CASE REPORT

J Forensic Sci, July 2008, Vol. 53, No. 4
doi: 10.1111/j.1556-4029.2008.00742.x
Available online at: www.blackwell-synergy.com

Soren Blau,[1] Ph.D.; Shelley Robertson,[2] F.R.C.P.A.; and Marnie Johnstone[3]

Disaster Victim Identification: New Applications for Postmortem Computed Tomography

ABSTRACT: Mass fatalities can present the forensic anthropologist and forensic pathologist with a different set of challenges to those presented by a single fatality. To date radiography has played an important role in the disaster victim identification (DVI) process. The aim of this paper is to highlight the benefits of applying computed tomography (CT) technology to the DVI process. The paper begins by reviewing the extent to which sophisticated imaging techniques, specifically CT, have been increasingly used to assist in the analysis of deceased individuals. A small scale case study is then presented which describes aspects of the DVI process following a recent Australian aviation disaster involving two individuals. Having grided the scene of the disaster, a total of 41 bags of heavily disrupted human remains were collected. A postmortem examination was subsequently undertaken. Analysis of the CT images of all body parts (n = 162) made it possible not only to identify and side differentially preserved skeletal elements which were anatomically unrecognizable in the heavily disrupted body masses, but also to observe and record useful identifying features such as surgical implants. In this case the role of the forensic anthropologist and CT technology were paramount in facilitating a quick identification, and subsequently, an effective and timely reconciliation, of body parts. Although this case study is small scale, it illustrates the enormous potential for CT imaging to complement the existing DVI process.

KEYWORDS: forensic science, disaster victim identification, forensic anthropology, computed tomography

The partially decomposed or partly burned body is not only one of the most objectionable, but also one of the most useless objects conceivable. (1)

In contrast to a single fatality, typically involving a relatively intact deceased, the event of a disaster, potentially involving multiple individuals poses different challenges for the forensic anthropologist and forensic pathologist during postmortem examinations. Disasters may involve aircraft and/or vehicle accidents, explosions, earthquakes (tsunami), fires, floods, infectious disease outbreaks, landslides, mudslides and avalanches, tornadoes, cyclones, war, and weapons of mass destruction. Therefore, individuals involved in disasters are typically subjected to extreme forces. Such forces may include heat (burning), impact (G-force, wave), crushing (e.g., structure collapse), bombing and explosion, freefall (impact), and/or environmental influences (temperature; humidity; water—warm, cold, salt, fresh; scavenger activity), all of which potentially leave the human body significantly disrupted. In most disaster cases, questions pertaining to the cause of death are secondary to those of identification. Further, issues of body part reconciliation are vital. It is important to provide closure for families, whose loved ones have been victims of a disaster. When extensive fragmentation of bodies has occurred, reconciling these remains may assist this process by assuring relatives that the remains released to them are those of their relative and include all those remains that could be reasonably recovered and identified.

[1]Centre for Human Identification, Victorian Institute of Forensic Medicine/Department of Forensic Medicine, Monash University, 3006 Vic., Australia.
[2]Victorian Institute of Forensic Medicine/Department of Forensic Medicine, Monash University, 3006 Vic., Australia.
[3]Disaster Victim Identification/Chemical, Biological & Radiological Crime Scene Unit, Macleod, Vic., Australia.

Received 21 May 2007; and in revised form 9 Sept. 2007; accepted 11 Nov. 2007.

The application of radiological techniques as a noninvasive means to investigate the human body has a long history. However, there has been increasing discussion among forensic medical practitioners about the extent to which sophisticated imaging can be used to assist in the analysis of the deceased (2). The detail of such investigations was augmented in the 1970s with the advent of computed tomography (CT), and in the 1980s with the ability to display axial CT images in three dimensions (3,4). Since this time, CT imaging has been used for a number of specific postmortem analyses including identification (5–10), facial approximation (11,12), sex determination (13), and aging (14). It has also been applied to the examination of archaeological (15) and paleopathological human remains (16). In addition, CT imaging has been used to augment the traditional autopsy (17–19) with one focus being on the assessment and interpretation of injuries (20–22). While traditional radiography has been widely used in mass disaster investigations (23), CT technology has been applied to intact charred (24,25) and decomposed single individuals (26). With the exceptions of U.S. military casualties (27) and one case in the U.K. (28), there are no examples of CT imaging being applied to disaster victim identification (DVI) scenarios. The potential to implement such technology in mass disasters to augment the DVI process has however been recognized (19,29,30).

The following case study describes a recent Australian aviation disaster in which the role of the forensic anthropologist and CT technology were paramount in facilitating a quick identification, and subsequently an effective and timely reconciliation of body parts.

Background

In February 2007, a light plane carrying two occupants crashed in a farm paddock in Victoria (Australia). The DVI Unit and the Crime Scene Unit (specialist police teams) responded to the incident under the direction of the Australian Transport Safety Bureau.

An initial evaluation of the scene revealed an estimated 250–300 separate human remains scattered over a distance of around 600 m from the site of impact. The remains consisted of various heavily disrupted unidentifiable tissue types, organs, and both body masses of Individual 1 and Individual 2. It was apparent that collection of the remains required a numbering system that could be utilized during the postmortem examinations to potentially aid in reconciling body parts.

Due to fading light conditions following the initial inspection of the scene, collection of the remains commenced at first light the day after the accident. A police team grided the scene and employed the simple method of an *X* and *Y* axis to record the body parts. Each grid square measured *c*. 25 by 25 m and was labeled with sequential letters and numbers (e.g., B1, B2, C1, C2, etc.) (Fig. 1). Varying numbers of body parts were located within each square. Individual grid squares were line searched, and all remains within that grid were located and marked.

Following established DVI protocols (31), each body part was assigned a separate DVI number based on the grid reference. A decision was made to collect and number identifiable organs, both body masses, and any remains containing teeth or bone separately. The remaining unknown tissue within each grid square was then collected together and marked as one number. A total of 41 numbers were allocated to the collected remains.

Once collected, the human remains were transported to the Victorian Institute of Forensic Medicine (VIFM) for examination. Following VIFM protocol, the remains were CT scanned using a Toshiba Aquilion^{TM} 16 multidetector CT scanner. The VIFM mortuary is the first in Australia to have installed a CT scanner, and one of the few mortuaries in the world to own a 16-slice scanner. Depending on the material contained within each bag (based on analysis of the preliminary scout views), different scan protocols were used including fine slice (0.5–2 mm) soft tissue and high detail (bone) algorithms.

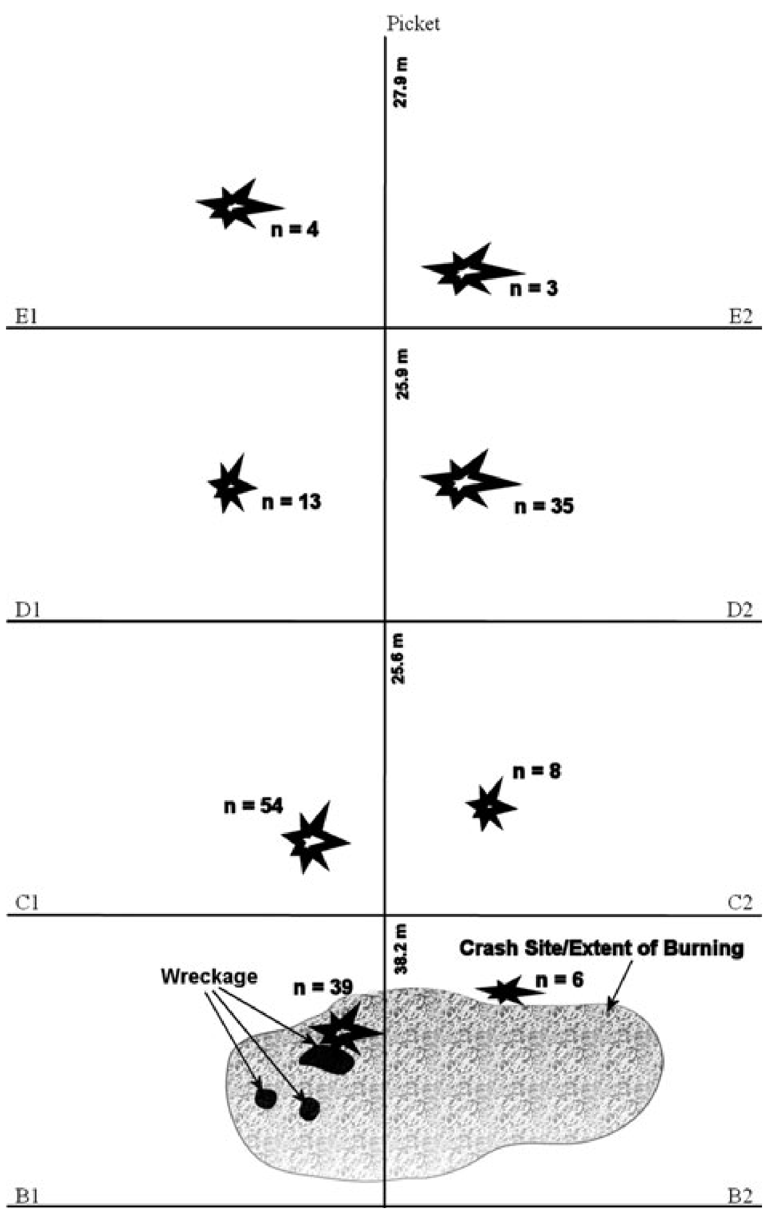

FIG. 1—*Schematic plan of crash site showing the approximate location of the plane wreckage and distribution of numbers (*n*) of partial and complete body parts. Grid references were used in the labeling of body parts.*

Preservation

The bags contained highly disrupted and partially burnt human remains. Although all fragmentary, body parts ranged in size from a single finger to a torso. In a number of fragments, the soft tissue masses were anatomically unrecognizable.

Analysis

The contents of each of the 41 body bags were examined by the forensic pathologist. Simultaneously, and in the same autopsy suite, the forensic anthropologist reviewed three-dimensional (3D) volume-rendered CT images of the specific bag being examined. The images were viewed using AquariusNET™ software. While the physical remains were predominantly unrecognizable (Fig. 2), the CT imagery allowed the forensic anthropologist to quickly and efficiently view, and identify, the side skeletal elements within the 162 body parts regardless of their size and preservation (Fig. 3).

The ability to remove the soft tissue layers digitally and view the skeletal elements almost instantly allowed the forensic pathologist to examine more effectively the physical remains and to develop an inventory of relatively intact body parts (Table 1). Positive identification was achieved by DNA analysis on the two largest body parts. In addition, both deceased individuals had antemortem fingerprint records. This meant that comparisons could be made between the two largest body parts, partial hands and fingers, and the unidentified body parts as a starting point for reconciliation all the other disrupted remains. Experience dealing with highly fragmentary and differentially preserved human remains allowed the forensic anthropologist and pathologist to assign each bag of remains to either Individual 1 or Individual 2 by a process of elimination.

FIG. 2—*Plan view of unrecognizable human remains from the crash site.*

FIG. 3—*Multiplanar reconstruction of remains illustrated in Fig. 2. This posterior view clearly shows the pelvis, sacrum, proximal right femur, lumbar, and thoracic vertebrae.*

The use of the CT scanner in this case meant that the remains did not have to be mechanically cleaned (and therefore disrupted any further) to identify body parts. While the need to clean remains is not detrimental to a case, obviating this phase of the analysis significantly sped up the reconciliation process. In addition, the number of body parts that had to be identified through DNA analysis was reduced. From a total of 41 bags of remains, (two of which contained soft tissue only), only five were sent for DNA analysis.

Results

Following 2 days of examination and analysis, a total of 34/41 (83%) of the bags collected at the scene could be reconciled (Fig. 4): 11 bags with a total of 49 body parts (two of which did not contain skeletal material) were reconciled to Individual 1 and 23 bags with a total of 86 body parts were reconciled to Individual 2. The extensive damage and associated fragmentation to the bodies resulted in a total of seven bags of remains (27 body parts, most of which contained small fragments of rib or crania) which could not be reconciled.

In addition to easily viewing the fragmentary skeletal remains, numerous metallic objects were observed on the CT images. Of particular importance for confirmation of identification were two surgical screws associated with a fragmentary left distal femur (Figs. 5 and 6). This information was reconciled with information from antemortem medical records for Individual 1.

Discussion

Prior to the use of CT scans, imaging of the contents of body bags would have been carried out using either standard radiography (with production of X-ray films) or an image intensifier (with concomitant hazards of radiation exposure). The use of CT images (specifically the 3D reconstructions) in this disaster scenario were of enormous anatomical and diagnostic value providing a timely and efficient means of initially examining the 41 bags of heavily disrupted human remains. There are, however, limiting factors such as commingling which need to be considered when using CT imaging to reconcile body parts. In the case presented in this paper, distinctive, identifiable clothing was located on a major body part. This clothing was consistent with antemortem information obtained for one of the deceased (Individual 2). A piece of this clothing was located with another bag (Bag 3) containing smaller body parts, including a complete right clavicle, cranial fragments, a left mandibular ramus, and fragmentary right pubic bone. Based on the association with the clothing, Bag 3 was initially assumed to have belonged to Individual 2. However, further examination of the CT images illustrated that Individual 2 already had a complete left and a fragmentary right medial clavicle which was part of a significantly larger body part suggesting therefore that Bag 3 belonged to Individual 1. However, Individual 1 already had a right pubic bone. Thus, it

TABLE 1—*Inventory of identified body parts as identified on the CT scans.*

Bag No.	Body Part/s	Comment
1	Partial occipital; complete cervical spine and partial thoracic vertebrae; partial sternum; partial ribs; partial left scapula; complete left clavicle; partial proximal left ulna; fragmentary right scapula; right proximal humerus; right proximal ulna; right fragmentary zygomatic; left mandible with five *in situ* teeth	
2	Right pelvis, right femur, right patella, right proximal tibia and tibia, right humerus and right proximal ulna and radius; right broken clavicle; left partial humerus and proximal radius and ulna; left mandible body with teeth; partial occipital; cervical vertebrae; thoracic vertebrae; partial ribs; partial left and right scapula	
3	Left hand with left distal radius and ulna	Fingerprints
4	Left fragmentary humeral head	
5	1 × right fragmentary rib	
6	4 × left rib fragments	
7	1 × unsided rib fragment; 1 × unsided fragmentary metacarpal, 1 × unsided carpal	
8	2 × cranial fragments; 1 × left rib fragment	Organs
9	Right hand including right distal ulna and radius	Fingerprints
10	No bone	Soft tissue only
11	Right mandibular molar in fragmentary bone and isolated canine	
12	Left proximal ulna; 1 × unsided midshaft	Midshaft = radius?
13	Left 3rd finger	Fingerprints
14	Maxillary midline fragment with left (21, 22) and right (11,12) *in situ* teeth	
15	Right mandibular ramus and body with 2 *in situ* molar; right zygomatic; right maxillary fragment with 7 *in situ* teeth (11,12,13,14,15,16,17)	
16	Right partial frontal bone	Hair
17	Left maxilla with 5 *in situ* teeth (24–28)	Some with restorations
18	Right maxillary fragment with 3 *in situ* teeth (13, 14, 15)	
19	Left maxilla with 5 *in situ* teeth (23, 24, 25, 26, 27)	
20	1 × right 1st finger	Fingerprints
21	Molar tooth	Restoration
22	Left mandibular condyle; cranial fragments including left zygomatic	
23	Isolated mandibular tooth	
24	3 × right carpals (scaphoid, capitate, and trapezoid)	
25	2 × right distal rib fragments	
26	Partial right hand with fingers 2–5	Fingerprints
27	No bone	
28	No bone	Partial heart
29	1 × unsided rib fragment; midshaft of long bone; cranial fragments; 1 × R? trapezoid	
30	5 × cranial fragments	
31	Left thumb	Fingerprints
32	Left distal ulna and radius with carpals (×6)	Associated with a ring
33	Left 5th finger	Fingerprints
34	Fragmentary left proximal tibia and distal femur	Associated with two surgical screws
35	Partial (distal) left thumb	Fingerprint
36	Left foot and ankle (i.e., fragmentary left distal tibia and fibula)	
37	Fragmentary proximal radius (R?); cranial fragments including left frontal fragment; long bone midshaft fragments; rib fragments	
38	Left calcaneus and talus; left distal tibia and fibula	
39	Right pelvis, right proximal femur, lumbar vertebrae; partial sacrum, right patella, left partial pelvis; right foot	
40	Left ischium and partial acetabulum with fragmentary femoral head	
41	Cranial fragments, fragmented ribs; right complete clavicle; left mandibular ramus; fragmentary pubic right bone; left zygomatic	

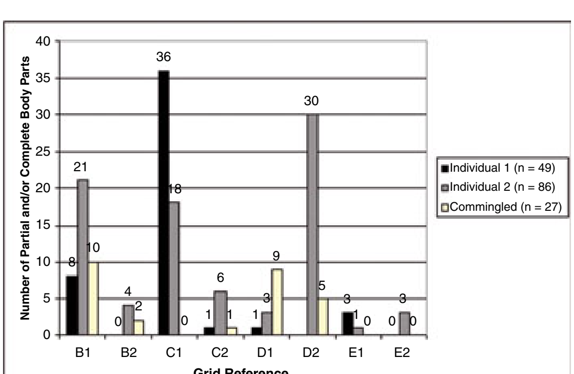

FIG. 4—*The location of partial and/or complete human remains according to the grid used to recover body parts.*

FIG. 5—*Heavily disrupted human remains. Arrows point to surgical screws.*

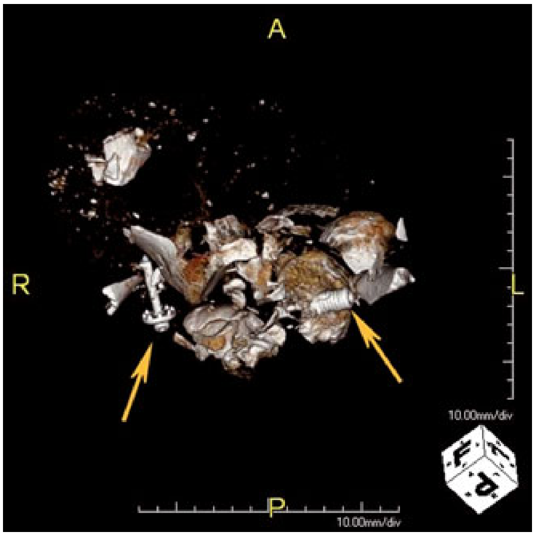

FIG. 6—*3D reconstruction showing the same body parts in Fig. 5. Yellow arrows point to surgical screws.*

became apparent that Bag 3 was in fact an example of commingled remains.

Conclusion

In light of the growing recognition of the reliability of CT scanning as an interpretative and diagnostic tool (32,33), such technology is increasingly being employed. Obviously not all mortuaries will have access to CT scanners and utilizing hospital imaging equipment for highly decomposed and/or disrupted remains poses health and safety risks. However, in settings where such equipment is colocated within a mortuary or available as a mobile unit, there is enormous potential for CT imaging to complement the existing DVI process.

While the case discussed in this paper involved two deceased, the potential for CT imaging to assist in disaster scenarios involving tens or hundreds of deceased should not be underestimated. In contrast to Brue's 1958 statement (see above quote), the partially decomposed or partly burned body should no longer be seen either as objectionable or useless. The implementation of CT imaging to DVI incidents significantly augments the ability to quickly and efficiently identify and reconcile highly disrupted body parts.

Acknowledgments

We would like to thank Melanie Archer and Chris O'Donnell for their comments on drafts of this paper. Discussions with Martin Coyne were also helpful.

References

1. Brues AM. Identification of skeletal remains. J Crim Law Crim Pol Sci 1958;48(5):551–63.
2. Rutty GN. Are invasive autopsies necessary? Forensic Sci Med Path 2005;1(2):71–4.
3. Attardi G, Betrò M, Forte M, Gori R, Guidazzoli A, Imboden S, et al. 3D facial reconstruction and visualization of ancient Egyptian mummies using spiral CT data. 1999. In Proc. Siggraph'99, http://medialab.di.unipi.it/Project/Mummia/SIGGRAPH99/. Accessed August 21, 2006.
4. Spoor F, Jeffery N, Zonneveld F. Imaging cranial growth and evolution. In: O'Higgins P, Cohen M, editors. Development, growth and evolution: implications for the study of hominid skeletal evolution. London: Academic Press, 2002;124–61.
5. Smith DR, Limbird KG, Hoffman JM. Identification of human skeletal remains by comparison of bony details of the cranium using computerized tomographic (CT) scans. J Forensic Sci 2002;47(5):937–9.
6. Haglund W, Fligner CL. Confirmation of human identification using computerised tomography (CT). J Forensic Sci 1993;38(3):708–12.
7. Riepert T, Rittner C, Ulmcke D, Ogbuihi S, Schweden F. Identification of an unknown corpse by means of computed tomography (CT) of the lumbar spine. J Forensic Sci 1995;40(1):126–7.
8. Reichs KJ, Dorion RBJ. The use of computerized axial tomography (CAT) scans in the comparison of frontal sinus configurations. Can Soc Forensic Sci J 1992;25(1):1–16.
9. Reichs KJ. Quantified comparison of frontal sinus patterns by means of computed tomography. Forensic Sci Int 1993;61:141–68.
10. Tatlisumak E, Yilmaz Ovali G, Aslan A, Asirdizer M, Zeyfeoglu Y, Tarhan S. Identification of unknown bodies using CT images of frontal sinus. Forensic Sci Int 2007;166:42–8.
11. Philips VM, Smuts NA. Facial reconstruction: utilization of computerized tomography to measure facial tissue thickness in a mixed racial population. Forensic Sci Int 1996;83(1):51–9.
12. Quatrehomme G, Cotin S, Subsol G, Delingette H, Garidel Y, Grevin G, et al. A fully three-dimensional method for facial reconstruction based on deformable models. J Forensic Sci 1997;42(4):649–52.
13. Uysal S, Gokharman D, Kacar M, Tuncbilek I, Kosa U. Estimation of sex by 3D CT measurements of the foramen magnum. J Forensic Sci 2005;50(6):1310–4.
14. Pasquier E, De Saint Martin Pernot L, Burdin V, Mounayer C, Le Rest C, Colin D, et al. Determination of age at death: assessment of an algorithm of age prediction using numerical three-dimensional CT data from pubic bones. Am J Phys Anthropol 1999;108:261–68.
15. Baldock C, Hughes SW, Whittaker DK, Taylor J, Davis R, Spencer AJ, et al. 3-D reconstruction of an ancient Egyptian mummy using x-ray computer tomography. J R Soc Med 1994;87(12):806–08.
16. Rühli FJ, Lanz C, Ulrich-Bochsler S, Alt KW. State-of-the-art imaging in palaeopathology: the value of multislice computed tomography in visualizing doubtful cranial lesions. Int J Osteoarcheol 2002;12(5): 372–9.
17. Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, et al. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)—a feasibility study. J Forensic Sci 2003;48(2):386–403.
18. Thali M, Braun M, Buck U, Aghayev E, Jackowski C, Vock P, et al. Virtopsy—scientific documentation, reconstruction and animation in forensic: individual and real 3D data based geo-metric approach including optical body/object surface and radiological CT/MRI scanning. J Forensic Sci 2005;50(2):428–42.
19. Dirnhofer R, Jackowski C, Vock P, Potter K, Thali MJ. VIRTOPSY: minimal invasive, image guided virtual autopsy. Radiographics 2006;26:1305–33.
20. West OC, Miirvis SE, Shanmuganathan K. Transsphenoid basilar skull fracture: CT patterns. Radiology 1993;188(2):329–38.
21. Myers JC, Okoye MI, Kiple D, Kimmerle EH, Reinhard KJ. Three-dimensional (3-D) imaging in post-mortem examinations: elucidation and identification of cranial and facial fractures in victims of homicide utilizing 3-D computerized imaging reconstruction techniques. Int J Legal Med 1999;113(1):33–7.
22. Thali MJR, Taubenreuther U, Karolczak M, Braun M, Brueschweiler W, Kalender WA, et al. Forensic microradiology: micro-computed tomography (micro-CT) and analysis of patterned injuries inside of bone. J Forensic Sci 2003;48(6):1336–42.
23. Walsh M, Reeves P, Scott S. When disaster strikes; the role of the forensic radiographer. Radiography 2004;10:33–43.
24. Thali MJ, Yen K, Plattner T, Schweitzer W, Vock P, Ozdoba C, et al. Charred body: virtual autopsy with multi-slice computed tomography and magnetic resonance imaging. J Forensic Sci 2002;47(6):1326–31.
25. Debouit F, Telmon N, Costagliola R, Otal P, Joffre F, Rouge D. Virtual anthropology and forensic identification: report of one case. Forensic Sci Int 2007;173(2-3):182–7.
26. Thali MJ, Yen K, Schweitzer W, Vock P, Ozdoba C, Dirnhofer R. Into the decomposed body—forensic digital autopsy using multi-slice computed tomography. Forensic Sci Int 2003;3:109–14.
27. Hall S. Virtual autopsy on U.S. military casualties. http://www.stuarthall.com/blog/_archives/2006/8/3/2192611.html. Accessed August 23, 2006.
28. Rutty G, Jeffery AJ, Bouhaidar R, Robinson C. The first reported use of multi-slice computed tomography for mass fatality radiological

investigation. Proceedings of the XXth Congress of the International Academy of Legal Medicine, 2006 Aug 23–26, Budapest. Budapest: Corvinus University, 2006.
29. Sidler M, Jackowski C, Dirnhofer R, Vock P, Thali M. Use of multislice computed tomography in disaster victim identification—advantages and limitations. Forensic Sci Int 2007;169(2-3):118–28.
30. Thali MJ, Yen K, Plattner T, Schweitzer W, Vock P, Ozdoba C, et al. Charred body: virtual autopsy with multi-slice computed tomography and magnetic resonance imaging. Forensic Sci Int 2002;47(6):1330.
31. Interpol disaster victim identification guide. http://www.interpol.int/Public/DisasterVictim/Guide/Default.asp. Accessed August 23, 2006.
32. Telmon N, Gaston A, Chemla P, Blanc A, Joffre F, Roug D. Application of the Suchey-Brooks method to three dimensional imaging of the pubic symphysis. J Forensic Sci 2005;50(3):507–12.
33. Yen K, Lövblad K-O, Scheurer E, Ozdoba C, Thali MJ, Aghayev E, et al. Post-mortem forensic neuroimaging: correlation of MSCT and MRI findings with autopsy results. Forensic Sci Int 2007;173(1):21–35.

Additional information and reprint requests:
Soren Blau, Ph.D.
Centre for Human Identification
Victorian Institute of Forensic Medicine
Department of Forensic Medicine
Monash University
57-83 Kavanagh Street
Southbank, 3006 Vic.
Australia
E-mail address: sorenb@vifm.org