F of the form, which is to be filled in by a forensically trained odontologist. Both tasks can be accomplished by interpreting a so-called dental CT, i.e. a panoramic jaw overview calculated from transversal CT slices [32], or a maximum intensity projection (MIP) image of the cranial CT data [18]. Since these visualization techniques allow a detailed description of a victim's dental status, we expect jaw resection not necessary in most cases, and thus the brittle teeth of burned victims, e.g. are not in danger of being destroyed further. The images (or, for that matter, the cranial CT data they are derived from), being of digital nature, can be sent to forensic odontologists electronically; ideally, a majority of the involved forensic odontologists would be able to do their valuable work in their offices while only a small number would be needed at the mortuary near the actual disaster site for those exceptional cases where artifacts due to metal used in dental restorations reduce the value of the CT images – a problem which will become less relevant in the future as amalgamic restorations become fewer nowadays – and for extracting teeth to be used for age estimation (discussed later). Both visualization techniques are also useful for comparison with antemortem radiologic images. While the postmortem dental CT can be compared to antemortem classic orthopantomographies (OPGs) or bitewing radiographs, MIP provides a three-dimensional

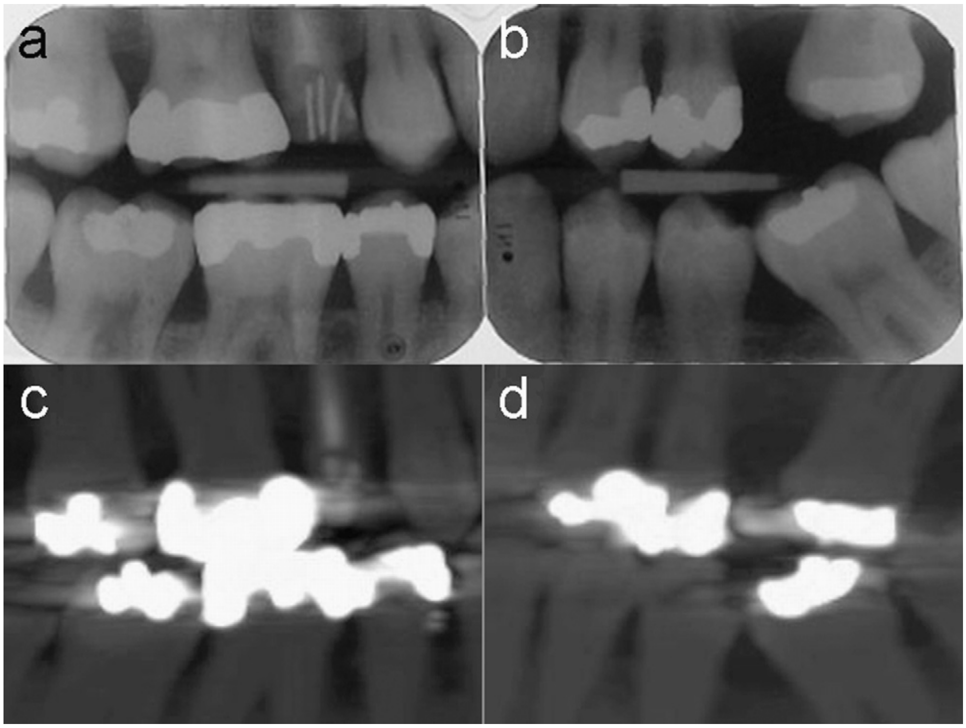

Fig. 4. Comparison between antemortem bitewing radiographs (a and b) and postmortem maximum intensity projection images rotated so as to be viewed from the same angle (c and d). Judging by the corresponding positions of restorations, the identity is highly probable.

model of the head which can be rotated in virtual space to match the viewing angles of any given antemortem images as shown in Fig. 4; this is of great advantage if antemortem image material does not become available until after the postmortem documentation is done. If the CT scanner has an extended CT range, different filling materials can be distinguished by their radiopacity [33], thus an oral examination will only be necessary in special cases. Dentures, if present, still must be removed and closely inspected, as no radiologic imaging method can reveal their ID-numbers.

Item 53 allows to record *specific details* of the same twelve regions of the body as item 31 (the state of the body), such as scars/piercings, skin marks, tattoo marks, malformations, and amputations, some of which are clearly distinguishable in CT images, and *item 55* allows to record *other peculiarities*.

In order to complete the PM form, before or after the CT examination the forensic pathologist should systematically do the following:

- Inspect the body as a whole, and specify race and complexion (item 35), describe body hair and pubic hair (in terms of extent and color; items 51 and 52), and record tattoos, scars, burns, etc. (items 31 and 53).
- Check the body from top to toe, and describe the hair of the head (in terms of type, length, color, shade of color, thickness, style, baldness and other; item 36), the eyebrows (item 38), eyes (item 39), and facial hair (item 41); check the nose for spectacle marks (item 40.02) and the lips for make-up (item 44.01); record the ID number of dentures, if present (item 45.03); check for nicotine stains on teeth, lips, and fingers (items 46.01 and 49.03) and for nail make-up on fingers and toes (items 49.03 and 50.02).
- If male, check circumcision status (item 54).
- Estimate the individual's age (item 31 A).
- If possible, measure the body height (item 32) and weigh the body (item 33).

By carrying out these steps one makes sure that those items of the PM form that are not suitable for documentation by CT do not remain blank.

Items El-60–El-65 are meant for recording findings of an *internal examination*, i.e. of a *full autopsy*. The goals, however, are not the same ones as a pathologist's performing a regular autopsy; in the DVI context one concentrates mainly on finding clues for the victim's identification and, secondarily, the cause of death. If full body CT scans are performed on all dead bodies instead of performing autopsies, these items can be used to record CT findings in the sense of a virtual autopsy. In this way, many features that can be helpful for the purpose of identification of a body may be found which otherwise might never be detected. But CT examination may even reveal clues for identification that would remain hidden to the eye during autopsy. This holds true especially for skeletal findings such as (but not limited to) osteosynthesis material, which is exemplified in Fig. 5. The possibility to compare such findings with antemortem X-ray images as demonstrated in Fig. 6 makes them particularly valuable. Thus, MSCT also has its value as a complementary method. Carrying out the necessary steps listed above and scanning a victim's body, storing the acquired data for later image reconstruction and interpretation, reduces the time spent per body, which is of great value if progressing decay

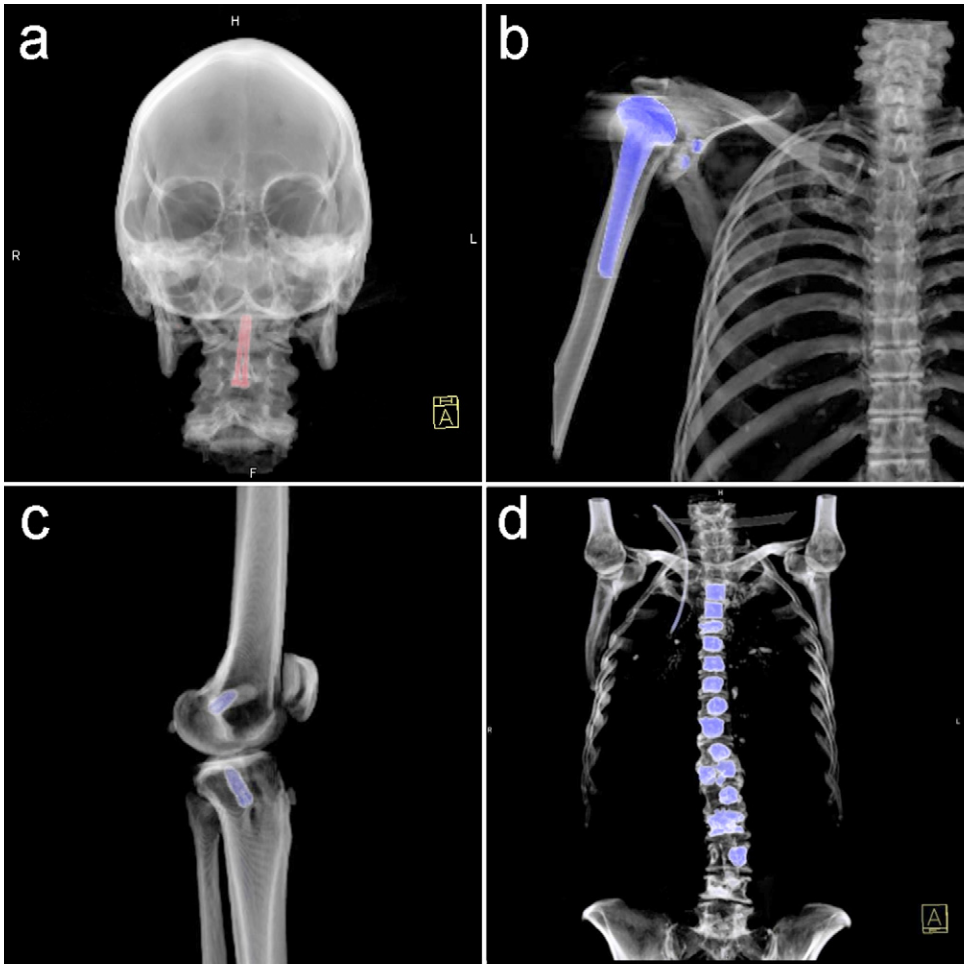

Fig. 5. Skeletal CT findings that are difficult, if not impossible, to find by autopsy. For visualization purposes, volumes with a radiopacity less than that of bone are not shown, and volumes with a radiopacity higher than a certain threshold are colored. In each picture, the threshold value has been chosen to separate the metal (a–c) or cement (d) from the bone. (a) Two screws in the dens axis. Parts of the jaws have been virtually cut away so as to allow a good frontal view on the axis. Item El-64.01 (vertebral column). (b) Right humeral arthroplasty. Item El-64.03 (limbs—right arm). (c) Cruciate ligament reconstruction. Item El-64.05 (limbs—right leg). (d) Vertebroplasty. Item El-64.01 (vertebral column).

threatens timely examination of all victims. We expect that it also reduces the number of forensic personnel needed at the disaster site, because after all bodies have been scanned, work on the CT data can then continue far from there and under ideal conditions.

The decision about a victim's *sex* (*item E2-71*) is usually based on inspection of external (primary and secondary) sexual characteristics, but the whole body CT scan also shows internal primary sexual characteristics. Three-dimensional reconstructions of a scanned victim's skeleton even make it possible to apply anthropological methods of sex determination to skeletal features if necessary [25–28], without the need for time consuming preparation of bones. To illustrate this, Fig. 7 shows the reconstruction of a male pelvis.

Age estimation may be very important to narrow the range of missing persons with which a PM data set has to be compared. In *item E2-72*, the *estimated age* and the *method used* are recorded. Methods of age estimation have been proposed in abundance [25–28], and many of them have been repeatedly revised by the original authors and by others. Some of these methods (those based on cortical bone remodeling in the proximal femur [36] or cranial suture closure [37]) can be applied to CT data, but review has revealed that none of these yield satisfyingly accurate results [38,39]. Newer methods proposed in recent years and specifically based on CT data can as yet not be used in the field in cases of mass fatality. For the prediction of age using CT data from pubic bones as proposed by Pasquier et al. [40], software specifically written for that purpose and not commercially available is a necessity; the dental method proposed by Vandevoort et al. [41] requires an X-ray microfocus CT unit and specific software. To date, with reasonable effort, the most precise and accurate age estimates can be obtained using lab methods measuring the racemization of aspartic acid in dentin [42–45] or bone and cartilage [46], while the methods of choice under field conditions are morphological methods applied to extracted teeth and best performed by forensically trained odontologists [44,47,48].

In *Item 73* the forensic pathologist records the *samples taken* during autopsy together with their purpose, place of storage and result. In cases where no autopsy but a full body CT scan is performed with a virtual autopsy in view, in addition to the basic examination postmortem biopsies can be taken under CT

Fig. 6. Comparison between antemortem X-ray images (a and d) and corresponding postmortem reformatted CT images (b, c and e). (a) Antemortem roentgenogram showing osteosynthesis of right tibia by medullary nailing. (b) Postmortem reformatted CT image showing the canal of the more proximal of the two screws in a) after removal of the osteosynthesis material. (c) Postmortem reformatted CT image showing the canals of the more distal screw and the marrow nail itself. Note also the dislocation of the fibula ad latus and ad axim as in a). (d) Antemortem roentgenogram showing intramedullary minimal osteosynthesis of left humerus my means of a helical wire [34,35]. (e) Postmortem reformatted CT image of a severely burnt body showing the same helix wire as in (d); due to the different configuration of the shoulder joint, only the humerus is seen from the same angle. The finding of this intramedullary helix wire was crucial for the identification in this particular case. For an explanation of the visualization technique see Fig. 5.

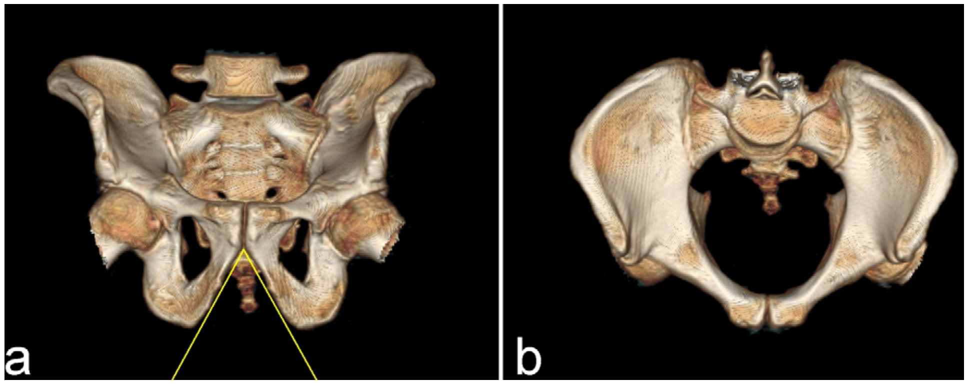

Fig. 7. 3D reconstruction of a male pelvis. The coloring is a feature of the reconstruction software displaying radiopacity differences. (a) Frontal view; the yellow lines accentuate the acute subpubic angle. (b) Cranial view showing the heart-shaped pelvic aperture.

guidance, either by an interventional radiologist or a trained forensic pathologist.

4. Conclusion

We conclude from our results that MSCT can be integrated as a valuable screening tool into the DVI process which has been proposed by Interpol. It does not make any other step in the process unnecessary, yet although extending that process by one more step, shall help reduce the time needed to acquire the postmortem data needed to establish the victims' identities. Performing CT scans of all victims of a MFI could prove especially helpful under either one of the following conditions:

(1) There is a large number of victims, and certain circumstances such as warm and humid climate and lack of cooled storage room threaten to prevent timely autopsy of all of them.
(2) Performing autopsies, even for medicolegal purposes, is not socially accepted at the place of the disaster by religious or other reasons.

A full body CT scan only takes about 10–15 min per body (including the positioning, etc.), theoretically allowing for 4–5 bodies to be scanned per hour; thus, reckoning with unforeseeable work pauses scanning 80 bodies per 24 h appears to be realistic. Since the scan acquires data that contain about 60% of the information for the extensive physical description in section D of the Interpol PM form – information which cannot be gathered in so short time by inspecting the actual corpse – time needed per corpse in the field is drastically reduced. Reformatting and interpreting of one victim's CT data can be done while the scanning of further bodies continues or even be postponed until all bodies have been scanned, depending on the available computer hardware and number of personnel. Theoretically, at a rate of 80 bodies per 24 h, three radiologists working simultaneously could do the work needed to gather all the information that is needed, but if interpretation is postponed as we suggest only one radiologist is needed on site for quality management.

The MSCT model used in our institute and in Egypt is an air-cooled system, necessitating pauses during full body scans of adequate collimation (e.g. 1 mm or less) so the tube can cool down. The water-cooled straton technology, in contrast, would allow to exploit the full potential of MSCT in the field, even with a victim number comparable to that of the tsunami in 2004. Other than efficient cooling, to fulfill the needs of a DVI team a CT scanner should have an extended field of view (FOV) so as to make images of, e.g. burned victims in fencer's posture possible and an extended CT scale which is needed to characterize different materials of high radiopacity such as dental filling materials [33].

Even under better conditions than those described above, performing CT scans in the course of the DVI process has advantages not reached by any other method. It allows observer-independent, objective documentation even of those items in the PM form that are not strictly quantifiable, such as, e.g. nose size (D2-40.01) or lip shape (D2-44.01). Any foreign body, be it small like a coronary stent or big like an arthroplasty, will be detected and can serve to support a victim's identity. If relevant AM information does not become available until a long time after the disaster, identification may still become possible, providing the CT data have been stored; if the examinations have been done without the use of CT it may be used for re-examination. The acquisition time of radiological data is even less by MSCT than by classic X-ray; the latter also has the disadvantage that the projection of available AM X-ray images must be known beforehand. In burned bodies, comparison of radiological data, specifically of the teeth, is often the only identification method leading to success. Using MSCT, this is possible without the need for jaw resection. The CT data can be distributed to forensic pathologists in suspected victims' home countries electronically, so the work can be done in a decentralized manner in geographically distant places (what could be called "teleforensics"), and the number of specialists needed at the actual disaster site can be reduced.

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