

Forensic Imaging for Causal Investigation of Death

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A 63-year-old man was found in the street after overrun by a car. Postmortem CT revealed multiple bone fractures, but surprisingly all without any relevant hemorrhage which would have been expected under such circumstances. A round radiopaque formation was found in the duodenum, which was reminiscent of ingested tablets. The toxicological analysis revealed high concentrations of zopiclone and alcohol. By combining radiologic and forensic results, zopiclone and alcohol intoxication were concluded as the cause of death, followed by a postmortem overrun accident.

Index terms: *Computed tomography; Forensic imaging; Virtopsy; Pre-autopsy CT; Forensic reconstruction*

INTRODUCTION

Pre-autopsy computed tomography (CT) and to some extent pre-autopsy magnetic resonance imaging (MRI) are increasingly entering the field of forensic medicine. Even though the gold standard for the post-mortem forensic assessment still is the forensic autopsy, imaging techniques gained a central role in forensic case assessment over the last decade (1). In general, imaging can non-invasively amply contribute to support forensic medicine both for diagnostic reasons and the documentation of findings. One of the further potential advantages is to store the imaging data unlimited and to facilitate second opinions, even years after burial.

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This article reports a case where the pre-autopsy CT imaging supported the forensic diagnosis of the cause and the manner of death. Furthermore it revealed findings, which were not directly available at autopsy, but could later be concluded by combining the radiologic report of the CT images with the results of autopsy and toxicological analyses. Hence, the notion was confirmed, that radiological expertise in the field of forensic imaging can be a highly valuable supplement for the reconstruction of the sequence of events.

CASE REPORT

A 63-year-old man was found in the street after overrun by a car. An emergency physician stated the on-site death. According to the whole setting of the accident and after hearing both the car driver and witnesses, when being overrun, the man was lying on the street already. As usual in such cases, one of the first debated questions was if the death occurred prior or subsequent to the overrun.

A postmortem CT imaging of the whole body was done prior to the autopsy. The examinations were performed on a 128-slice dual-source CT system (Somatom Definition Flash, Siemens AG, Forchheim, Germany). The examination

started with anterior-posterior and lateral scout views. The parameters were for the entire body including the head pitch 0.35, gantry rotation time 1.0 seconds, tube voltage 120 kV, effective tube current time product 550 mAs_{eff} and field of view 50 cm. Image reconstructions were performed using the filtered backprojection. Reconstructed images were transferred for further processing, reformatting and displaying to the syngo multimodality work place (Syngo MMWP, Siemens AG, Forchheim, Germany). The subsequent consensus report of two radiologists (one board-certified radiologist with substantial experiences of clinical CT reporting for more than 20 years and one resident with 2 years experiences of clinical CT reporting as well as each with one year experience in postmortem imaging), revealed as the main findings multiple bone fractures of the skull, ribs, vertebrae and extremities as well as a distinct laceration of the spleen. All these lesions were without any relevant surrounding hemorrhage which would have been expected under these circumstances. In the duodenum, a round radiopaque formation was found which was reminiscent of a conglomeration of ingested tablets which indicates medication intake before death (Fig. 1A-C). The radiologic report concluded that the man was overruled postmortem, after having died shortly before due to another reason, presumably as a consequence of intoxication.

The subsequent autopsy was done on the following day by two forensic pathologists being unaware of the radiologic report. In the autopsy report, the stomach and duodenum were documented to contain a brownish friable mass. However, a blister of zopiclone tablets was found in the personal belongings of the man (zopiclone AbZ, 7.5 mg), containing altogether fourteen tablets, nine of them having been removed. Indeed, zopiclone could be identified with the toxicological analysis of the stomach content and urine. Additionally, blood samples were collected from the saphenous vein. The blood concentration of zopiclone was 507 ng/mL and with regard to products of decomposition which might influence the result, the blood concentration of zopiclone was estimated to approximately 660 ng/mL at the time of death (therapeutic concentration in the serum is considered 10 to 50 ng/mL). In addition, a blood alcohol concentration of 1.39‰ was measured. A laceration of the spleen as well as multiple fractures in various regions of the body were also documented, however all with almost no surrounding hemorrhage. Zopiclone and alcohol intoxication were concluded as cause of death, followed by a subsequent overruled accident.

After autopsy, the forensic pathologists got access to the radiological report.

Computed tomography images were consulted for second reading as a radiopaque formation, which was described in the radiological report, had not been found during the autopsy. Both radiologists independently considered the radiopaque formation to be located within the duodenum, most probably within a duodenal diverticulum. The density of the formation was documented with 90 Hounsfield units (HU).

To further examine the observed finding, zopiclone tablets were scanned with the same CT scanner which was used for the postmortem imaging. First, one tablet was put in a bottle, filled with water, and scanned directly, the same procedure was repeated with an aggregate of five tablets, scanned directly and after one hour. *In vitro* imaging of these tablets revealed nearly the same density (88 HU) as above measured within the radiopaque formation (Fig. 1D). This was true for both, the scans of the single tablet and the aggregate of five tablets.

The final forensic report revealed zopiclone in combination with alcohol intoxication as the cause of death followed by an overruled accident based on the autopsy results, including toxicological analysis and supported by the CT findings in combination with the *in vitro* scans of zopiclone.

DISCUSSION

Radiological expertise in forensic situations will be increasingly demanded. The increasing use of imaging techniques for forensic purposes is appreciated by the specifically established term "Virtopsy" for the additional pre-autopsy whole-body CT or MRI respectively (1, 2). These scans are non-invasive. The body integrity can be assured, which should not be neglected, as some religious communities have objections to autopsy (3). Even though the use of MRI in traumatic causes of death was recently demonstrated to be promising (4), the CT in particular revealed certain advantages (5). CT is widely available and thus easy accessible for forensic pathologists also. Examinations are short, can be performed postmortem without contraindications and advanced two-dimensional and three-dimensional post-processing are easily available (Fig. 1E-G).

The gold standard for post-mortem forensic assessment is still the forensic autopsy. However, different studies

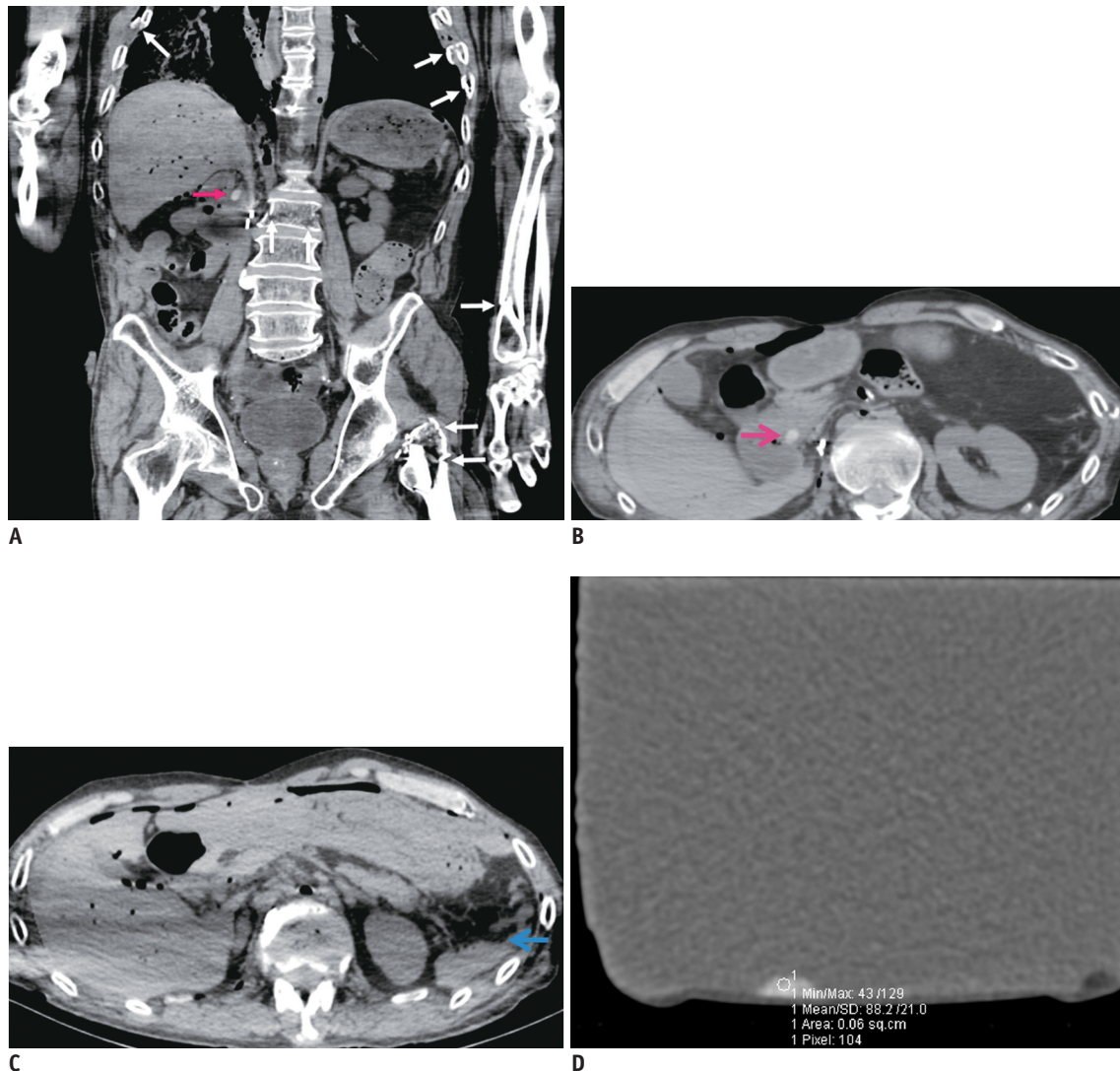


Fig. 1. Assessment of main findings to determine cause of death in pre-autopsy computed tomography.

A-C. Main findings in pre-autopsy computed tomography (CT). Non-contrast enhanced whole body postmortem CT imaging of 63 years old male overrun victim revealed multiple bone fractures of skull, ribs, vertebrae and extremities (white arrows, **A**), all without any relevant surrounding hemorrhage. In duodenum, round radiopaque formation (red arrows in **A**, **B**) was found which was reminiscent of conglomeration of ingested tablets indicating medication intake before death. Density of radiopaque formation was determined to be 90 Hounsfield units. Hemorrhage was also almost missing in internal organs. Distinct laceration of spleen was documented, also without any relevant surrounding hemorrhage (blue arrow, **C**). **D.** *In vitro*-scan of zopiclone tablets. CT scan of zopiclone tablets was performed. Representative scan of aggregate of five tablets is presented here.

published over the last decade have demonstrated that a combination of autopsy techniques and cross-sectional imaging can augment the value of postmortem examinations (3, 6, 7). The sensitivity of the imaging methods in these studies ranged from 100% (e.g., pneumothorax) to approximately zero (e.g., pulmonary embolism), which might in part be also due to the lacking forensic background of radiologists in order to detect specific forensic signs and to interpret them in the context of postmortem-induced changes (8).

However, the increasing need of imaging techniques in

forensic medicine will open new and interesting fields of activity for radiologists. In the presented case, the pre-autopsy CT imaging substantially supported the forensic diagnosis of cause and manner of death and furthermore revealed findings, which have not been directly seen in autopsy on first sight. Both, CT imaging and autopsy independently from each other, concluded that the overrun of the man occurred subsequent to death due to other reasons, most likely intoxication. Both, imaging and autopsy, revealed multiple bone fractures of the skull, ribs, vertebrae and extremities, all without any relevant

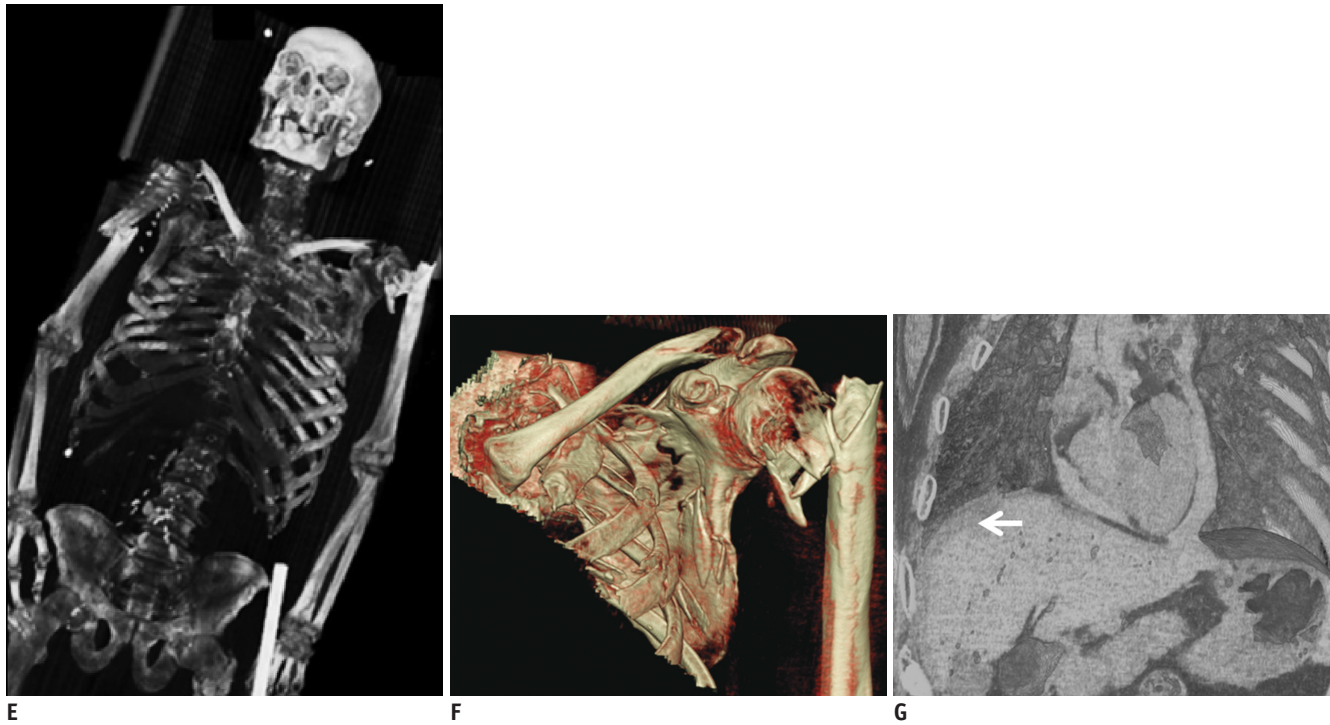


Fig. 1. Assessment of main findings to determine cause of death in pre-autopsy computed tomography.

E-G. Two-dimensional (2D) and three-dimensional (3D) post-processing possibilities of CT in forensic reconstruction. For visualization in court, in particular 2D and 3D post-processing reconstructions are useful to demonstrate significant findings to medical laity (e.g., judges, lawyers). Significant fractures of humeri were visualized (**E**, **F**). Small hematoma of liver capsule (white arrow, **G**) was also demonstrated to underline that only minor hemorrhage was detected, however man had been overrun.

surrounding hemorrhage which would have been expected under these circumstances. All these findings were hints, but no definite proof of the cause of death and the sequence of events. Whereas a round radiopaque formation in the duodenum was directly and rapidly identified in the imaging as source and origin at the autopsy only slight hints could be observed by the brownish mass in the stomach and duodenum. Days later, the time-consuming toxicological analysis confirmed the agent zopiclone in blood serum, urine and stomach content.

According to previous works, the blood concentration of zopiclone in fatal cases had been reported with 400–3900 ng/mL (9) and dose increases reached a factor of 30–120 above the recommended doses in extreme cases (10). In the presented case, indeed, the determined blood concentration was rather in the lower range. However, a blood alcohol concentration of 1.39‰ was measured and alcohol may increase the central respiratory and circulatory depression. The fatal interaction of alcohol and zopiclone in fatal poisoning has also been described in the literature (11). According to our own experiences and autopsies, in a lot of benzodiazepine (and benzodiazepine-related) drug intoxications and further in the central nervous system

active substances were also detectable. In the reported cases, a significant majority of intoxications also had a history of former drug or alcohol abuse and/or other psychiatric conditions (12).

The CT images were consulted for a second analysis after comparing radiological and autopsy report. Here the radiopaque formation was judged to be located within a duodenal diverticulum. Postmortem- and transport-induced changes in the body condition and the condition of the ingested medication explained why it was not present in a similar way at the standard autopsy procedure. A literature review revealed that massive ingestions of active ingredients may form bezoars which are radiopaque and may be associated with serious toxicity (13).

The radiological density of drugs should depend on the drug itself, its amount, the amount of leftover of food as well as on post-ingestion and post-mortem intervals. Of note, a CT scan can only detect the presence of a radiopacity. Indeed, there are other radiopaque materials, such as feces and normal food or plants and also other drugs in a therapeutic dosage in the gastrointestinal tract, which are not clues of intoxication. Also a number of compounds have been previously identified as being

radiopaque (14, 15). Thus a positive CT finding can only support the suspicion.

Of note, *in vitro* imaging of zopiclone tablets revealed nearly the same density (88 HU) as measured within the radiopaque formation; the reported density of 90 HU was well in line with the HU densities of these active ingredients as described in the literature (16). Zopiclone and alcohol intoxication could be determined as the cause of death followed by a post mortem overrun accident based on both, forensic and radiological reports. The driver of the car was thus relieved off a criminal offense.

Although the post-mortem imaging cannot be regarded yet as a substitute for autopsy, it has meanwhile proven to be a useful tool to determine the cause of death, to augment autopsy and to improve the legal certainty in complex cases. Clinical radiologists should play an important role in this future assessment of forensic cases and it seems worthwhile to increasingly set up interdisciplinary forensic-radiologic collaborations.

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