CQ 8: Is Postmortem Imaging Useful for the Detection and Quantification of Intracorporeal Gas?

Recommendation Grade:

Condition assessment: B

Cause of death determination: C1

Postmortem CT enables the detection of abnormal gas in various parts of the body. Compared to autopsy, CT allows for easier identification of intracorporeal gas, and also enables evaluation of its distribution and volume. Intravascular gas may be observed as a result of cardiopulmonary resuscitation (CPR) or putrefaction. Free intraperitoneal gas can be evaluated for signs of gastrointestinal perforation. In cases where exogenous air embolism is suspected, postmortem CT is particularly useful for assessing the distribution and volume of gas.

Explanation

● Background

Postmortem CT has been reported to detect gas accumulation in various parts of the body.[1] [2]While autopsy often results in the loss of information regarding the distribution and volume of gas, postmortem CT allows for easy and detailed evaluation of both.

● Non-Traumatic Deaths Without the Possibility of Exogenous Air Embolism

In cases of non-traumatic death with no evidence of exogenous air embolism (e.g., from medical procedures or decompression injury), the presence of intravascular gas on postmortem CT is generally attributed to cardiopulmonary resuscitation (CPR) or putrefaction.[1–2][4]

Several studies have reported a correlation between CPR and gas accumulation in various organs,[1] [6] [7] [11] [13–15] suggesting that such findings may help infer the origin of intracorporeal gas. In the cranium and liver, for example, gas introduced into the cardiovascular system by chest compressions may migrate retrogradely into the venous system.[11]There are also reports of widespread intravascular gas distribution following prolonged CPR.[14]

Intravascular gas observed on postmortem CT performed within a few hours after death (including during the agonal period) is believed to primarily consist of carbon dioxide.[23] After cardiac arrest, anaerobic metabolism leads to lactic acidosis and reduced CO_2 excretion due to respiratory failure, causing a rise in CO_2 concentration in the blood. When chest compressions are applied, this dissolved CO_2 may outgas, becoming visible as intravascular gas.[24]

Putrefaction-related gas tends to extend from the vasculature into the parenchymal organs, and the putrefactive process is broadly categorized into early, intermediate, and late stages.[9] Putrefactive gas increases with longer postmortem intervals, and this can occur even in refrigerated bodies, albeit at a

slower rate.[5] While the detection frequency of gas increases as the postmortem interval lengthens, environmental factors (such as storage temperature and humidity) have a significant impact, making accurate estimation of the postmortem interval based solely on gas findings difficult.

Free intraperitoneal gas is a useful indirect sign of gastrointestinal perforation, as reported in previous studies.[10 12] In cases of bowel perforation, a characteristic distribution and volume of gas has been observed.[25] On postmortem CT, gastric perforation due to autolysis may be detected. When typical findings of putrefaction or peritonitis are absent, autolytic perforation should be considered in the differential diagnosis.[10]

● Air Embolism Due to Trauma or Iatrogenic Causes (Excluding Decompression Injury)

Air embolism can occur when gas (such as air or oxygen) is introduced into the vasculature due to medical procedures or trauma. Postmortem CT enables clear detection of gas within blood vessels throughout the body, as well as in body cavities including the subcutaneous tissues, thoracic cavity (mediastinum, pleural spaces), abdominal cavity, and retroperitoneum.[21 22] By using 3D reconstruction, it is possible to visualize the overall gas distribution and even quantify the gas volume.[3 22] Injection of gas into the arteries or veins of the limbs can lead to fatal air embolism, depending on the volume and rate of injection.[13] Even small amount of gas, if injected rapidly, have been reported to cause death.[26]

While arterial air embolism following trauma is frequently reported, deliberate gas injection has also been observed in cases of suicide or homicide.[22] In addition, paradoxical air embolism—in which venous gas enters systemic circulation via a cardiac shunt (e.g., patent foramen ovale) or pulmonary capillary shunting—has been documented.[21 22 27] These arterial and venous air embolisms can result in pulmonary circulation obstruction or ischemic injury to the heart and brain, potentially leading to death.[28 29] Therefore, the detection and quantification of intravascular gas is valuable for determining the cause of death.

For information on decompression-related disorders, refer to CQ50.

Column: Historical Background of Air Embolism

Numerous cases of arterial air embolism following trauma have been reported, and remarkably, a comparison between arterial air embolism and postmortem findings was already published in 1769.[30 31] In cases of arterial air embolism following chest trauma, the primary mechanism is thought to be a traumatic alveolar–pulmonary vein fistula.[16] Head and neck trauma has also been reported as a cause of venous air embolism.[3] Furthermore, the first report of iatrogenic arterial air embolism was published in 1928.[32]

◯ Literature Search Strategy and Selection (April 3, 2023)

【PubMed】

1) Gas in Postmortem Imaging

#	Search formula	Number of articles
1	Search(((postmortem CT) OR (postmortem imaging)) OR (post-mortem CT)) OR (post-mortem imaging) in the last 10 years	6,196
2	Search(#1)AND "gas" in the last 10 years	128
3	Search(#2)NOT "diving" in the last 10 years	115

2) Air in Postmortem Imaging

#	Search formula	Number of articles
1	Search((("postmortem CT")OR "postmortem imaging")OR "post-mortem CT")OR "post-mortem imaging" in the last 10 years	6,196
2	Search(#1)AND "air" in the last 10 years	134
3	Search(#2)NOT "diving" in the last 10 years	124

●Additional Sources Not Captured by the Search Strategy

References［30］,［31］,［32］

■References

1） Shiotani S et al:Cardiovascular gas on non-traumatic postmortem computed tomography (PMCT）: the influence of cardiopulmonary resuscitation. Radiat Med 2005;23:225-229（level 4b）

2） Egger C et al：Distribution of artifactual gas on post-mortem multidetector computed tomography（MDCT）. Int J Legal Med 2012；126：3-12（level 4b）

3） Jackowski C et al：Visualization and quantification of air embolism structure by processing postmortem MSCT data. J Forensic Sci 2004 ；49：1339-1342（level 5）

4） Jackowski C et al：Intrahepatic gas at postmortem computed tomography：forensic experience as a potential guide for in vivo trauma imaging. J Trauma 2007；62：979-988（level 4b）

5） Singh MKC et al：Progressive gas formation in a deceased person during mortuary storage demonstrated on computed tomography. Forensic Sci Med Pathol 2009；5：236-242（level 5）

6） Takahashi N et al：Intrahepatic gas at postmortem multislice computed tomography in cases of nontraumatic death. Jpn J Radiol 2009；27：264-268（level 4b）

7） Yokota H et al：What is the origin of intravascular gas on postmortem computed tomography? Leg Med 2009；11：S252-255（level 4b）

8） Christe A et al：Clinical radiology and postmortem imaging（ Virtopsy） are not the same：

Specific and unspecific postmortem signs. Leg Med 2010；12：215-222（level 5）
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14) Zenda T et al：Intravascular gas in multiple organs detected by postmortem computed tomography：effect of prolonged cardiopulmonary resuscitation on organ damage in patients with cardiopulmonary arrest. Jpn J Radiol 2011;29:148-151（level 5）
15）Arata S et al：Characteristics of high-echoic objects in the hepatic vessels of patients with cardiopulmonary arrest：a prospective cohort study. Emerg Med J 2012;29:213-218（level 4b）
16）Brook OR et al：Arterial air emboli on computed tomography （CT） autopsy. Injury 2012；43：1556-1561（level 5）
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18）Egger C et al：Development and validation of a postmortem radiological alteration index：the RA-Index. Int J Legal Med 2012；126：559-566（level 4b）
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22) Makino Y et al：Massive gas embolism revealed by two consecutive postmortem computed-tomography examinations. Forensic Sci Int 2013；231：e4-10（level 5）
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31) Marsh PL et al：Iatrogenic air embolism：pathoanatomy, thromboinflammation, endotheliopathy, and therapies. Front Immunol 2023;14:1230049
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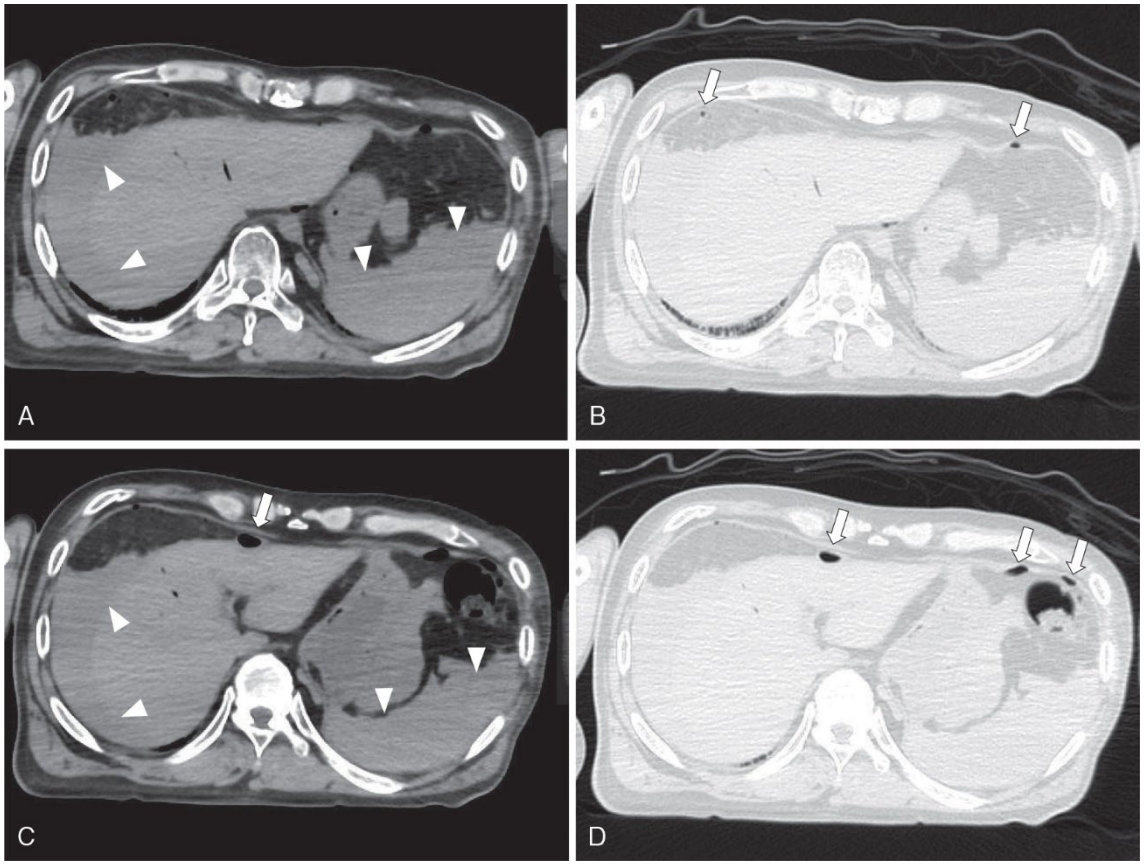

Figure. Male in his 70s – Small Intestinal Perforation (Traffic Accident)

A large amount of fluid accumulation is observed between the liver and the abdominal wall, as well as in the left upper abdomen (△). On mediastinal window settings (A, C), the findings are subtle, but on lung window settings (B, D), extraluminal gas can be identified along the liver surface and in the left abdominal region (⇨).