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CASE REPORT

Progressive gas formation in a deceased person during mortuary storage demonstrated on computed tomography

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Abstract We report the case of an 82-year-old woman with a past history of diabetes mellitus who died following blunt head injury sustained in a fall resulting in an acute subdural hematoma. Serial postmortem CT scans of the chest and abdomen performed over a 3-day period demonstrated progressive intra-hepatic and intra-cardiac gas formation whilst the deceased was stored in a standard mortuary refrigerator at a nominated temperature of 4°C. Measured mortuary refrigerator temperatures over a 7 day period showed statistically significant day to day variability in temperatures above 4°C as well as variations in temperature depending on location within the refrigerator space. In the absence of other known factors associated with such gas formation, putrefaction seems the likely cause despite a lack of obvious external features. This phenomenon must therefore be taken into account when interpreting the presence of visceral gas on postmortem CT and relating such gas to the cause of death.

Keywords Forensic science · Postmortem changes · Computed tomography · Gases · Mortuary practice · Refrigeration · Putrefaction

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Introduction

The gold standard for detecting cause of death is the autopsy, however, radiological imaging by computed tomography (CT) and magnetic resonance imaging (MRI) have recently been proposed as an adjunct to conventional autopsy and have been proven to be superior in detecting postmortem gas [1, 2].

Postmortem gas formation as detected on CT imaging may occur as a result of putrefaction within 24–48 h of death [3] depending on the atmospheric temperature and humidity. Studies have also reported the presence of postmortem intra-cardiac gas (ICG) due to gas embolism resulting from trauma and cardiopulmonary resuscitation [1], and intra-hepatic gas (IHG) associated with sepsis, necrotic bowel and gastrointestinal distension [4–6] in the absence of visible signs of putrefaction on the body.

A recent experimental study involving healthy sheep undergoing simulated diving studies in a decompression chamber has shown progressive development of intravascular gas bubbles on the CT scans of control subjects who were dead at the time of decompression (thus not breathing air at high pressure) despite the fact that all carcasses were intact and stored in a mortuary refrigerator. The authors suggest that this phenomenon was due to postmortem "autolysis" [7].

Case report

The deceased was an 82 year old woman with a past history of non–insulin dependent diabetes mellitus, hypertension, dementia, Parkinson's disease, atrial fibrillation and spondylosis. She was the resident of a hostel and was prescribed warfarin.

One morning in autumn at around 0830 h she had a fall at the hostel and hit the right side of her head. There was no loss of consciousness or other neurological deficit at the time. She then attended lunch but began to feel drowsy and became unconscious.

An ambulance was called at 1212 h and her Glasgow Coma Score on arrival at hospital was 7. A CT scan of the brain showed a large acute left subdural hematoma with mass effect. She was treated palliatively after discussion with family members and subsequently died 6 days later at 0855 h. There were no other signs of trauma to the body, no penetrating injury and no cardio-pulmonary resuscitation was instituted.

Postmortem whole body CT scanning was performed at the time of admission to the Victorian Institute of Forensic Medicine (VIFM) and on 2 subsequent occasions over the period of a 3 day public holiday weekend using a mortuary located Toshiba Aquilion16 multi-detector scanner (Toshiba Medical Systems Corporation, Tochigi, Japan) with postmortem intervals of 7–72.5 h (Table 1). Images were reviewed on a TeraRecon Inc AquariusNet workstation v1.7.2.18 (San Mateo, CA 94403, USA), and the presence and location of gas outside the bowel lumen recorded for each examination.

The deceased arrived at the VIFM 7 h after death. She was placed in the mortuary refrigerator (Coplematic 9RB1-0765-TFD, Emerson Climate Technologies, Sidney, Ohio) after her weight and height were recorded. She was only removed from the refrigerator to have CT scans performed and replaced immediately following each scan.

Temperatures in the refrigerator where the body was kept prior to and after the CT scans, were recorded over a 7 day period using Thermotag™ temperature loggers or tags (Table 2). These tags consist of a Thermochron iButton™ temperature recorder (Dallas Semiconductor, 4401 South Beltwood Parkway Dallas, Texas 75244, USA) mounted on a plastic oval measuring 8.5 × 5 cm. The Thermotags™ were set to record temperatures between −10°C to +85°C every half hour.

After consultation with the deceased's next of kin and the coroner, an autopsy was not performed as it was felt that issues of medico-legal significance could be satisfactorily addressed by review of medical documents, external examination of the body and postmortem radiological studies.

Results

External examination

External examination of the deceased was conducted by a specialist forensic pathologist 3 days after death and documented a slim, elderly, white female with a height of 163 cm, weight of 48 kg and a BMI of 18.1 kg/m^2. The examination revealed subcutaneous "butterfly" cannulas in the skin of the anterior abdominal wall bilaterally with the cannula on the right connected to a syringe for administration of pain relief medication and faint greenish pigmentation of the anterior abdominal wall. There were no external signs of scalp injury or trauma to the thoracic and abdominal cavities. No other features of decomposition were detected.

Radiologic examination with multi-detector CT scan (Table 1)

The first CT scan, with a postmortem interval of 7 h, revealed a large left convexity subdural hematoma

Table 1 Distribution of postmortem gas on CT

Day	Time (h)	Postmortem Interval i.e. time of death to CT scan (h)	PMCT findings	
			IHG	ICG
1	1555	7	+	−
2	1523	30.5	++	+
4	0929	72.5	++	++

The annotations −,+ and ++ represent no gas, minimal amounts of gas and moderate amounts of gas

Table 2 Mean temperatures over 7 days measured within the mortuary refrigerator

Thermotag	Placement	Mean (°C)	Range (°C)	SD (°C)	95% CI (°C)
1	At the refrigerator door entrance	6.4	5.0–10.0	1.0	6.3, 6.5
2	At the refrigerator door exit to the mortuary	5.6	4.5–8.5	0.8	5.5, 5.7
3	Middle of the refrigerator adjacent to the cool air fan	5.0	3.5–8.5	1.0	4.9, 5.1
4	Middle of the refrigerator opposite the cool air fan	5.2	3.5–10.0	1.2	5.1, 5.3

Fig. 1 Postmortem axial CT scan through the lateral ventricles showing a *left* convexity subdural hematoma causing mass effect and midline shift to the *right*

compressing the ipsilateral lateral ventricle and causing midline shift to the right (Fig. 1).

CT scan of the abdomen and pelvis revealed small locules of subcutaneous gas density adjacent to the femoral veins at the site of postmortem venous puncture for toxicological analysis (Fig. 2) and in the anterior abdominal wall where cannulas had been inserted during life for the administration of pain relief medications (Fig. 3). This is a

Fig. 2 Postmortem axial CT scan through the pelvis on day 1 showing gas in the soft tissues of both groins as a result of postmortem venous access for toxicological analysis (*arrows*)

Fig. 3 Postmortem axial CT scan through the abdomen on day 1 showing gas within the anterior abdominal wall bilaterally adjacent to subcutaneous cannulas used during life for pain relief (*arrows*)

well-recognized phenomenon in clinical radiological practice whereby gas is introduced along the line of needle tracks and has been demonstrated on CT in an experimental sheep model [7]. There were also 1 or 2 small bubbles of IHG and no ICG (Fig. 4a and Fig. 5a). No obvious septic focus was identified in the abdomen or pelvis although there was considerable bilateral basal lung consolidation consistent with pneumonia. Infection of the urinary tract or septicemia could not be excluded by the CT technique and no microbiological specimens of urine or blood were collected.

The second CT scan performed after a postmortem interval of 30.5 h, revealed substantially more IHG and minimal ICG (Fig. 4b and Fig. 5b).

The third CT scan performed after a postmortem interval of 72.5 h, showed similar volume and distribution of IHG but more ICG (Fig. 4c and Fig. 5c).

Temperatures within the mortuary refrigerator (Table 2)

Mean temperatures over the 7 days varied between locations in the refrigerator being coolest (5°C) in the middle adjacent to the cool air fan (tag 3) and warmest (6.4°C) at the refrigerator door entrance (tag 1) although all 4 tags showed 7-day means of 1–2.4°C above the manufacturer's nominated temperature of 4°C. The difference in mean temperatures between tags 1 and 3 was statistically significant. Using a 2 sample t-test the p value < 0.0001 and the 95% confidence interval (CI) is between 1.2 and 1.5°C. Mean temperatures at all 4 locations also varied depending

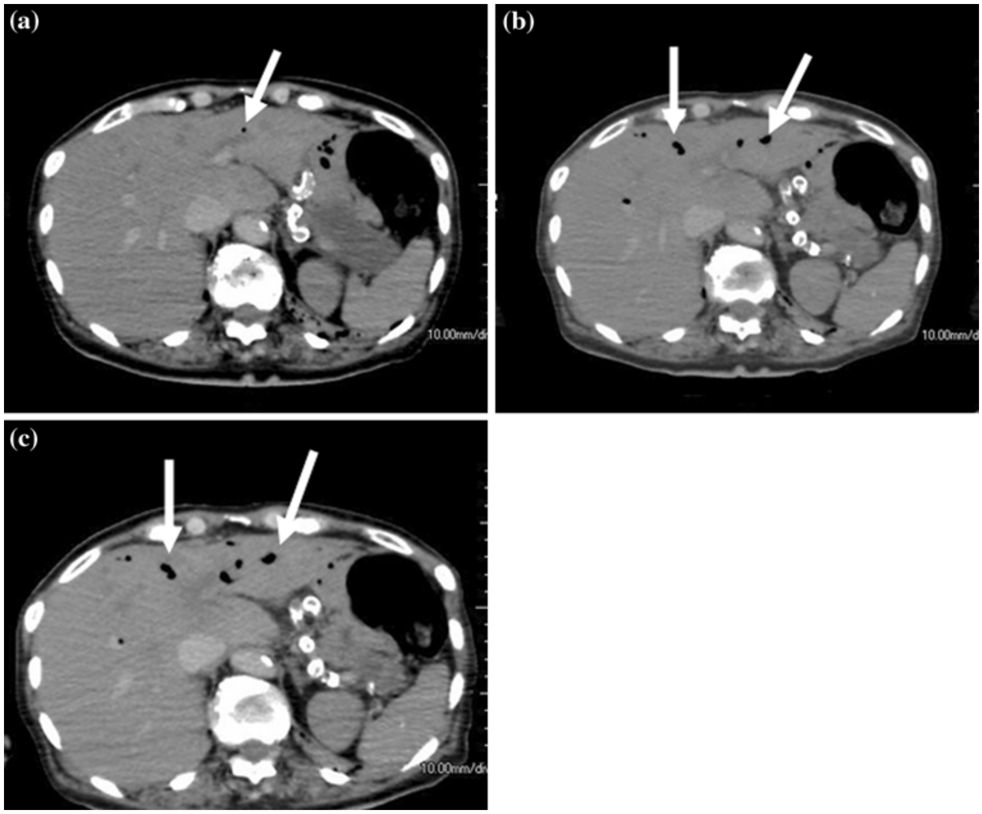

Fig. 4 **a** Postmortem axial CT scan of the abdomen on day 1 showing minimal IHG (*arrow*). **b** Postmortem axial CT scan of the abdomen on day 2 showing more IHG within vascular structures (*arrow*) compared to the scan on day 1. **c** Postmortem axial CT scan of the abdomen on day 3 showing similar volume and distribution of IHG (*arrow*) compared to the scan on day 2

on the day of the week, being coolest on Sunday and warmest on Wednesday (Fig. 6). This day to day variation was also statistically significant for tag 1 and tag 3. For tag 1 the mean Sunday to Wednesday difference of 0.6°C using a 2 sample t-test had a p value = 0.0027 and 95% CI of 0.2 and 1°C, and for tag 3 the mean Sunday to Wednesday difference of 0.7°C had a p value = 0.0001 and 95% CI of 0.4 and 1.1°C.

Discussion

This case report highlights the development of postmortem intravascular gas as detected by CT scanning, in a deceased individual being cooled in a standard mortuary refrigerator.

Gas is identified on CT as regions of very low density reflected in negative Hounsfield numbers. A Hounsfield number is a normalized value of the calculated x–ray absorption coefficient of a pixel (picture element) on a computed tomogram, expressed in units or numbers, where that unit for air is defined as -1000 and that of water is zero. It is not possible to differentiate between CO_2 and other gases based on these Hounsfield numbers, thus room air or gas derived from bacteria in the process of putrefaction have the same CT appearance. The only way to discriminate between such gases is by gas chromatographic analysis of retrieved gas specimens using a needle aspiration technique [8].

Early body decomposition is characterized by 2 processes. The first is autolytic digestion of body tissues by endogenous enzymes seen most commonly in the pancreas, gastric wall and liver. The second is putrefaction whereby tissue breakdown occurs due to the actions of bacteria and other micro-organisms [9]. Gas formation is a hallmark feature of putrefaction. Advanced putrefaction is characterized by gaseous bloating of the body and organs [10].

The etiology of postmortem gas detected on CT is multifactorial and not necessarily related to putrefaction. It has been reported following penetrating trauma [3] and cardiopulmonary resuscitation [1]. IHG has also been reported with sepsis, necrotic bowel and gastrointestinal distension [4–6] in the absence of visible signs of putrefaction on the body.

The circumstances of the deceased in this case reveal none of these factors i.e. there was no history of penetrating trauma or blunt trauma to the abdomen, no CPR or bowel necrosis, nor did she show external signs of advanced decomposition, save for minor skin greening on the lower

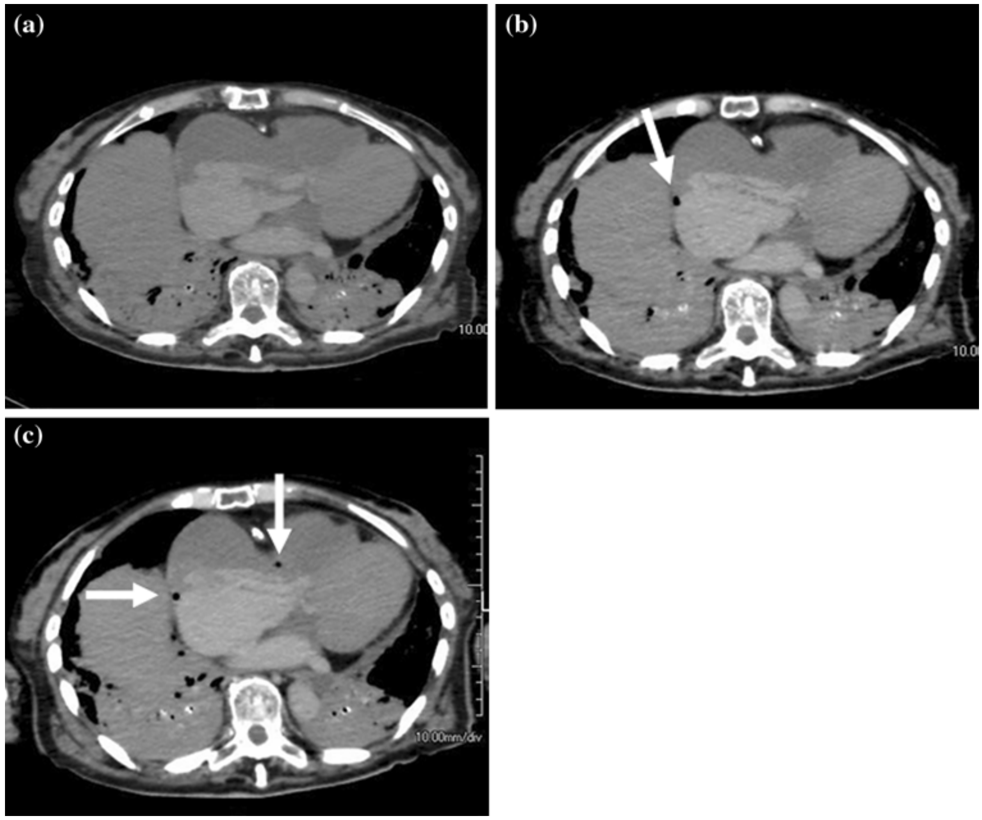

Fig. 5 **a** Postmortem axial CT scan of the chest on day 1 showing no ICG. **b** Postmortem axial CT scan of the chest on day 2 showing development of minimal ICG in the *right* atrium (*arrow*). **c** Postmortem axial CT scan of the chest on day 3 showing greater volume ICG in the right heart compared to the scan on day 2 (*arrow*)

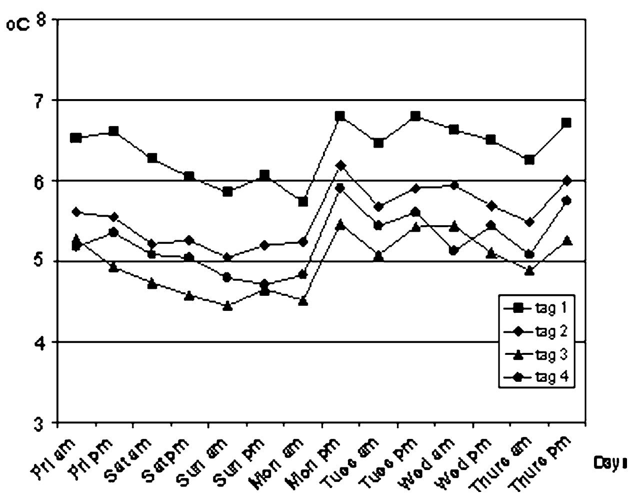

Fig. 6 Graph showing the mean distribution of temperatures in the mortuary refrigerator over a 7 day period. Tag 1 is adjacent to the refrigerator door entrance, tag 2 at the refrigerator door exit to the mortuary, tag 3 in the middle of the refrigerator next to the cool air fan and tag 4 in the middle of the refrigerator opposite to the cool air fan

anterior abdominal wall. The only apparent mechanism for gas to have developed in the heart and hepatic vasculature was by putrefaction i.e. the product of micro-organism action on body tissues. Of importance, the distribution of gas in this case is the same as that described in previous reports of trauma-associated gas i.e. vascular structures in the liver and cardiac chambers, especially the right heart.

Given the absence of any overt external signs of putrefaction except for slight greening of lower abdominal skin, and very obvious gas formation on CT, it seems that putrefactive gas detected on CT scanning can predate external features of putrefaction and may in fact be the first sign of such decomposition. Moreover this study suggests that IHG and ICG can develop in a standard mortuary refrigerator progressively over time.

There are 2 possible explanations for this observation. The first is that the mortuary refrigerator was not operating at the designated temperature allowing for micro-organism growth, or that the recommended refrigerator temperature has failed in this individual to inhibit bacterial metabolism leading to the production of putrefactive gases.

Australian Department of Health and Aging guidelines for the facilities and operation of hospital and forensic mortuaries, standard 4.4.1 (2004) states “a body cold store having a capacity appropriate for the mortuary workload should be maintained at a temperature of about 4°C” [11]. This is also the recommended temperature stated in a standard text on postmortem procedures [12]. Temperatures recorded in the standard refrigerator located in the VIFM mortuary over a period of 7 days using Thermo-tag™ temperature loggers have indicated that the mean temperatures in the refrigerator over a week are slightly above 4°C (range 5–6.4°C) and that there is statistically significant temperature variation within the refrigerator depending on proximity to the entrance/exit doors and cool air fan, being consistently cooler adjacent to the cool air fan and warmest adjacent to the front entrance to the refrigerator (Fig. 6). The temperature has also been shown to vary over a working week being coolest during the weekend when activity in the mortuary refrigerator is minimal and greatest in the early part of the week when activity is maximal with mortuary staff regularly opening and closing the refrigerator doors to access deceased persons for transport to and from the mortuary dissection room.

This finding is not unexpected or unusual. An experimental study looking at maggot development on pig carcasses in a veterinary cooler (similar to a standard walk-in cooler for human cadaver use) with a designated temperature listing of 4°C had recorded room temperatures fluctuating over 5°C when the carcasses were in position [13].

In addition to the recorded VIFM refrigerator temperatures being slightly elevated above recommended guidelines, the deceased in this case had several potential reasons for more rapid putrefaction than might be expected. She was a diabetic with possible elevated blood glucose levels promoting bacterial overgrowth and a site of possible sepsis was detected on the postmortem CT scans, notably bi-basal consolidation in the chest suggestive of pneumonia.

The exact mechanism by which bacteria are apparently able to survive in the refrigerated body to produce gas is unclear but the phenomenon of survival in the cooler is anecdotally well recognized with maggots and confirmed in an experimental pig cadaver study [13]. Maggots are observed to aggregate into masses on a feeding substrate leading to a metabolically generated, local increase in temperature above the ambient. This heat generated within the microclimate is believed to maintain maggot development even under refrigeration conditions.

This case suggests that any analysis of postmortem gas, in particular attributing that gas to the mechanism of death, must take into account the possibility of putrefactive gas formation. Given that this seems to be a progressive phenomenon, the time delay between death and CT scanning is critical even if the deceased is held in a standard mortuary refrigerator and there are no external features of putrefaction. It is recommended and indeed it is our practice at VIFM that bodies are scanned as soon as practicable after death in order to exclude putrefaction as the cause of IHG or ICG. This is most critical in scuba deaths where gas embolism is potentially a very significant contributor to death [7, 14].

In conclusion, abnormal visceral gas as detected by CT scanning, can develop in the deceased rapidly after death without external signs of putrefaction. The distribution of this gas is similar to that seen in other reported cases of ICG resulting from trauma and cardiopulmonary resuscitation [1], and IHG associated with necrotic bowel and gastrointestinal distension [3] but in the absence of those predisposing factors. On that basis this gas is presumed to be due to putrefaction, indeed the progression of gas formation over time supports this presumption. Temperature variability in the refrigerator, hyperglycemia of diabetes and underlying pulmonary or other organ sepsis may well have been contributory factors.

Key points

1) Putrefactive gas can be detected in the liver and heart on postmortem CT in the absence of external evidence of putrefaction
2) Putrefactive gas formation can progress despite the deceased being stored in a mortuary refrigerator
3) Temperatures within a conventional mortuary refrigerator vary significantly depending on the position within the refrigerator and days of the week
4) CT scanning of the deceased should be performed as soon as possible after death in order to avoid putrefactive gas artifact

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Conflict of interest All authors are employees or postgraduate fellows of the Victorian Institute of Forensic Medicine.

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