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ETHICS AND FORENSIC RADIOLOGY

# Role of virtopsy in the post-mortem diagnosis of drowning

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**Abstract**

*Purpose* Due to admitted limits of autopsy-based studies in the diagnosis of drowning, virtopsy is considered the new imaging horizon in these post-mortem studies. The aim of our study was to evaluate the role of virtopsy performed through computed tomography (CT) in the forensic diagnosis of drowning.

*Materials and methods* We retrospectively examined the CT data of four cadavers recovered from sea water and suspected to have died by drowning. Each patient underwent a full-body post-mortem CT scan, and then a traditional autopsy.

*Results* All the cadavers showed fluid in the airways and patchy ground-glass opacities in the lung. Only one patient had no fluid in the digestive tract; this patient had a left parietal bone fracture with a large gap and other multiple bone fractures (nose, clavicle, first rib and patella). One of the three patients who had fluid in the digestive tract had no fluid in the paranasal sinuses. This latter patient showed cerebral oedema with subarachnoid and intraventricular haemorrhage, multiple bone fractures (orbital floor, ribs, sacrum and acetabular edge) and air in the heart, in the aorta and in bowel loops.

*Conclusion* To date, there are no autopsy findings pathognomonic of drowning. This study proves that virtopsy is a useful tool in the diagnosis of drowning in that it allows us to understand if the victim was alive or dead when he entered the water and if the cause of death was drowning.

**Keywords** Autopsy · Virtopsy · Drowning, Computed tomography · Forensic medicine · Post-mortem changes

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## Introduction

Drowning is the third leading cause of unintentional injury death worldwide, accounting for 7 % of all injury related deaths [1]. The autopsy diagnosis of drowning is one of the major problems in forensic medicine, especially when there is a delay in recovering the corpse. The forensic diagnosis of drowning is based on macroscopic and microscopic findings but the pathological proof is often difficult or even impossible to obtain [2, 3]. Furthermore, the macroscopic and microscopic findings in the fresh drowned corpse are non-specific and will disappear with putrefaction [4].

At present, in the autopsy diagnosis of drowning, the demonstration of diatoms in the submerging fluid and in the body of the victim is the gold standard [2]; however, there are no reliable tests permitting an unequivocal diagnosis of drowning. The main limit in the diagnosis of drowning is that even if a body is recovered from water, it may not have drowned and the proof that death was due to drowning may constitute one of the most difficult problems in forensic medicine. In order to overcome the limits of the conventional autopsy in the diagnosis of drowning, post-mortem radiological imaging techniques are taking a prominent role. Computed tomography (CT) virtual autopsy (virtopsy)

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represents an effective imaging modality in the diagnosis of drowning, even if drowning can not be diagnosed solely through CT [5–10]. In drowning victims, inhaled and aspirated fluid enters the paranasal sinuses as it passes through the nasal cavity; hence, as proved by recent reports, the CT finding of fluid accumulation in the maxillary and sphenoidal sinuses is supportive of the diagnosis of drowning [10–12].

The aim of our study was to verify the role of multidetector CT in the forensic diagnosis of drowning and as a tool to differentiate a death by drowning from a non-drowning death.

## Materials and methods

The CT data of four cadavers (two male, two female; mean age, 34 years) recovered from water and suspected to have died by drowning were retrospectively examined.

Two of the cadavers were recovered after the air crash of a Tuninter ATR 72 which ditched off the coast of Palermo on the 6th of August 2005. The other two bodies were found in 2012 close to Palermo in an area of the sea below a cliff-top.

Each patient underwent a full-body post-mortem CT scan without contrast medium administration. The two cadavers recovered in 2005 (a 39-year-old man and a 52-year-old woman) were studied with a 40-channel multidetector CT scanner (Brilliance 40, Philips Medical Systems, Cleveland, OH, USA) using the following parameters: slice thickness 3 mm, increase in layer 1.5 mm, 120 kV, 280 mAs, filter B. The two cadavers found in 2012 (a 25-year-old man and a 21-year-old woman) were studied with a 128-channel multidetector CT scanner (Somatom Definition AS + Siemens 128, Siemens Medical Solutions, Erlangen, Germany) using the following parameters: slice thickness 0.6 mm, increase in layer 0.3 mm, 120 kV, 225 mAs, filter B-20.

Acquired images were transferred to a dedicated post-processing workstation for the visualisation with volume rendering technique as 3D and multiplanar reconstruction images.

All CT scans were evaluated by the same radiologist and the following findings were recorded:

1. presence of fluid in the paranasal sinuses;
2. presence of fluid in the mouth and in the upper airways;
3. presence, extent and distribution of ground-glass opacities in the lung;
4. presence and extent of pleural effusion and pneumothorax;
5. presence of fluid in the oesophagus, stomach and bowel;
6. presence of air in the cardiac chambers, in the arteries and veins;
7. presence of any anomaly in the head, neck, mediastinum, abdominal and pelvic viscera and skeleton.

After the CT scan, each cadaver underwent conventional autopsy, and histological, chemical and toxicological examinations on the collected fluids and tissues were performed. The autopsies were performed by a forensic pathologist with significant experience in forensic autopsies.

After receiving the autopsy reports and information from the histological, chemical and toxicological examinations, the CT images were reviewed and the agreement between the CT findings and the autopsy results was discussed.

The present study is an observational study and so it is not subject to the directive 2001/20/CE of the European Parliament regulating the application of a good clinical practise during clinical experimentation (Art. 1 para. 1; Art 2/c) and so it was not necessary to request the approval of the Ethics Committee.

## Results

The evaluation and reconstruction of CT data of the four cadavers showed that all of them had fluid in the trachea and bronchi and patchy ground-glass opacities in the lung (Fig. 1). However, in only three of the cadavers, was there fluid in the paranasal sinuses. From the comparison of

**Fig. 1** Axial multidetector computed tomography (MDCT) image reveals ground-glass opacities in the lung parenchyma and air in the cardiac chambers

virtopsy and autopsy, we noticed that the presence of fluid in the paranasal sinuses was not noticed during the autopsy. The only patient without fluid in the paranasal sinuses, and who had died in 2005 after the air crash, had cerebral oedema with subarachnoid and intraventricular haemorrhage, cerebral venous congestion, multiple bone fractures in the head (fracture of the orbital floor with orbital emphysema and herniation of the inferior rectus muscle), in the chest (multiple rib fractures) and in the pelvis (fracture of the sacrum and of the acetabular edge with haemarthrosis); moreover, this patient showed haemothorax seen as the "haematocrit sign" [13], pneumomediastinum and air in the heart chambers, aorta, pulmonary artery and its lobar branches, descending thoracic aorta and in the arterial and venous splanchnic vessels.

Regarding the evaluation of the gastrointestinal tract, only one of the cadavers had no fluid in the digestive tract (Fig. 2). The absence of water in the stomach suggests either rapid death by drowning, or death prior to submersion. This patient without fluid in the digestive tract had a left parietal bone fracture with a large gap (maximum diameter, 18 mm) and probable loss of brain substance (Fig. 3). Moreover, this cadaver had other multiple bone fractures (nose, clavicle, first rib, humerus, femur and patella): in particular, he showed a displaced multi-fragmented fracture of the nasal bones and septum with severe soft-tissue swelling of the left orbital area and chin area and avulsion of teeth 31 and 32 and blood and air in the adjacent subcutaneous tissue.

The forensic reconstruction revealed that one of the two dead bodies fallen from a 20-m rocky cliff, despite having suffered a major head injury that led to the fracture of the zygomatic process and of the greater wing of sphenoid bone without significant brain lesion, did not die because of the head injury; these fractures indeed did not cause immediate death as demonstrated by the fact that sea water was present both in the airways and in the digestive tract (Fig. 4). In the second patient who precipitated from the rocky cliff instead, the absence of fluid in the digestive tract and the presence of a skull fracture with significant brain lesion suggest that the primary cause of death had occurred before immersion in sea water.

## Discussion

Forensic thanatology is a part of forensic medicine devoted to the study of the phenomena of death. In the case of corpses recovered from water, autopsy post-mortem

**Fig. 3** Three-dimensional MDCT reconstruction shows a left parietal bone fracture with a large gap and a right humeral fracture

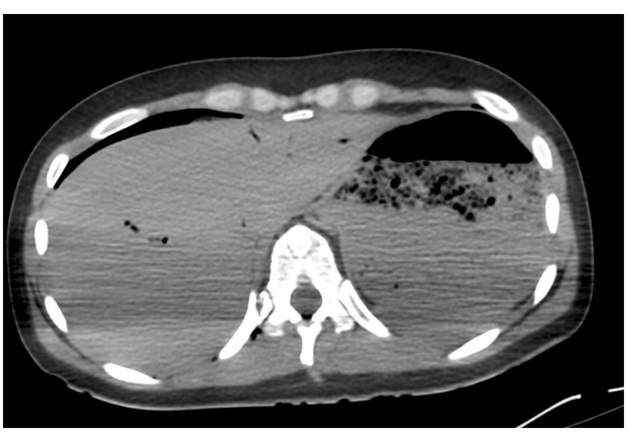

**Fig. 2** Axial MDCT images demonstrate the absence of fluid level in the stomach

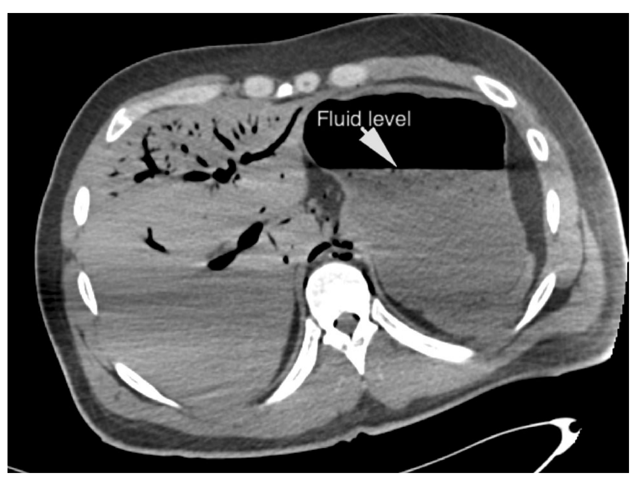


**Fig. 4** Axial MDCT image shows fluid level in the stomach (*arrow*)

diagnosis has several limits primarily related to the inability to certainly state whether the cause of death of the recovered corpse occurred before or after the dive.

The autopsy diagnosis of drowning is based on macroscopic and microscopic findings [2, 3]. Externally, the presence of foam at the mouth or nostrils, or both, is important. Internally, lungs are waterlogged, over-distended often to a degree which causes them to overlap the pericardium, and, sometimes, increase in weight. Other macroscopic findings can be pleural effusion, fluid collection in the stomach, a lighter spleen weight and haemorrhage into the middle ears. Regarding the microscopic findings, classical histological examination through haematoxylin and eosin staining shows intra-alveolar oedema and dilatation of the alveolar spaces with secondary compression of the septal capillaries. However, the macroscopic and microscopic findings in the fresh drowned corpse are non-specific and will disappear with putrefaction.

At present, in the autopsy diagnosis of drowning, the demonstration of plankton and, more especially, diatoms in the submerging fluid and in the body of the victim is the gold standard [2]. The polymerase chain reaction method represents a new perspective for identifying diatoms but its higher sensitivity could be hampered by a higher risk for contamination [4]. Recently, Seo et al. [3] suggested a DNA coprecipitation method for the detection of diatoms in heart blood as a simple and safe tool for the diagnosis of drowning.

To overcome the limits of the conventional autopsy in the diagnosis of drowning, post-mortem radiological imaging techniques are taking a prominent role. The progressive development of medical technologies led to revolutionise the autopsy process, until the birth of the Virtopsy project in the Institutes of Forensic Medicine, Radiology and Neuroradiology at the University of Bern, in Switzerland [5].

The use of virtopsy contributes both to the identification of the corpse and to hypothesise the cause of death. Currently, CT is the most widely used diagnostic tool in virtopsy.

Post-mortem CT proved to be useful in imaging victims who have suffered a water-related death. In a study by Levy et al. [11], CT images from victims who were confirmed to have died by drowning showed fluid in the paranasal sinuses and mastoid air cells, and ground-glass opacity in the septal lines. Furthermore, there was evidence of frothy fluid in the airways or high-attenuation airway sediment. As a result in the study by Levy et al. [11], post-mortem CT did show conclusive radiological signs of drowning as primary cause of death.

In our retrospective evaluation of cadavers recovered from sea water, we noticed that characteristically all the cadavers had fluid in the airways and patchy ground-glass opacities in the lung. Among the four cadavers, only one had no fluid in the digestive tract; the absence of water in the stomach suggests either rapid death by drowning, or death prior to submersion. This patient had a left parietal bone fracture with a large gap; moreover, he had multiple bone fractures (nose, clavicle, first rib and patella). On the other hand, one of the three patients with fluid in the digestive tract did not show fluid in the paranasal sinuses; this latter patient showed cerebral oedema with subarachnoid and intraventricular haemorrhage, multiple bone fractures (orbital floor, ribs, sacrum, acetabular edge) and air in the heart, in the aorta and in bowel loops.

The most important limitation of the present analysis was the limited number of cadavers evaluated. Moreover, we did not use contrast medium. Further observations and analyses based on larger cohorts of drowned cadavers are needed.

## Conclusions

As widely known in the literature, there are no autopsy findings pathognomonic of drowning. This study shows that post-mortem CT performed prior to autopsy may help to understand if the victim was alive or dead when he entered the water and if the cause of death was drowning. It is therefore clear that virtopsy can play a prominent role in the diagnosis of drowning, even if it is too early to predict whether it might replace classic autopsy.

**Conflict of interest** Giuseppe Lo Re; Federica Vernuccio; Maria Cristina Galfano; Dario Picone; Livio Milone; Giuseppe La Tona; Antonella Argo; Stefania Zerbo; Sergio Salerno; Paolo Procaccianti; Massimo Midiri; Roberto Lagalla declare no conflict of interest.

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