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“Blind spots” in forensic autopsy: Improved detection of retrobulbar hemorrhage and orbital lesions by postmortem computed tomography (PMCT)

P.M. Flach [a,b,c,*], T.C. Egli [a,c], S.A. Bolliger [a], N. Berger [a,b], G. Ampanozi [a], M.J. Thali [a], W. Schweitzer [a]

[a] Institute of Forensic Medicine, University of Zurich, Winterthurerstrasse 190/52, 8057 Zurich, Switzerland
[b] Department of Diagnostic and Interventional Radiology, University Hospital of Zurich, Raemistrasse 100, 8091 Zurich, Switzerland
[c] Institute of Forensic Medicine, University of Bern, Buehlstrasse 20, 3012 Bern, Switzerland

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ABSTRACT

Objectives: The purpose of this study was to correlate the occurrence of retrobulbar hemorrhage (RBH) with mechanism of injury, external signs and autopsy findings to postmortem computed tomography (PMCT).

Methods: Six-teen subjects presented with RBH and underwent PMCT, external inspection and conventional autopsy. External inspection was evaluated for findings of the bulbs, black eye, raccoon eyes and Battle’s sign. Fractures of the viscerocranium, orbital lesions and RBH were evaluated by PMCT. Autopsy and PMCT was evaluated for orbital roof and basilar skull fracture.

Results: The leading manner of death was accident with central regulatory failure in cases of RBH (31.25%). Imaging showed a high sensitivity in detection of orbital roof and basilar skull fractures (100%), but was less specific compared to autopsy. Volume of RBH (0.1–2.4 ml) correlated positively to the presence of Battle’s sign ($p < 0.06$) and the postmortem interval. Ecchymosis on external inspection correlated with RBH. There was a statistical significant correlation between bulbar lesion and RBH. Orbital roof fracture count weakly correlated with the total PMCT derived RBH volume. Maxillary hemosinus correlated to maxillary fractures, but not to RBH.

Conclusions: RBH are a specific finding in forensically relevant head trauma. PMCT is an excellent tool in detecting and quantifying morphological trauma findings particularly in the viscerocranium, one of the most relevant “blind spots” of classic autopsy. PMCT was superior in detecting osseous lesions, scrutinizing autopsy as the gold standard.

1. Introduction

In clinical practice polytraumatized victims with trauma to the head and the maxillofacial region are routinely examined by unenhanced computed tomography (CT) as the most appropriate method according to the American College of Radiology [1] and as reported in the literature [2–7]. In clinical radiology the main diagnostic indication for an orbital CT are suspected foreign bodies, fractures and visual loss in trauma, orbital compartment syndrome due to retrobulbar hemorrhages, bulb lesions [8–13]. In patients, extra- and/or intraconal retrobulbar hemorrhage (RBH) is uncommon, even if it is co-existing with orbital fracture (0.45–0.6%) [14]. RBH causes a mass effect in a confined space – the orbit – and may lead to an orbital compartment syndrome, resulting in visual loss due to decreased perfusion from the compromised vascular flow. Literature suggests that irreversible visual loss may occur after approximately 120 min in facial trauma patients [15–17].

Assessing traumatic orbital injuries may also be performed by magnetic resonance imaging (MR), but may not be readily available or even be contradicted if a ferromagnetic foreign body is present – however, in some indications MR replaces increasingly CT due to better soft tissue differentiation and no dispersion of radiation [2]. MR will reveal more detail about soft tissue changes or bulb pathologies with the drawback of little information on the osseous findings. Therefore, MR could be considered as a supplementary examination to CT in trauma patients, if indicated [1,2].

* Corresponding author at: Institute of Forensic Medicine, Virtopsy, University of Zurich, Winterthurerstrasse 190/52, CH-8057 Zurich, Switzerland; Department of Diagnostic Radiology, University Hospital, University of Zurich, Raemistrasse 100, CH-8091 Zurich, Switzerland. Tel.: +41 44 635 56 11/255 18 18; fax: +41 44 635 68 11.

E-mail addresses: Patricia.flach@irm.uzh.ch, Patricia.flach@usz.ch (P.M. Flach).

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Ultrasonography (US) and radiographic examinations may also be considered but are rarely performed and is contradicted in a case of a ruptured globe [2,13].

Since decades conventional X-ray examinations made their way into routine work of the forensic pathologist and supplemented classic autopsy in order to detect foreign bodies (e.g. projectiles) or fractures [18–22]. During the last decade with the course of ongoing development there was a paradigm shift that pioneered forensic imaging [23–26]. Postmortem CT (PMCT) increasingly replaced conventional, 2-dimensional plain radiography as a 3-dimensional cross-sectional modality [27–31]. PMCT is more sensitive and has the ability to show structures without superimposition and allows for precise anatomical location. In particular, recent literature already showed the great potential of postmortem imaging of bony structures as well as the depiction of air-containing structures that may even exceed the accuracy of classic autopsy examination [32–39]. Thus, the usage of PMCT is widely accepted.

The cross-sectional approach of PMCT offers the possibility of reconstructions in any plane, which come handy especially for orbital diagnoses. Volume rendered images can also be taken to court and aid in understanding for non-medical persons and display findings in a non-graphic way [40]. The acquired PMCT data can also give additional information on the impact of a violent act and help to reconstruct the inflicted injury [41–45].

A variety of blunt or sharp traumata may cause retrobulbar hematomas that can easily be overlooked during autopsy, if no superficial correlation on external inspection, like a black eye or un-physiological movement of adjacent bony structures, exists. Additional signs may be raccoon eyes (panda eyes), which is a periorbital ecchymosis and may be a diagnostic clue for skull fracture [46]. The so-called Battle's sign may also accompany the raccoon eyes. The Battle's sign is determined as an ecchymosis behind the ear due to rupture of the posterior auricular artery and this may be the only sign of a basilar skull fracture [47]. This type of fracture is rare in surviving victims (4%) of a severe head injury, but in postmortem examination the trauma to the head is frequently so rigorous that basal skull fractures occur more often [48]. Postmortem these findings may not occur as the retroauricular ecchymosis needs time to develop and often the agonal interval is too short to display those signs.

Autopsy is still considered the gold standard for postmortem investigation. In clinical practice CT is the gold standard to rule out trauma-related orbital pathology. In forensic medicine the usage of PMCT for the detection of retrobulbar hemorrhage (RBH) has not been evaluated yet, even though disclosure of such pathologies is not easily feasible by classical autopsy techniques without invasive dissection of the deceased's face or supplementary opening of the orbital roof once the skull has been opened [46]. Therefore, crucial information on the course of the inflicted trauma may be overlooked, if not suspected, and forensic information may be lost due to ethical reluctance to invasive damage the deceased's face and simply not being part of a standard autopsy. Currently, there are no publications in literature with focus on RBH and forensic findings. The purpose of this study was to correlate the occurrence of retrobulbar hemorrhage (RBH) with mechanism of injury, external signs and autopsy findings to PMCT.

2. Materials and methods

2.1. Study population

In the Institute of Forensic Medicine, University of Bern, Switzerland, postmortem CT scanning (PMCT) was introduced in 2003. A retrospective analysis from 2003 to 2010 of the institutional DICOM (digital imaging and communications in medicine) database and autopsy records was performed in order to identify cases with PMCT documented RBH. Only cases with blunt and sharp trauma to the head and therefore potential RBH were included. Accordingly, cases with natural causes of death, decomposition and subjects being under the age of 18 years were excluded. There were a total of 31 cases that had undergone both PMCT and subsequent classical autopsy and met the selected criteria. RBH was identified on PMCT in 16 of these 31 cases. Institutional board approval was obtained.

The study population with RBH (16 subjects), detected on PMCT, consisted of 12 males and 4 females with an age ranging from 18 to 73 years (average: 38.1 years, median: 34.5 years). The mean time interval between the time of death and imaging was 26.8 h (ranging from 1.2 to 68.5 h). The mean time interval between the time of death and autopsy was 40.2 h (range: 2.5–85 h). The manner of death was accident ($n = 8$), suicide ($n = 6$) and homicide ($n = 2$). The cause of death was determined as central regulatory failure ($n = 7$), exsanguination ($n = 3$), combined central regulatory failure with exsanguination ($n = 2$), cardiac arrest ($n = 2$) and combined cardiac arrest and exsanguination ($n = 2$).

The mechanisms of injury were firearm injury to the head, blunt head trauma, exsanguination, and fall from standing position or from great height.

2.2. CT imaging

Postmortem imaging was performed on a 6-slice CT scanner (Somatom Emotion 6, Siemens Medical Solutions, Erlangen, Germany) in the cases evaluated from 2005 to 2010 ($n = 8$) and on a 4-slice CT-scanner (Light Speed QX/i unit, General Electric Medical Systems, Milwaukee, WI, USA) in cases, evaluated from 2003 to 2005 ($n = 8$). All examinations at least included an unenhanced PMCT scan from head to pelvis in supine position. Raw data acquisition of the head was performed with the following settings: collimation 6×1.25 mm (6-slice Siemens CT) or 4×1.25 mm (4-slice GE CT). Image reconstruction was calculated using the cerebrum window/soft kernel and bone window/hard reconstruction kernel with slice thicknesses of 5 mm and 1.25 mm, using an increment of half the slice thickness. Image review and reconstructions were primarily carried out on a Leonardo workstation (syngo®, 2008C, MultiModality Workplace, Siemens Medical Solutions, Germany) with standard supplementary coronal and sagittal reconstructions. A PACS (picture archiving and communication system) workstation (Sectra AB, Linköping, Sweden) was used for individual read-out. A board-certified and forensic experienced radiologist performed the image interpretation. Each dataset underwent a complete evaluation similar to clinical radiology reports.

2.3. External inspection

External inspection of the body was performed by a forensic pathologist with written and photographic documentation and additional drawings on body diagrams. The information about the external findings was accessed by the reading radiologist.

2.4. Autopsy

Conventional autopsy with standard examination of all three body cavities (skull, thorax and abdomen) and the organs, along with sampling for histology and toxicology, was performed by a board-certified forensic pathologist and a resident.

In order to cover all potential evidence in each case, the forensic pathologist was informed about the PMCT findings before performing the autopsy. Patently, this excluded double blinding of the participants of the retrospective study. Autopsy as the established