CASE REPORT

Differentiation of ante-mortem and post-mortem fractures with MRI: a case report

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ABSTRACT. We describe a case of a fatal speed flying accident in which the victim was electrocuted, burned and fell from a great height. Post-mortem imaging revealed acute appearing fractures on CT, without bone marrow oedema on MRI. Based on the known clinical imaging findings of bone marrow oedema in acute fractures, we concluded that the speed flyer died from electrocution rather than the fall and that the fractures occurred post-mortem. Radiological imaging augmented the reconstruction of the peri-mortem events. Further research is needed to assess whether bone marrow oedema in acute fractures is a reliable vital sign.

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“[Holmes is] beating the subjects in the dissecting-rooms with a stick...to verify how far bruises may be produced after death” [1].

The differentiation between ante-mortem and post-mortem injuries was not only of interest to Arthur Conan Doyle’s fictional detective Sherlock Holmes, but is of critical value in real forensic investigations. The distinction is key to the reconstruction of the sequence of events and determining the manner and cause of death. Several autopsy findings, collectively known as vital reactions, are useful for this distinction. Examples include pulmonary fat embolism and soot aspiration. Pulmonary fat embolism requires active blood circulation and soot aspiration requires active respiration, neither of which occurs after death. Over the last decade, cross-sectional imaging techniques such as CT and MRI have been introduced in the practice of forensic medicine and the field of forensic radiology has evolved significantly [2–6]. The main advantages of CT and MRI over traditional autopsy are the permanent and objective documentation of forensic findings and the non-invasive approach. Moreover, advanced forensic imaging also provides additional means to assess vital reactions [7, 8]. Here we describe a complex accidental death in which post-mortem CT (PMCT) and post-mortem MR (PMMR) aided reconstruction of the sequence of peri-mortem events and determined the cause of death.

Case circumstances

An experienced 21-year-old male speed flyer (speed flying is a hybrid extreme sport combining paragliding

with downhill skiing) collided with a high-voltage line. Witnesses reported a bright flash on contact with the wire. The victim was immediately set aflame and fell to the ground on fire. Extensive cardio-pulmonary resuscitation was not successful. The corpse was delivered to the Centre of Forensic Imaging at the University of Bern for external examination and whole body PMCT and PMMR. External inspection revealed non-lethal second- and third-degree burns of the skin and soft-tissue lacerations to the face. The case history and external examination could not specify whether death occurred from electrocution or from the fall. The time interval between death and post-mortem imaging was 4 h for PMCT and 6 h for PMMR. Imaging was performed using a helical 6-slice CT (Somatom 6, Siemens Medical Solutions, Forchheim, Germany) and a 1.5 Tesla MR unit, (Magnetom Symphony, Siemens AG, Erlangen, Germany). PMCT and PMMR revealed the following relevant findings: Grade I anterolisthesis of the fifth thoracic vertebral body, fractures of the left and right first ribs and the right scapula, a Type III dens fracture, mild compression fractures of the sixth and seventh thoracic vertebral bodies, a compression fracture of the first lumbar vertebral body with dislocated superior end plate bone fragment and a fracture of the right iliac bone. In addition, PMMR revealed diffuse oedema involving the major muscle groups surrounding the axial skeleton.

Discussion

From a radiological point of view, the most interesting findings related to the peri-mortem sequence were noted in the vertebral column. PMCT of the spine displayed sharp fracture margins without sclerosis, which is consistent with acute fractures (Figure 1) and with the observed fall from a great height. In contrast, the spine fractures demonstrated no signal change in the marrow

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Figure 1. Multiplanar reconstruction CT images of the vertebral fractures. (a) Type III dens fracture; (b) compression fracture of the sixth and seventh thoracic vertebra; (c) compression fracture of the first lumbar vertebra with a ventrally displaced bone fragment.

on the short tau inversion recovery (STIR) or T_1 weighted (T_1W) sequences in the PMMR. Based on the PMMR images only, their appearance was very similar to chronic or healed fractures (Figure 2). High bone marrow signal intensity on STIR sequences, with corresponding low bone marrow signal change on T_1W images, are accepted and commonly used signs of acute bone injury in clinical MRI [9, 10]. These alterations of bone marrow signal are caused by oedema, which is the result of active haemorrhage into the trabecular spaces from injured capillaries and vessels [11]. However, these radiological findings have not only been described in living patients—Buck et al [12] observed both the high-signal intensity on STIR sequences and the low-signal in T_1W images in PMMR in five cases of known ante-mortem trauma. This observation is important from a physiological point of view and leads to the deduction that when blunt trauma to a living person is severe enough to fracture a bone, blood circulation will promote active haemorrhage into the bone marrow. On MRI, these bone marrow haemorrhages appear as high-signal intensity on STIR and low-signal on T_1W images. Consequently, if these bone marrow signal changes are

absent after blunt trauma in an acutely fractured bone, then there has been no active haemorrhage. Since active haemorrhage is promoted by blood circulation, it may be concluded, that the vertebral fractures noted in the speed flyer must have occurred at a time when there was no blood circulation, *i.e.* after death. It is, therefore, safe to assume that the victim did not die from the fall, but rather from electrocution when he made contact with the high-voltage line, some seconds before the fall that induced the vertebral fractures.

Conclusions

The distinction between ante-mortem and post-mortem injuries is elementary to the practice of forensic medicine for the reconstruction of a sequence of events, as portrayed by Doyle when writing about Holmes' experiments more than 100 years ago. Several imaging-based vital signs have been proposed in the literature and the findings in this case suggest that objective, non-invasive differentiation between ante-mortem and post-mortem bone injury, relying on the presence or absence

Figure 2. Comparison of CT and MRI findings of the vertebral fractures. (a) Type III fracture of the dens; (b) fractures of the sixth and seventh thoracic vertebra; (c) fracture of the first lumbar vertebra. There is no signal change in the bone marrow in any of the fractures on MRI. Discrete prevertebral oedema can be seen in (a) and (c).

of bone marrow oedema on PMMR, may also represent a sign of vitality. However, further studies are needed to evaluate this observation.

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