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A Case of Hanging with Limited Specific Postmortem Brain Imaging

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Abstract

In Japan, the number of autopsies has steadily decreased. Therefore, postmortem imaging methods have positioned as valuable supplemental or complementary tools in autopsy procedures. We clinicians are increasingly faced with the need to infer cause of death from postmortem imaging findings. We report computed tomography (CT) and magnetic resonance imaging (MRI) findings of a 41-year-old man who committed suicide by hanging. CT revealed fractures of the left superior horn of the thyroid cartilage. Head MRI showed high signal intensity in the basal ganglia on the T_1-weighted image and high-intensity rims along the cerebral cortex on the diffusion-weighted image; however, these were considered normal postmortem changes. There were no significant findings in the heart, major blood vessels, or abdominal organs. The contents of the stomach were minimal, and no tablets or other evidence suggestive of drug overdose were identified. Traumatic changes were not observed. Based on the scene and his circumstances, it was speculated that he died by hanging and an autopsy was not performed. This case highlights the importance of understanding normal postmortem brain imaging changes to estimate the true cause of death.

Keywords: postmortem computed tomography, postmortem magnetic resonance imaging, hanging

Introduction

Hanging, a frequently observed method of suicide, involves various mechanisms that can lead to fatal consequences. The applied pressure on the neck compresses nerves and major vessels like the jugular veins, resulting in a disruption of blood circulation to the head and subsequent central respiratory failure that causes oxygen deprivation. In addition, hanging may cause various soft tissue injuries and bone lesions. Fractures of the thyroid cornu and hyoid bone are commonly observed in hanging cases and are frequently encountered during autopsy.

In Japan, the annual registration of autopsies was around 40,000 cases in the 1980s. However, this number has steadily decreased since 1990 and is currently around 7,000 cases per annum, which is much lower than the number of autopsies conducted in the United States or European countries.[1)] On the contrary, the number of postmortem imaging is increasing year by year. In 2018, the number of postmortem imaging conducted in Japan was 58,689 out of the 170,174 cases of all unnatural deaths recorded (34.5%).[2)] As conventional autopsy rates decline, advancements in technology and decreasing costs have positioned postmortem imaging methods, such as computed tomography (CT) and magnetic resonance imaging (MRI), as valuable supplemental or complementary tools in autopsy procedures.[3,4)] Postmortem CT reliably diagnoses fractures, fracture-related gas bubbles, lung emphysema, and brain edema, enhancing the diagnostic outcome.[3,5,6)] Detecting hemorrhages and soft tissue emphysema during medicolegal investigations of fatal hanging is crucial for establishing vitality during the incident. The use of MRI is suggested due to its superior visualization of soft tissues than CT or radiography. MRI can particularly visualize intramuscular hemorrhages and lymph node swellings; however, it may not effectively reveal certain traumatic alterations like osseous lesions.[7-9)]

In this study, we report a case of hanging where post-

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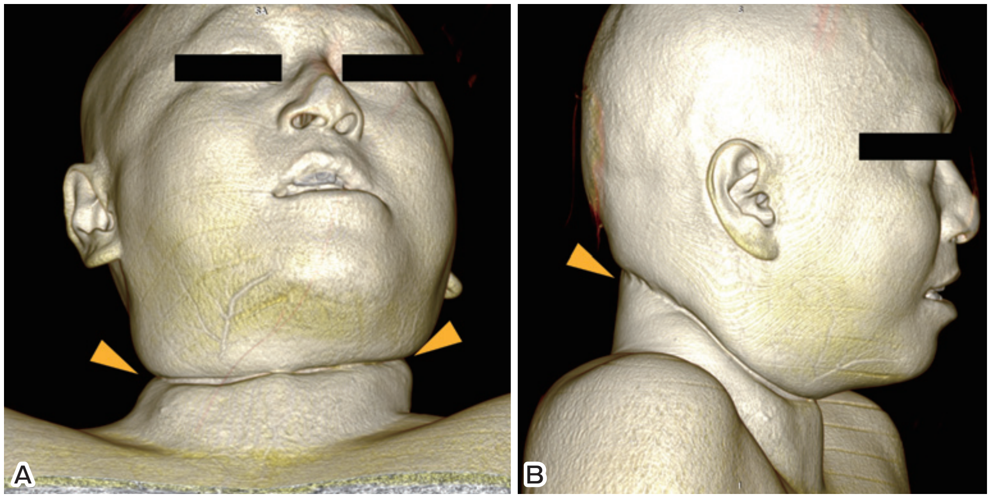

Fig. 1 Postmortem computed tomography (CT) 3D-volume-rendering images showing a ligature mark around the neck of the decedent; anterior (A) and lateral (B) views.

mortem CT and MRI were performed; however, limited specific findings were available. We reviewed the available literature on CT and MRI findings about cases that involve hanging. In light of this case and our review of the literature, we question the potential for postmortem imaging to substitute traditional invasive autopsy in determining the cause of death in hanging cases. Furthermore, we emphasize the importance of understanding normal postmortem changes when interpreting postmortem imaging.

Case Report

A 41-year-old man was found dead, hanging at a sandy beach. The man was hanging from a bamboo rack used for drying fishing gear, with a 1.5-cm-thick rope around his neck, and both feet touching the sandy beach. He was identified through his belongings. When he was found, his rectal temperature was 35°C and the ambient temperature was 29°C. Therefore, he was considered to be found relatively early after death (1-2 h). Upon external inspection of the body, a strangulation mark was detected, and there were no other noticeable injuries throughout the body. A toxicological examination of his urine or blood was not performed. Three hours after the body was found, postmortem CT and MRI were performed to investigate the cause of death.

Both whole-body routine CT and head CT examinations were performed with a 16-row-detector CT scanner (Alexion; Canon Medical Systems, Otawara, Japan). A ligature mark was identified using CT and 3D-volume-rendering images (Fig. 1). CT also revealed fractures on the left superior horn of thyroid cartilage (Fig. 2A-D). The hyoid bone was not fractured and fracture-related gas bubbles were not found. Bone lesions of the cervical spine or the skull were not detected. A loss of the gray-white matter differentiation throughout the entire brain and brain swelling with sulcal effacement were observed in the head CT scan image (Fig. 2E). CT scan also showed the obscuration of the lentiform nucleus. However, there were no changes in attenuation values suggestive of localized cerebral infarction or intracranial hemorrhage. In the CT scan of the lungs, an increase in attenuation in the lower fields of both sides was observed due to the effect of gravity. There were no significant findings in the heart, major blood vessels, or abdominal organs. The contents of the stomach were minimal, and no tablets or other evidence suggestive of drug overdose were identified. Traumatic changes were not observed.

A head and neck MRI was performed using a 1.5 T whole-body scanner (Magnetom Essenza, Siemens, Erlangen, Germany). During the evaluation of a neck lesion, sagittal imaging sequences were conducted with T_1-weighted image (T_1WI), T_2-weighted image (T_2WI), and short-tau inversion recovery sequences, each having a slice thickness of 3 mm. Axial T_1WI, T_2WI, T_2-star (T_2*)-weighted imaging (T_2*WI), and diffusion-weighted imaging (DWI) sequences were performed to examine the brain tissue. The apparent diffusion coefficient (ADC) map was automatically generated by DWI. Basi-parallel anatomic scanning (BPAS) was performed to evaluate the surface appearance of the vertebrobasilar artery in the cistern.

High signal intensities of the globus pallidus and thalamus were observed on T1WI of the brain than that of the surrounding white matter (Fig. 3A). There was no abnormal signal in the putamen, caudate nucleus, hippocampus, or brain stem. A low signal intensity was observed on T_2WI of the globus pallidus (Fig. 3B). The boundary between the white and gray matter of the brain was somewhat indistinct, but not completely lost. On T_2*WI, hypointense areas were observed in the globus pallidus, but no signal changes suggestive of microhemorrhages were noted (Fig. 3C). On DWI, high-signal-intensity rims along the

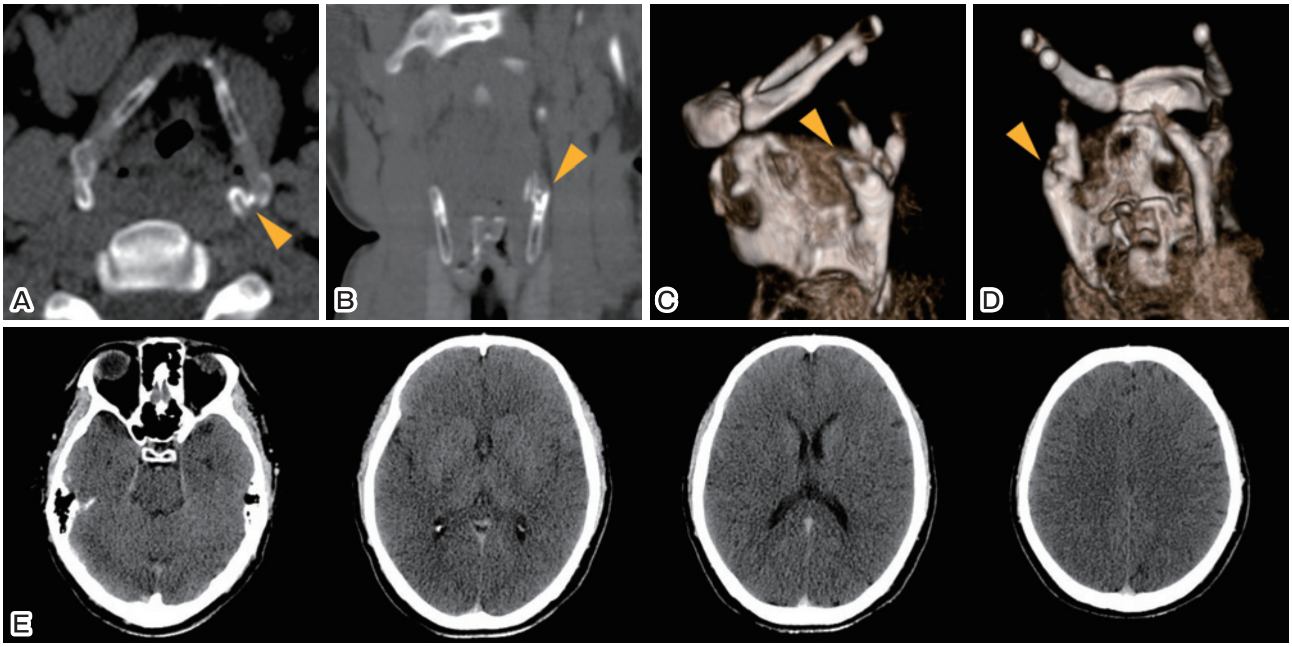

Fig. 2 A fracture of the left superior horn of thyroid cartilage diagnosed on CT (A and B) and 3D-volume-rendering images; lateral (C) and posterior (D) views.
CT scans of the brain showed loss of the gray-white matter interface and obscuration of the lentiform nucleus and sulcal effacement (E).

cerebral cortex were observed (Fig. 3D). No high signal intensity changes suggesting acute cerebral infarction in the brain parenchyma were noted. On the ADC map, a low-signal-intensity rims along the cerebral cortex that is supposed to correspond with the DWI findings was not observed (Fig. 3E). On BPAS, there were no irregularities in the appearance of the vertebrobasilar artery (Fig. 3F).

On neck MRI, there were no signal changes indicative of spinal cord injury (Fig. 4). No findings suggestive of intervertebral disc dislocation or ligament damage were also observed. Hemorrhages within muscles, such as those in the sternocleidomastoid or sternohyoid muscles, were not found. Lymph node hemorrhage and swelling were not detected.

Based on the scene and the circumstances of the man, we speculated that he died of hanging, and an autopsy was not performed.

Discussion

In this case, suicide by hanging was strongly suspected based on the circumstances. Postmortem CT and MRI were conducted to determine the cause of death. On a head CT scan, there was a loss of gray-white matter differentiation throughout the entire brain, and brain swelling with sulcal effacement was not observed. CT scan also showed the obscuration of the lentiform nucleus. In the bone CT images, a fracture of the thyroid cartilage was identified. On MRI, a high signal intensity of the globus pallidus and thalamus on T_1WI and high-signal-intensity rims along the cerebral cortex on DWI were observed. It is necessary to distinguish the imaging findings that are due to hanging from the normal postmortem changes.

CT scans of hanging victims frequently reveal abnormalities such as cerebral infarction, subcortical hematoma, and subarachnoid hemorrhage.[8,10-14] Damage to the carotid arteries or vertebrobasilar system resulted in severe hypoxia, causing cerebral infarction.[8,11,15] The hemorrhage occurred owing to the same mechanism observed in dural sinus thrombosis: prolonged elevation of venous pressure, caused by persistent venous occlusion, leads to blood stasis and endothelial damage in the capillary and cortical venous bed.[10,12-14] If the elevated venous pressure surpasses the resistance of the vein wall, rupture occurs, resulting in various types of cerebral hemorrhage. The representative CT findings of cerebral hemorrhages caused by venous hypertension due to compression of the jugular veins were large hematoma, petechial hemorrhages, or small subcortical hemorrhages.[11,16] In very rare cases, the spontaneous rupture of vessels within a high pressure venous system resulted in subarachnoid hemorrhage.[17,18] The detection of this infarction or hemorrhage in hanging cases can be described as a "vital sign," meaning that the patient was still alive until the incident. It is possible that such vital signs were not observed owing to near-instantaneous death in this case.

In most reports, hyoid or thyroid fractures were detected in cases of hanging.[5,8-22] The systematic review of Gascho *et*

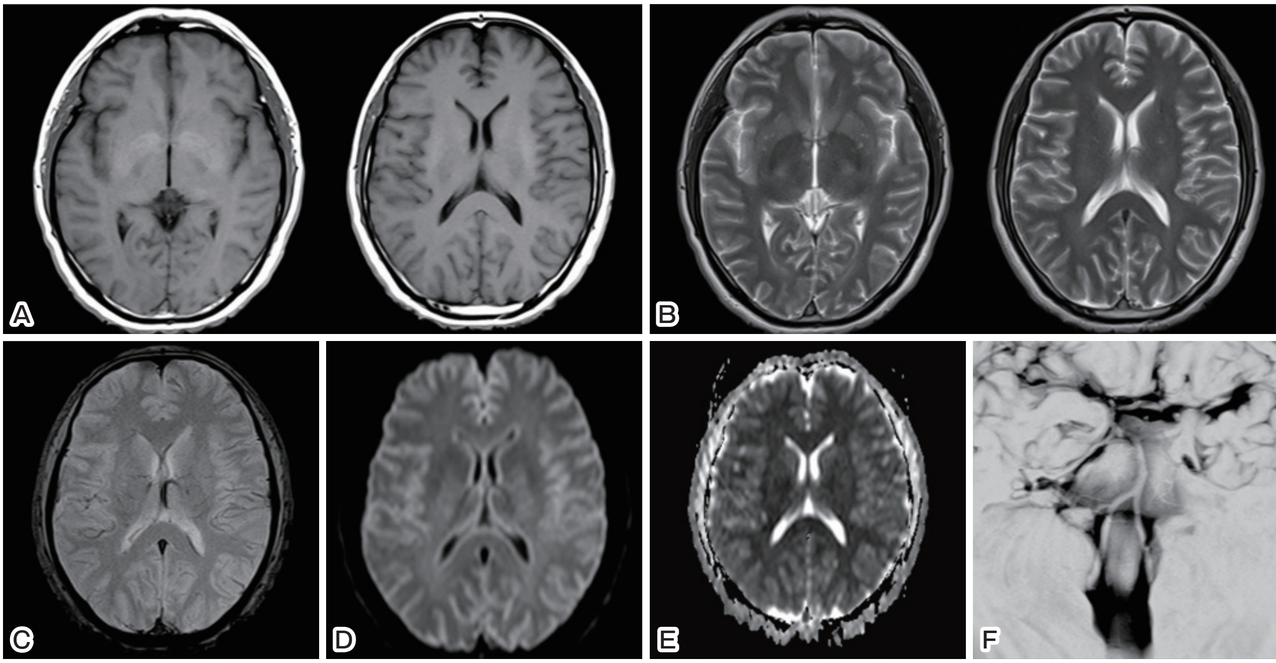

Fig. 3 Postmortem magnetic resonance imaging (MRI): T_1-weighted image (T_1WI) of the brain showing a high signal intensity of the globus pallidus and thalamus compared to surrounding white matter (A). T_2-weighted image (T_2WI) showing a low signal intensity of the globus pallidus (B). T_2-star-weighted imaging showing hypointense areas in the globus pallidus (C). Diffusion-weighted imaging showing high-signal-intensity rims along the cerebral cortex and the ventricular wall (D). Apparent diffusion coefficient map showing high-signal-intensity rims along the cerebral cortex (E). Basi-parallel anatomical scanning showed no irregular appearance of the vertebrobasilar artery (F).

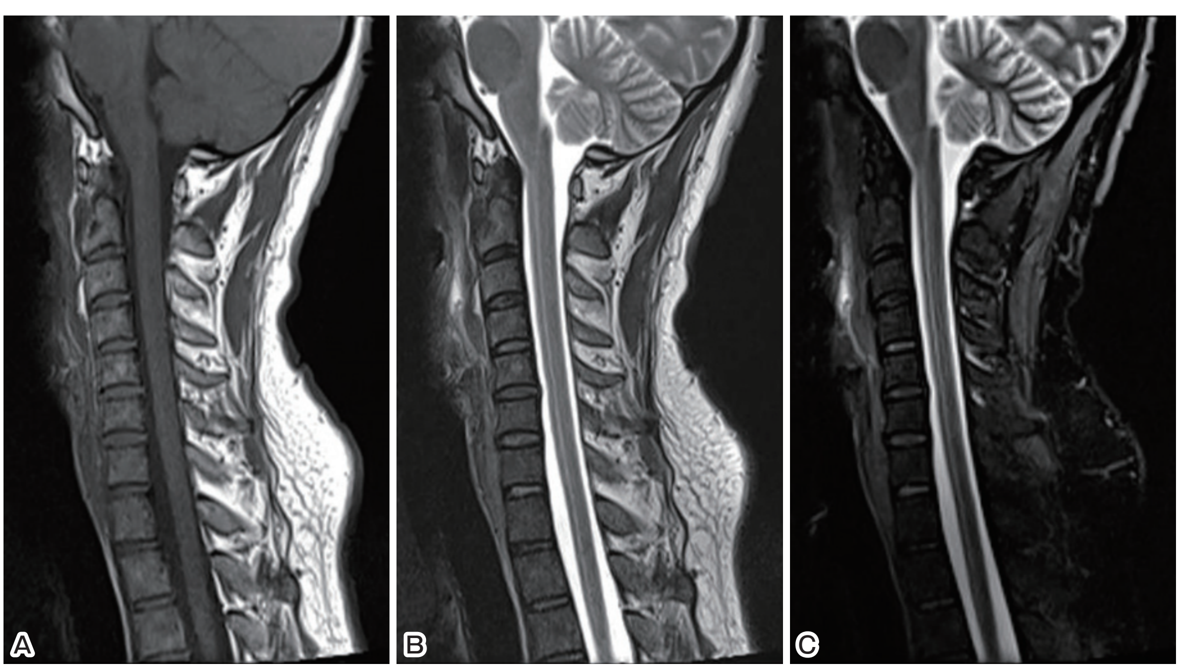

Fig. 4 Postmortem MRI of the neck: sagittal image of T_1WI (A), T_2WI (B), and short-tau inversion recovery (C) showing no evidence of spinal cord injury or soft tissue damage.

al. reported that the detection rate of thyroid cartilage fractures by postmortem CT in hanging cases was comparable to that of autopsy (31 out of 124 cases; 25%).[9] On the contrary, the detection rate of hyoid bone fractures by postmortem CT was 30 out of 124 cases (24.2%), surpassing the detection rate by autopsy (21%). The assessment of fractures on CT scans and during autopsy is subjective, and it is influenced by the experience of the examiner. In addition, detecting small fractures on CT depends on the quality of the images, which can be enhanced through adjustments to CT protocols and radiation doses in postmortem radiology.[23] Currently, there is great variability in the radiological scan parameters.[24] It is necessary to establish a general postmortem radiological protocol. This improvement in image quality enables even the smallest fractures to be visualized.

In some instances, it is challenging to determine whether a fracture occurred owing to the circumstances of death or as a result of extensive dissection performed during autopsy.[19,25] Postmortem CT allows for the visualization of findings before autopsy, which can help rule out injuries caused by medical procedures. In addition, CT scans may reveal hidden injuries related to strangulation or neck trauma, even in cases initially not suspected to involve strangulation. Hyoid or thyroid fractures may go unnoticed during standard autopsies.[25] Identifying such fractures before autopsy enables forensic pathologists to employ appropriate dissection techniques for the neck.[26] Therefore, CT is more effective than autopsy in detecting these tiny fractures.

Pathological conditions of the basal ganglia that can cause high signal intensity on T_1WI include calcification, parenteral nutrition, portosystemic encephalopathy, and neurofibromatosis.[27] However, none of the CT images in this case displayed any evidence of these conditions. Global cerebral ischemia may induce the generation of free radicals due to hypoxemia and accumulation of iron, which can cause high signal intensity on T_1WI in the basal ganglia and thalamus.[15,28-30] Typically, such characteristic signal changes were reported to appear more than 1 week after the onset of cerebral ischemia, and it is unlikely to occur over a short period, as in this case.[31] However, Kobayashi *et al.* reported similar characteristic high signal intensity on T_1WI in postmortem MRI and speculated that postmortem hypothermia shortened the T_1 value of the iron component.[32,33] Therefore, the high signal intensity changes observed on T_1WI of the globus pallidus and thalamus can be considered normal postmortem changes resulting from postmortem hypothermia. High-intensity rims along the cerebral cortex on DWI without accompanying changes in ADC values have also been observed in typical postmortem changes.[32,33] This could be due to a T_2 shine-through effect; however, the prolonged T2 signal at this location remains unexplained.

Detecting soft tissue hemorrhages in cases of hanging can be considered a crucial indicator, suggesting that the individual was alive at the time of the event.[4,34] Postmortem MRI showed nearly identical findings to autopsy in detecting these hemorrhages.[9] Only MRI was able to indicate a lymph node hemorrhage as a possible indicator of strangulation.[8] In this case, although specific postmortem MRI findings of hanging were not obtained, there were no other findings suggestive of an alternative cause of death, such as vertebral artery dissection or upper cervical spinal cord injury.

Therefore, the CT and MRI of the brain in this case showed no abnormalities other than normal postmortem changes. The brain edema observed on CT or signal intensity changes in the basal ganglia and cerebral cortex on MRI could be mistaken for effects of hanging, particularly for those unfamiliar with typical postmortem changes. When estimating the cause of death using postmortem imaging, familiarity with normal postmortem changes is of utmost importance. Based on the identification of thyroid cartilage fracture on CT and many negative findings, it was presumed that he died of asphyxiation from suicide by hanging. Therefore, an autopsy was considered unnecessary. For cases of suicidal strangulation with clear circumstances and an obvious sequence of events, an autopsy may be omitted, and a combination of CT and MRI may offer a suitable alternative method. These postmortem images could be used in other accidental or suicidal cases that might otherwise only receive an external examination. The question of whether postmortem imaging can completely replace conventional autopsy remains a debate. Due to the limited availability of large-scale studies on CT and MRI findings involving hanging cases, additional research with a robust sample size is warranted. As postmortem imaging becomes readily available in the future, we hope that the number of bodies with unknown causes of death will significantly decrease, possibly even reaching zero.

Conclusion

We reported a case of strangulation in which a fracture of the thyroid cartilage was the only determining factor for diagnosis. Understanding normal postmortem image changes is essential for identifying the true cause of death. As the number of autopsies decreases, the importance of postmortem imaging will continue to grow. It is necessary to emphasize the importance of postmortem image changes to forensic pathologists, diagnostic radiologists, and other physicians.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Patient Consent

Informed consent was obtained from the family of the patient for publication of this case report and any accompanying images. This research was approved by the ethics committee in our institution.

Conflicts of Interest Disclosure

We have no conflicts of interest concerning the materials or methods used in this study or the findings presented in this manuscript. We have completed and submitted to the Japan Neurosurgical Society our COI self-report for the past 3 years. The contents of this article have not been previously published or presented.

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