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.

CASE REPORT

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.

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.

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 direct 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.

Index terms: Computed tomography; Forensic imaging; Virtopsy; Pre-autopsy CT; Forensic reconstruction
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 where 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 overrun 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 overrun 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 overrun 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...
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
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.

REFERENCES

1. Thali MJ, Dirnhofer R, Vock P. The Virtopsy Approach: 3D Optical and Radiological Scanning and Reconstruction in Forensic Medicine, 1st ed. London: CRC Press, 2009:1-536
2. Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, et al. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)—a feasibility study. J Forensic Sci 2003;48:386-403
3. Roberts IS, Benamore RE, Benbow EW, Lee SH, Harris JN, Jackson A, et al. Post-mortem imaging as an alternative to autopsy in the diagnosis of adult deaths: a validation study. Lancet 2012;379:136-142
4. Ross S, Ebner L, Flach P, Brodhage R, Bolliger SA, Christie A, et al. Postmortem whole-body MRI in traumatic causes of death. AJR Am J Roentgenol 2012;199:1186-1192
5. Paperno S, Riepert T, Krug B, Rothschild MA, Schultes A, Staak M, et al. [Value of postmortem computed tomography in comparison to autopsy]. Rofo 2005;177:130-136
6. Levy AD, Harcke HT, Getz JM, Mallak CT, Caruso J, Pearse L, et al. Virtual autopsy: two- and three-dimensional multidetector CT findings in drowning with autopsy comparison. Radiology 2007;243:862-868
7. Woisetschläger M, Lussi A, Persson A, Jackowski C. Fire victim identification by post-mortem dental CT: radiologic evaluation of restorative materials after exposure to high temperatures. Eur J Radiol 2011;80:432-440
8. Christie A, Flach P, Ross S, Spendlove D, Bolliger S, Vock P, et al. Clinical radiology and postmortem imaging (Virtopsy) are not the same: specific and unspecific postmortem signs. Leg Med (Tokyo) 2010;12:215-222
9. Jones AW, Holmgren A. Concentrations of zolpidem and zopiclone in venous blood samples from impaired drivers compared with femoral blood from forensic autopsies. Forensic Sci Int 2012;222:118-123
10. Boniface PJ, Russell SG. Two cases of fatal zopiclone overdose. J Anal Toxicol 1996;20:131-133
11. Koski A, Ojanperä I, Vuori E. Interaction of alcohol and drugs in fatal poisonings. Hum Exp Toxicol 2003;22:281-287
12. Hajak G, Müller WE, Wittchen HU, Pittrow D, Kirch W. Abuse and dependence potential for the non-benzodiazepine hypnotics zolpidem and zopiclone: a review of case reports and epidemiological data. Addiction 2003;98:1371-1378
13. Lapostolle F, Finot MA, Adnet F, Borron SW, Baud FJ, Bismuth C. Radiopacity of clomipramine conglomerations and unsuccessful endoscopy: report of 4 cases. J Toxicol Clin Toxicol 2000;38:477-482
14. Tillman DJ, Ruggles DL, Leikin JB. Radiopacity study of extended-release formulations using digitalized radiography. Am J Emerg Med 1994;12:310-314
15. Jaeger RW, Decastro FJ, Barry RC, Gerren L, Brodeur AE. Radiopacity of drugs and plants in vivo-limited usefulness. Vet Hum Toxicol 1981;23(Suppl 1):2-4
16. Aghayev E, Jackowski C, Christie A, Thali M. Radiopaque stomach contents in postmortem CT in suicidal oral medication intoxication: report of three cases. J Forensic Leg Med 2010;17:164-168