CQ 6: Do Postmortem Changes in Body Temperature Affect Imaging Findings?

Recommendation Grade: C1

Changes in body temperature after death can influence imaging findings on postmortem CT, MRI, and ultrasound. In particular, freezing has a significant impact on image appearance. Understanding how temperature-related changes affect imaging is essential for accurate interpretation of postmortem images.

Explanation

● Background

Unlike in living bodies, homeostasis is lost in postmortem imaging. Due to early postmortem changes, the body cools down and gradually approaches the ambient temperature. This decrease in body temperature affects image contrast in postmortem CT, MRI, and ultrasound. Furthermore, when a body is stored in a freezer or exposed to freezing temperatures, the resulting frozen state can have an even greater impact on imaging findings.

● Imaging Changes Due to Postmortem Changes and Body Temperature Decline

Postmortem changes are generally divided into early and late phases, although there are no strict criteria to distinguish them. Early postmortem changes include body cooling, drying, livor mortis (postmortem lividity, hypostasis), rigor mortis, and blood coagulation. Late changes include autolysis, putrefaction (gas formation), decomposition, and skeletonization.[1] When using postmortem imaging to investigate the cause of death, it is crucial to distinguish between true pathological findings and postmortem changes. Because body temperature declines rapidly and continuously after death, its impact on imaging findings—especially during the early phase—must be carefully considered. Temperature-related imaging changes are associated with the molecular kinetic energy of water.

Water reaches its maximum density at 4°C, but when cooled to 0°C and frozen, its density decreases by approximately 10%.[2] This is due to the loss of molecular motion and the formation of a stable crystalline structure. Additionally, the solubility of gases in liquid is also temperature-dependent. As temperature decreases, the kinetic energy of liquid molecules decreases, making it easier for gases to remain dissolved—thus, gas solubility increases.[3]

● Imaging Findings on Postmortem CT Affected by Temperature Changes

CT visualizes differences in X-ray attenuation and expresses them as CT values (Hounsfield Units, HU), where water is defined as 0 HU and air as −1000 HU. Due to density changes caused by temperature variation, the HU values of fluids such as cerebrospinal fluid (CSF), blood, and serous fluid also change. It has been reported that when body temperature drops from 40°C to 4°C, the HU values of CSF, blood, and serous fluid increase by approximately 10 HU. Despite this change, it

remains possible to differentiate fluid accumulation due to hemorrhage from that due to non-bloody body fluids.[4]

In studies where postmortem CT was performed before and after cooling, it was found that intravascular gas decreased with reduction in temperature, suggesting that temperature control affects gas visibility.[5]

● Imaging Findings on Postmortem MRI Affected by Temperature Changes

MRI captures the behavior of hydrogen nuclei in water and fat using strong magnetic fields and radiofrequency pulses. Because the behavior of hydrogen atoms is highly sensitive to temperature, MRI is particularly susceptible to temperature-related changes.[2] Additionally, it has been reported that magnetic susceptibility effects become more pronounced as temperature decreases.[6]

In postmortem head MRI, temperature reduction affects image quality and signal characteristics[7]:

- T1-weighted images may show hyperintensity in the basal ganglia
- T2-weighted images may show hypointensity in fat
- FLAIR images may demonstrate incomplete suppression of cerebrospinal fluid (CSF)
- Diffusion-weighted imaging (DWI) may show hyperintensity in the cerebral cortex and periventricular regions, along with a global decrease in apparent diffusion coefficient (ADC) values.

Incomplete CSF suppression on FLAIR can be corrected by adjusting the inversion time (TI) based on the body temperature, which restores suppression to a level similar to that seen in the living body.[8] [9] Likewise, signal suppression failure in short-tau inversion recovery (STIR) sequences for fat can also be improved through temperature-adjusted inversion parameters.[10]

Studies have reported temperature-dependent correlations for T1, T2, and T2* relaxation times in various tissues, including the brain, cerebrospinal fluid (CSF), heart, subcutaneous fat, liver, and paraspinal muscles.[8] [9] [11–14] In MR spectroscopy (MRS), a linear relationship has also been demonstrated between frequency shift and temperature, with metabolite peaks shifting approximately 0.01 ppm toward lower frequencies for every 1°C decrease in temperature.[2] [15] Experimental studies using brain specimens with controlled temperature variations have measured relaxation times and magnetization transfer ratios (MTR).[16] T1 values showed clear temperature dependence across various brain regions, with temperature coefficients ranging from 3.4 to 17.4 ms/°C. In contrast, T2* and MTR values showed linear temperature dependence only in the basal ganglia and thalamus, with much smaller coefficients—approximately 0.2 ms/°C for T2* and 0.002 for MTR. T2 values did not demonstrate any temperature dependence in any region examined. In an animal model of drowning, a linear relationship between water temperature and lung T1 values has also been reported.[17]

Further studies have examined the relationship between deep body temperature and T1, T2, and proton density in serous fluid, blood, CSF, and decomposed CSF, showing that correction to 37°C enables accurate differentiation among them.[18] Additionally, temperature-controlled cooling systems

have been developed to eliminate temperature fluctuation during imaging, enabling precise quantification during high-field, long-duration scans.[19] These advancements facilitate the collection of more detailed and reliable MRI data under controlled postmortem conditions.

● Postmortem Ultrasound Findings Affected by Temperature Changes

The human body shares many acoustic properties with water, and ultrasound images are reconstructed based on the speed of sound in water. As body temperature decreases, organs such as the liver become denser, leading to a decrease in sound velocity. In contrast, fat tissue becomes stiffer with cooling, resulting in an increase in sound velocity.[20] This leads to a reduced difference in sound velocity between fat and surrounding tissues, which in turn causes a decrease in image contrast between those tissues on ultrasound.[21 22]

● Effects of Freezing on Postmortem Imaging

When water freezes, its volume increases and its density decreases. Frozen areas appear as low-attenuation regions on postmortem CT.[2 15 23-25] Some studies have reported that these CT findings can be used to estimate the extent of freezing.[26 27] In postmortem MRI, image contrast in T1- and T2-weighted images decreases as temperature drops, and for this reason, MRI at temperatures below 10°C is not recommended.[28] Moreover, once tissue becomes frozen, T2 relaxation times shorten dramatically, making signal acquisition impossible, and frozen regions appear as hypointense to signal void areas. Although ultrasound findings specific to freezing have not been reported, it is known that the speed of sound doubles from approximately 1,500 m/s in water to about 3,000 m/s in ice,[29] which may influence image interpretation. Because freezing causes substantial changes in the physical properties of tissues and can significantly affect imaging findings, it is important to assess the body's condition externally to better interpret internal states.

During thawing, small gas bubbles may be generated, which can confound estimation of the postmortem interval.[30] In animal studies using MRI, methylene peak area ratios and shortened T2 values in bone marrow MR spectroscopy (MRS) have been shown to help identify whether tissues had been previously frozen, which can aid in interpretation.[31] In CT of muscle, thawing at 2°C is preferred 19°C, and it is recommended that the freeze-thaw cycle be limited to only one repetition to preserve imaging quality.[32]

Column: Body Temperature Measurement Using MRI

MRI has the capability to detect subtle temperature changes, and in clinical settings, it has been used for temperature monitoring during hyperthermia therapy and to observe temperature variations between intracranial lesions and cerebrospinal fluid (CSF).[33-35] In postmortem MRI, absence of physiological motion allows for more precise temperature measurements. The apparent diffusion coefficient (ADC), calculated from diffusion-weighted imaging (DWI), shows a strong correlation with temperature, and has been used to estimate body temperature from ADC values in the eyeball and

CSF.[36 37] Additionally, by analyzing phase changes induced by proton frequency shifts, it is possible to generate temperature difference maps during the cooling process of a body.[38] Such detailed temperature distribution data may be valuable in applications such as postmortem interval (PMI) estimation.

○ Literature Search Strategy and Selection (April 19, 2024)

【PubMed】

#	Search formula	Number of articles
1	(postmortem OR cadaver) AND (computed tomography OR magnetic resonance OR ultrasound OR imaging) AND (temperature)	512
2	#1 AND finding	169
3	#1 AND freezing	64
4	#1 AND (cold OR cooling)	59
5	#1 AND (warmed OR heating)	40

【医中誌 Ichushi-Web (Japan Medical Abstracts Society Database)】

#	Search formula	Number of articles
1	(死後/AL or (死後検査/TH or Autopsy/AL or (死亡時画像診断/TH or Ai/AL)) and imaging/AL) and (温度/TH or 温度/AL) and (PT=会議録除く)	30

●Additional Sources Not Captured by the Search Strategy

References［2］,［3］,［5］,［14］,［20］,［21］,［22］,［24］,［25］,［29］

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