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Contribution of postmortem multidetector CT scanning to identification of the deceased in a mass disaster: Experience gained from the 2009 Victorian bushfires☆

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ABSTRACT

CT scanning of the deceased is an established technique performed on all individuals admitted to VIFM over the last 5 years. It is used primarily to assist pathologists in determining cause and manner of death but is also invaluable for identification of unknown deceased individuals where traditional methods are not possible. Based on this experience, CT scanning was incorporated into phase 2 of the Institute's DVI process for the 2009 Victorian bushfires. All deceased individuals and fragmented remains admitted to the mortuary were CT scanned in their body bags using established protocols. Images were reviewed by 2 teams of 2 radiologists experienced in forensic imaging and the findings transcribed onto a data sheet constructed specifically for the DVI exercise. The contents of 255 body bags were examined in the 28 days following the fires. 164 missing persons were included in the DVI process with 163 deceased individuals eventually identified. CT contributed to this identification in 161 persons. In 2 cases, radiologists were unable to recognize commingled remains. CT was utilized in the initial triage of each bag's contents. If radiological evaluation determined that bodies were incomplete then this information was provided to search teams who revisited the scenes of death. CT was helpful in differentiation of human from non-human remains in 8 bags, recognition of human/animal commingling in 10 bags and human commingling in 6 bags. In 61% of cases gender was able to be determined on CT using a novel technique of genitalia detection and in all but 2 cases this was correct. Age range was able to be determined on CT in 94% with an accuracy of 76%. Specific identification features detected on CT included the presence of disease (14 disease entities in 13 cases), medical devices (26 devices in 19 cases) and 274 everyday metallic items associated with the remains of 135 individuals. CT scanning provided useful information prior to autopsy by flagging likely findings including the presence of non-human remains, at the time of autopsy by assisting in the localization of identifying features in heavily disfigured bodies, and after autopsy by retrospective review of images for clarification of issues that arose at the time of pathologist case review. In view of the success of CT scanning in this mass disaster, DVI administrators should explore the incorporation of CT services into their disaster plans.

1. Introduction

Mass disasters pose considerable difficulty for forensic investigators not least being the large number of deceased persons involved. The dramatic forces of heat, explosion, flood or building collapse that are usually associated with such disasters result in gross disruption to, or at least disfigurement of the involved individuals. The major focus of forensic investigation in such disasters is human identification. In order to deal with the difficulties of such a task, international protocols have been established to facilitate speedy and accurate identification of the deceased for both judicial and family purposes.

The International Criminal Police Organization (Interpol) Disaster Victim identification (DVI) guide or plan [1] is a widely accepted five phase process and although not specified, may be implemented if there are two or more fatalities in a particular incident. Phase 2 of that plan involves extensive examination of the remains using available scientific techniques including fingerprint, radiological, anthropological, odontological and genetic analysis.

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These procedures are supplemented by autopsy examination and where possible photographic recording. All information from this postmortem (PM) phase is entered onto pink Interpol PM forms. Traditionally plain radiographic examination of remains has been used in DVI phase 2 to assist in victim identification [2,3]. Increasingly forensic centers are utilizing multidetector computed tomography (MDCT) and magnetic resonance imaging (MRI) scanning of the deceased to assist pathologists in determining cause and manner of death [4,5]. CT scanning has also been reported to be of value in the identification of deceased persons in cases of charred bodies discovered following house fires [6,7] and on a larger scale, in a multi-motor vehicle accident, using a mobile CT scanner [8]. Other authors have suggested that CT scanning would be useful in the mass disaster scenario both for the evaluation of dentition [9,10] and for assistance in the completion of the Interpol PM forms incorporating items such as age, gender, height, medical devices and natural disease [11].

Subsequent to the 2002 Bali bombing in which 202 persons were killed including 88 Australians, the Victorian Institute of Forensic Medicine (VIFM) in Melbourne applied for a grant from the Victorian State Government to purchase and install a MDCT scanner into the mortuary. The primary aim of this installation was to assist in the identification of victims if such a disaster was to occur in Victoria. In April 2005, a CT scanner was installed into the mortuary and since that time all biological material submitted to the Institute has been scanned and images stored on a picture archive and communication system (PACS) server. To date well over 15,000 deceased persons have been studied with the CT images used predominately for assistance in determining cause and manner of death. CT has also been proven to be highly successful in the identification and reconciliation of grossly fragmented and scattered remains following a light plane crash in Victoria [12]. Based on that positive experience, VIFM has included CT scanning into the phase 2 component of its DVI process.

Victoria is a state of Australia, with a population of ~5.5 million [13]. February 7, 2009 (known locally as "Black Saturday") was a day of unprecedented extreme weather conditions including strong, northerly winds and a maximum temperature of 46.4 °C. Devastating bushfires engulfed wooded regions on the outskirts of the capital city Melbourne, resulting in the destruction of 2000 houses, the loss of whole towns and multiple fatalities. This paper describes the unique contribution of postmortem CT scanning to the complex process of victim identification at VIFM.

2. Materials and methods

On February 7, the DVI process of VIFM was activated. As part of that protocol, all deceased individuals or their remains were CT scanned as soon as practicable within their unopened body bags at the mortuary of VIFM. No attempt was made to alter the deceased's posture, manipulate contents into optimal position or remove any foreign material prior to scanning. CT images were initially assessed by radiologists to determine if there were any significant technical issues precluding analysis such as poor CT procedure. If such problems were encountered, bags were rescanned. Despite the common "pugilistic" attitude of many deceased persons exposed to extreme heat [14], only 2 body bags could not be scanned completely due to the contorted upper limbs restricting entry to the CT gantry. To facilitate scanning of one individual in such a position, anatomical dissection of the upper limbs was performed by a pathologist prior to repeat CT scanning thus allowing repositioning of the protruding limbs so that the study could be completed. All victims showed varying degrees of heat effect from minor skin loss to extreme burning with gross destruction of soft tissue and bone. In some cases only fragments of heavily burnt or "calcined" bone was available for assessment. All presumed human remains were scanned, no matter how small or admixed with building materials or debris.

2.1. Scanning protocol

Images were acquired using a 16 channel MDCT scanner (Aquilion16®, Toshiba Medical Systems, Minato-ku, Tokyo, Japan) installed inside the mortuary at VIFM. Scan data were stored on the Institute's PACS server (IMPAX®, Agfa HealthCare NV, Mortsel, Belgium). MDCT scanning protocols were similar to those used for routine cases admitted to the Institute. Scans were performed by mortuary technicians trained in CT technique and accredited by the relevant state authority (Radiation Safety Section of the Victorian Department of Health) to perform radiographic procedures. In most cases 2 scan runs were undertaken; the first using 0.5 mm collimation reconstructed into 2/1.6 mm overlapping axial slices from the sternal notch to the feet and a second from the top of the head to the sternal notch in 1/0.8 mm overlapping axial slices using both soft tissue and bone convolution kernels. When isolated remains or individual body parts were detected by technologists on the preliminary CT "scout" view of the bag contents, only 1/0.8 mm overlapping axial slices were reconstructed.

2.2. Workstations

Images were reviewed by 2 teams of 2 radiologists experienced in forensic imaging employing Vitrea®2 (Vital Images, Inc. Minnetonka, Minnesota, USA) and AquariusNet (TeraRecon Inc., San Mateo, CA, USA) thin client workstations. Multiplanar reformatted (MPR) images as well as three-dimensional (3D) surface shaded display (SSD) volume rendered reformats for bones and a 3D maximum intensity projection (MIP) algorithm with color coding of high density picture elements (pixels) were assessed. This later sequence (known as "blue metal") proved very useful for the assessment of metallic objects within the body bags. All findings detected on 3D images were confirmed on the MPR slices. To maximize the quality of image interrogation, CT scans were read by 2 radiologists sitting in tandem. Findings were transcribed onto a data sheet constructed specifically for the DVI exercise (Fig. 1). This sheet was appended to the routine phase 2 documentation and made available to all interested parties at the time of autopsy as well as police investigators. Approximately 30 min of analysis time was required to complete each data sheet.

2.3. Image interpretation

Initial radiological overview of the bags contents determined the stated condition of bodies. Each was assessed as being intact if all bones were present with or without overlying soft tissue (Fig. 2), severely burnt if the body was predominately intact but depleted of at least one bone with or without overlying soft tissue (Fig. 3), incomplete remains if no normal body compartment was present including bones and/or soft tissue (Fig. 4), or an individual body part. This is an adaptation of the Crow–Glassman scale used by forensic anthropologists as a means of visually describing burnt remains [15]. Subsequently images where more rigorously analyzed for identification features and the presence of commingling or non-human tissue.

2.3.1. Identification criteria

Interpretation of images for identification purposes was based primarily on radiological criteria rather than odontological or anthropological characteristics. Identification features on CT were considered to be either general, i.e. age and gender of the deceased person or specific for that individual. Radiologists attempted to detect and identify the 4 specific category items considered to be of value for investigators, i.e. teeth, medical devices (Fig. 5), disease processes and objects of everyday living that might be uniquely associated with the deceased (Fig. 6). The detection of teeth and/or dental work was recorded to inform dentists of their presence but no attempt was made to perform a complete dental analysis and interpretation of bones was limited to basic anatomical analysis and detection of bony pathology rather than full anthropological interpretation. Determination of age and gender was based on visualization of specific anatomical structures including epiphyses and disease processes rather than anthropological measurements although CT images were subsequently reviewed by anthropologists or odontologists in order to confirm specific autopsy findings.

2.3.2. Species and gender determination

Determination of species was based on CT assessment of bones, looking for human or animal anatomical characteristics (Fig. 7). A museum of dried animal skulls (cat, dog and fox) was made available to the radiologists and subsequently CT scanned. Three-dimensional reconstructed images of the CT data were compared with suspected animal remains on the workstations. If animal bones alone were identified (Fig. 8), findings were promptly referred to the mortuary director and the bag contents expeditiously viewed by an experienced anthropologist. On physical confirmation of the CT findings, those bags were immediately removed from the DVI process. If commingled animal and human remains were detected on CT scanning then the entire bag contents were processed using routine phase 2 procedures including autopsy.

Gender was itemized as male, female or "not able to be determined". The detection of internal and external genitalia on CT (Fig. 9) as well as less specific findings of brassiere underwire (Fig. 10), jewellery and watches, were used for determination of gender. Despite severe destruction of the body, genitalia could in many cases still be identified notably the crura of the penis and prostate, as well as breasts, vagina, labia, cervix and uterus. Gender was assigned as "definite" if internal and/or external genitalia were clearly seen, "probable" if genitalia were