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CASE REPORT

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Central Nervous System Consequences of an Unusual Body Disposal Strategy: Case Report and Brief Experimental Investigation*

ABSTRACT: The body of a 73-year-old man was dismembered by his female companion for the purpose of covert disposal. The method employed included skillful separation of body parts with hacksaw and knife, piecemeal disposal of fragments, and prolonged boiling of the decapitated head. The latter treatment resulted in marked shrinkage of cranial dura mater, separation of dura mater from skull, and extrusion of brain fragments into the resultant enlarged epidural space through a dural defect due to the disproportionately greater shrinkage of dura mater compared to brain parenchyma. This resulted in curd-like brain fragments filling an enlarged epidural space and overlying a shrunken, leathery dura mater. The cranial dura mater, still adherent to the skull base, resembled a "shrunken brain" in contour but contained only the remnants of brain tissue not already extruded through the dural defect. This unusual thermal artifact is rarely illustrated or mentioned in forensic literature. The development of this postmortem artifact likely requires the presence of a specific combination of conditions which must be, but apparently rarely are, simultaneously present.

KEYWORDS: forensic science, brain, dura mater, thermal injury, postmortem artifact, dismemberment, epidural brain herniation

Certain scalp, cranial, and central nervous system (CNS) artifacts produced by thermal injury are commonly encountered, and they are well-illustrated and described in the forensic pathology literature. These include scalp color changes, splitting, charring and disintegration of the scalp; artifactual color changes and fractures of the skull; and artifactual epidural "hematoma" (typically a mixture of blood and skull bone marrow 1–9).

Less frequently encountered or described as thermal artifact are small collections of subdural blood. In our experience, artifactual subdural blood collections do not exceed more than a few milliliters in volume and tend to be localized to areas of most extensive thermal injury, which typically include a significant co-located thermally-induced epidural hematoma. In addition, small amounts of extravasated subarachnoid blood may be seen as artifact. One of the least common central nervous system thermal artifacts is a readily-apparent shrinkage of the brain and its coverings within the cranial cavity, associated with extrusion of brain tissue into the epidural space (6,10–14). A case is described in which postmortem thermal injury resulted in a striking example of this unusual intracranial artifact. It is suggested that the estimations of actual brain "shrinkage" in such cases may be difficult.

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Case Report

Persistent inquiry as to the welfare of her 73-year old uncle by a concerned niece eventually led to the discovery of his dismembered body, most of which was recovered in a freezer and refrigerator located in his apartment. His female companion, still living in the apartment, was taken into custody. She alleged that the decedent had died as a result of a heart attack approximately two weeks before, and she had decided to dismember his body for covert disposal in order to avoid contact with authorities. Investigation revealed her to be a fugitive, wanted for unlawful flight from another state to avoid prosecution for the murder of her 9-year-old daughter.

The decedent's female companion described the dismemberment technique as using a hacksaw and scalpel-like instrument with replaceable blades. After decapitation by severing the neck at the C7-T1 level, the head was boiled for several hours in a water-filled metal pot, with wine added to the solution during the process to offset the objectionable odor. When her expectation that the skull would fragment with vigorous boiling was unfulfilled, she began the process of sharp dissection of scalp and other soft tissues from the skull and upper spine. Portions of the cooked scalp, facial, and neck soft tissues were diced, and were being used as a dietary supplement for her two cats. Scene investigators discovered body parts in 15 assorted types of common kitchen food containers and plastic wrappings, sequestered in both freezer and refrigerator. A hacksaw and plaster of Paris molds of the decedent's hands and face were also found. During the subsequent trial of the decedent's female companion, which resulted in her conviction for the murder of her daughter, testimony revealed that she dismembered the daughter's body with instruments similar to those used in this case.

Autopsy Findings

General Autopsy Examination

The only cooked body parts were skull and upper neck, and diced soft tissue derived therefrom. Dismembered body parts which did not demonstrate evidence of cooking had been frozen, and were thawed just prior to autopsy. Dismembered body parts discovered included: skull and upper neck with skin and partial soft tissue removed; fragment of scalp with gray-brown hair; upper torso; lower torso; hands; feet; diced tissue composed of scalp and facial skin with some subcutaneous tissue; stomach and intestines; liver; and right lung. These bodies parts were variously packaged in plastic bags, a metal boiling pot (skull with upper neck), plastic containers with lids, or aluminum pans with aluminum foil covers. The heart, left lung, a portion of tracheobronchial tree, esophagus and great vessels were contained within the upper torso fragment, and the lower torso fragment contained the spleen, pancreas, adrenals, kidneys, ureters, a portion of urinary bladder, prostate and the attached external genitalia. A 6-in. surgical scar was present in the left inguinal area. The only missing body parts were both upper extremities from shoulders to wrists, both lower extremities from hips to ankles, and a portion of the removed head and neck skin and underlying soft tissue. Evidence of perimortem traumatic injury was not found in the available parts. The gross appearance of most organs was unremarkable. The heart weighed 450 g and it showed an estimated 75% stenosis of the right coronary artery and 50% stenosis of the proximal left anterior descending coronary artery.

Microscopy of portions of the diced scalp and facial tissue including fragments of nose, torso skin margins, lung, spleen, heart, aorta, pancreas, prostate, and adrenal gland was performed (brain findings are described below). Sections revealed mild to focally severe autolysis (the latter most evident in pancreas, adrenals, liver and spleen). Abnormal findings included pulmonary emphysema, extensive aortic atherosclerosis, cardiac myocyte hypertrophy and extensive myocardial interstitial fibrosis, and benign prostatic hypertrophy. No gross or microscopic evidence of recent trauma was present.

Toxicology

Broad-screen toxicology studies, including screening for heavy metals, were negative.

Radiology

Radiographic study of all recovered body parts revealed no evidence of remote or recent skeletal trauma.

Tool Mark Analysis

Skull, cervical vertebrae, and lumbar vertebrae were examined for tool marks, and they revealed mechanical trauma at the only two areas of spinal disarticulation, the C7-T1 level and the L3-L4 level. One group of tool marks was typical of a sharp instrument such as a knife, and the other group by a tool such as a saw. The saw cut characteristics were consistent with that produced by the hacksaw found at the scene. The tool mark analyst commented that the overall quality of the disarticulation demonstrated an unusually high level of ability to negotiate through an area of complex anatomical features with a minimum amount of mechanical trauma.

Identification

All body parts recovered were consistent with the missing uncle's known physical characteristics by physical anthropology analysis, without any duplications to suggest comingling of remains. Positive identification of the decedent as the missing uncle was ultimately accomplished by fingerprint analysis.

Cranio-cerebral Examination

Opening of the calvarium revealed extensive curd-like small fragments of gray-tan colored brain tissue filling a very enlarged epidural space (Fig 1). Histologically, these fragments were thermally-damaged brain tissue admixed with small amounts of extravasated blood. The curd-like brain fragments surrounded what initially appeared to be a "shrunken brain" covered by dark brown, leathery-appearing thickened dura mater (Fig. 2). An irregular dural defect in the left anterior frontal area (Fig. 2) allowed continuity between the tightly packed fragmented brain tissue within the

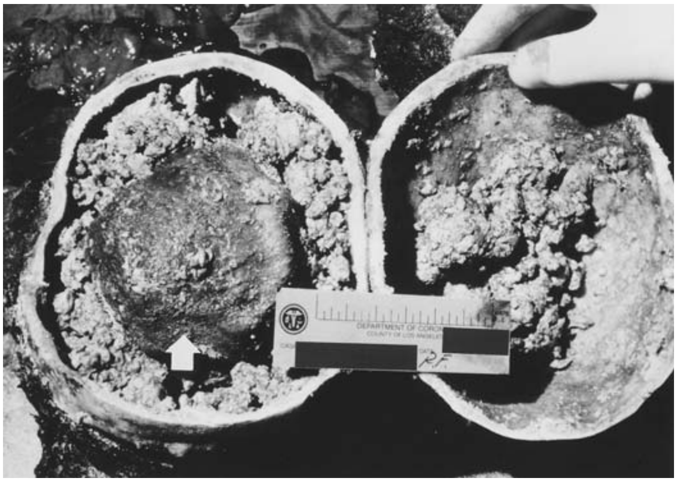

FIG. 1—*Appearance of the intracranial contents after removal of the calvaria and a portion of the curd-like brain fragments that filled the enlarged epidural space. The upper surface of the centrally located dark brown structure attached to the base of the skull has been exposed (arrow). (Scale = inches.)*

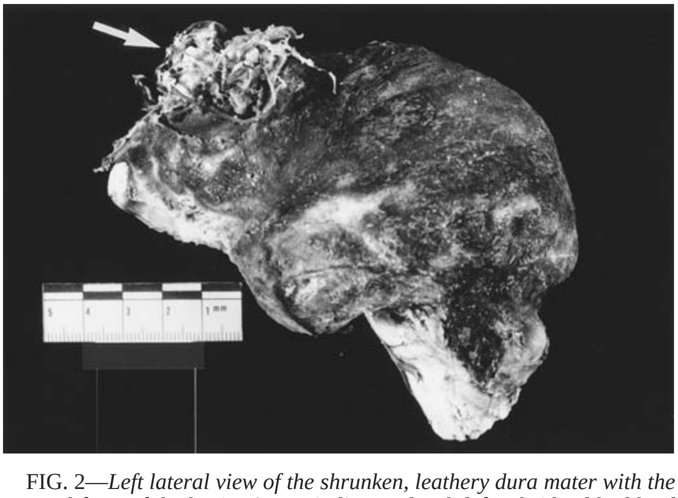

FIG. 2—*Left lateral view of the shrunken, leathery dura mater with the general form of the brain. Arrow indicates dural defect bridged by blood vessels in left anterior frontal area. (Scale in Figs. 2–4 = metric.)*

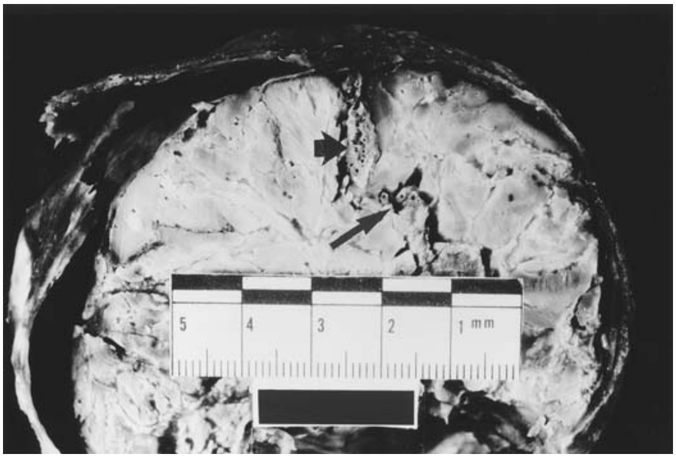

FIG. 3—*Coronal section of specimen seen in Fig. 2 at mid frontal level. Upper arrow indicates right side of the midline, calcified falx cerebri. Lower arrow (the tip of which is to the left of midline) indicates anterior cerebral artery complex, displaced from right to left and upward. Note disarranged, tightly packed brain fragments have replaced normal brain architecture.*

confines of the shrunken cranial dura (Fig. 3) and the more loosely-packed brain fragments in the epidural space. The cooked brain surrounded by the dura mater consisted of numerous, tightly-packed fragments with complete disruption of normal brain architecture. Clefts between fragments and displaced vessels formed a pattern indicating a streaming effect of fragments from right to left and upward (Fig. 3). The direction of flow was consistent with the fragments following the path of least resistance towards the left anterior frontal dural defect and into the enlarged epidural space. The dural defect was bridged by interlacing blood vessels derived from both meninges and brain, which formed a sieve-like structure through which brain tissue passed into the epidural space. The dark color of the external surface of the dura mater was due to a thin diffuse layer of thermally altered epidural blood. There was also sparse extravasated blood in the dura, and a thin layer of blood was widely but irregularly distributed in the subdural and subarachnoid space. This sparse but widespread extravasation of blood in epidural, intradural and subdural spaces, and the small amounts of blood admixed with the brain fragments in the epidural space and those still contained within the shrunken dura, was interpreted as thermal artifact. This appearance was considered to be the result of compression and fragmentation of thermally-altered brain tissue from dural shrinkage, with brain fragments squeezed into the epidural space through the dural rupture. No evidence of perimortem cranio-cerebral trauma was identified (e.g., skull fracture, focal large hematoma, and focal pooling of subarachnoid blood). Fragments of brain tissue also filled the subarachnoid space (i.e., internal to the cranio-spinal dura and external to the cerebellum, brain stem, and rostral cervical spinal cord pial surface) in the posterior fossa and rostral cervical spinal canal.

Microscopically, cytologic detail in routine histologic sections were expectedly suboptimal, reflecting both autolysis and thermal artifact, but all major cell types and tissues were easily recognized. The dura mater demonstrated typical thermal artifact and small amounts of epidural, intradural, subdural, and subarachonid blood without evidence of tissue reaction. No significant diagnostic abnormality was evident in the brain tissue.

The case was closed as cause of death undetermined, manner of death homicide.

Materials and Methods

To aid our interpretation of the findings, three simple experimental observations were performed in addition to routine autopsy and gross neuropathologic examination of the human remains in this case. First, two 5.0 × 10.0 cm rectangles of unfixed adult human dura mater were obtained from a separate autopsy case. One of these fragments was placed in boiling normal saline (boiling temperature by measurement 198°F), and removed and measured at 10 min intervals for 30 min. The second fragment was used as an untreated control. Human tissue use for such purposes in our department is authorized by Government Code section 27491. 45(a)(1). Second, an intact, whole beef brain without dura mater was obtained from a retail meat market, boiled in saline, and periodically removed, measured and weighed at intervals of 10, 20, 30, 60, 90, and 120 min. Third, routine histologic examination of the boiled beef brain tissue, using hematoxylin and eosin stains was performed in order to compare its appearance with the human brain tissue from this case.

Results

The boiled fragment of dura mater rapidly underwent shrinkage, becoming dark tan, curled, and more brittle and susceptible to tearing when manipulated (Fig. 4). Its general appearance was quite similar to that of the dura mater from our case. When measured after 10 min of boiling, its dimensions were 2.5 × 4.0 cm (original dimensions 5.0 × 10.0 cm). Further boiling did not result in additional shrinkage.

The reduction in linear measurement, volume, and weight of the boiled beef brain was much less rapid and much less dramatic than that of the human dura mater. The original linear measurements in anterior-posterior, coronal, and vertical height parameters of the unboiled beef brain were 14.0 × 11.0 × 6.0 cm, respectively, and its original weight was 532 g. Boiling resulted in a very gradual reduction in linear measurements to 13.0 × 10.0 × 5.0 cm, respectively, and a weight reduction to 398 g, achieved after 120 min of boiling. At the initial measurement period of 10 min, the beef brain linear measurements were unchanged from baseline and the weight loss was only 2.0 g.

The histologic appearance of the beef brain tissue was very similar to that of the human tissue from our case, described above, both

FIG. 4—*A = 5.0 × 10.0 cm rectangle of untreated, fresh human dura mater. B = appearance of dural fragment (originally identical to that designated as "A") after boiling in normal saline for 10 min.*

with regard to the degree of autolysis and alterations secondary to thermal artifact.

Discussion

Thermal injury to scalp, skull and central nervous system tissues are frequently encountered in forensic case material, generally in the context of residential fires, fires resulting from automobile or airplane crashes, or due to attempted disposal of remains by burning in instances of homicide (1–9).

Altered facial and scalp skin and soft tissue color changes (e.g., yellow, tan, brown and/or black), charring, and skin splitting and blistering may be seen. Heat-induced skull fractures may include fine crisscrossing heat fractures of the surface (patina-type fracture), splintering, fragmentation, loss of only the outer table of the skull (lamination fracture) which exposes the diploic space, and linear, stellate or bursting fractures. Burned bone may be tan, brown, black, or gray to white in color, depending on the intensity and duration of burning. Thermal fractures of skull have a tendency to parallel scalp burn line edges. If skull fracture lines are remote from burned bone and soft tissue (e.g., skull base fractures with only calvaria burns), traumatic fracture should be considered. If fracture lines on inner and outer table are offset, rather than superimposed, thermal injury is more likely. Since burned bone is more fragile, differential diagnosis includes postmortem fracture during body transport or by collapse of structures on a burned body in, for example, residential fires. The former can be minimized by gently handling of burned bodies, and the latter excluded or included in the differential diagnosis by information obtained by scene investigation and interview of first responders.

Epidural hematoma resulting from thermal postmortem artifact is typically chocolate-brown in color, has a spongy character and crumbles readily. It is more likely to be diffuse, or to at least extend across the midline, in contrast to epidural hemorrhage secondary to perimortem trauma. Its source may be blood from venous sinuses, emissary veins, or bone marrow. In the latter instance, liquefied fat may be demonstrable histologically within the artifactual epidural hematoma (1).

The presence of subdural hemorrhage should cause the examiner to look carefully for evidence of perimortem trauma, particularly if it is seen in the absence of heat-induced epidural hemorrhage. Traumatic subdural hemorrhage is frequently bilateral, but most often unilateral. If bilateral, it is not in continuity across the midline. It may be widely spread or, less commonly, well-circumscribed. Depending on duration, it may be associated with evidence of tissue reaction, underlying subarachnoid hemorrhage, or brain injury. Particularly in the presence of skull fracture, juxtaposed epidural hemorrhage may occur.

We have rarely encountered small (e.g., 1 to 2 mL) subdural hemorrhage in juxtaposition to large thermally-induced epidural hematomas, without evidence of mass effect or other findings to suggest perimortem trauma, and conclude that this specific aggregate of findings may infrequently be the result of postmortem thermal injury.

Brain tissue directly exposed to intense heat without interposed fluid may undergo desiccation and become friable and severely charred. Less severe degrees of thermal injury, particularly where soft tissue and cerebrospinal fluid (CSF) remain intact between the heat source and the brain, will cause increased firmness of brain parenchyma. Examination of such brains by routine methods can still be very useful, since overall structural integrity is often well-preserved.

There are few reports in the literature which describe brain tissue extruded into the epidural space in association with postmortem thermal artifact.

Reuter (10) described an instantly fatal high voltage electrical death in which a portion of skull was severely charred, dura was detached from the skull inner table in a circular area, and the resulting enlarged epidural space was filled with a pulp of brain and charred blood. Dotzauer (11) observed this phenomenon in burned bodies, typically restricted to the epidural space underlying areas which demonstrated the most severe burns. The appearance of the extruded cerebral tissue in the epidural space in sagittal sections of the head was described as similar in shape to a cauliflower or mushroom. The extremes of age range of such cases are represented by two residential fire victims. One was described by Schneider (12) in the frontal region of an 80-year-old female residential fire victim, and the second by Kondo and Ohshima (13), restricted to the left temporal lobe area in an 8-year-old girl found in a burned residence. Knight's publication (6) is singular among modern forensic pathology texts in noting this phenomenon, referencing the 1994 article by Kondo and Ohshima. A prior edition of this same text (1991), clearly describes the same phenomenon as a consequence of postmortem thermal artifact. Denton and his colleagues (14) observed epidural herniation of brain tissue in 2 of 14 victims of a disaster in which two small passenger airplanes crashed and burned at an airport runway intersection.

Based on our autopsy and experimental observations, it appears that the infrequent occurrence of the thermal artifact seen in this case requires a unique combination of factors. First, there must be thermal injury to the head area. The heat delivery method is not specific. Extrusion of at least limited amounts of brain tissue into a focally enlarged epidural space has been described in such varied circumstances as high voltage electrical burns (10), residential fires (6,11–13), and airplane crash fires (14). Previous reports have suggested that temperatures in the range of 1200–1600°F (for house fires) (9) or much higher temperatures resulting from high voltage electrical burns or fires generated by airplane fuel, are required to produce this unusual artifact. In contrast, our case demonstrates that temperature in the range of only approximately 200°F (i.e., near boiling) was sufficient to reproduce this effect. Second, some time is required, at least a few minutes, with this feature probably subject to variation dependent on rate of temperature increase, maximum temperature elevation, relative exposure of the head to the heat source, and other undetermined factors. For example, we found no descriptions of this type of thermal artifact in reports of CNS pathologic changes following judicial electrocutions. In a single case report in which extrusion of brain tissue into the epidural space did result from a high voltage electrical burn (10), it appears that the victim was in prolonged contact with the heat source based on the skull bone being described as charred and "calcined." Such extensive thermal effects may well have occurred after a longer period of heat exposure than the intracranial changes identified in this case. Third, the dura mater must separate from the inner table of the skull, creating an enlarged epidural space into which the brain tissue can extrude. There is considerable individual variation in the ease with which cranial dura mater can be stripped from the inner table of the skull. In general, such separation is more difficult in the very young and in the elderly. The dura mater normally is more adherent to the skull at unfused cranial suture lines (due to its continuity with outer table periosteum at such sites), at the skull base, and around the foramen magnum. The age range of reported cases of this thermal artifact is 8 years to 80 years, indicating that age group alone is not a predictive factor. Fourth, disproportionate shrinkage of dura mater more than brain parenchyma is required in order to create the pressure differential favoring extrusion of a significant volume of brain tissue into the extradural compartment. This differential shrinkage was observed in our simple experiment on boiled human dura mater and beef brain. Fifth, there must be a defect in the shrunken dura through which brain parenchyma can extrude into the enlarged epidural space created by the separation and shrinkage of dura mater from the inner table of the skull. If no dural defect develops, the expected result would be that clearly illustrated by Fig. X-26 in the classic forensic medicine textbook by Spitz and Fisher (4), where intact, shrunken dura is surrounded by a large, vacant epidural space. It is likely, in the absence of a dural defect, that the progressively compressed brain tissue will be displaced downward into the spinal canal subarachnoid space. Sixth, persistence of a fluid environment in the cranial cavity is probably necessary for this type of thermal artifact to occur. The fluid in most instances will be the endogenous CSF. In the case described here, the CSF lost at decapitation was replaced by boiling water in the pot in which the head was immersed. The fluid must be present until moist brain fragments are extruded into the epidural space, although continued thermal injury may result in superimposed loss of scalp, fractures of the skull, and loss of CSF. If intracranial fluid loss occurs early in the thermal injury process, it can be postulated that the resultant desiccation with attendant tissue shrinkage, charring, etc., will lead to an entirely different, and more commonly encountered appearance. This speculation is supported by a recent study in which fully fleshed, unembalmed human heads were burned under controlled conditions (15). Brain tissue was described as exhibiting a variety of reactions to heat including shrinkage, expansion and fungating or moist oozing from preexisting openings. No extrusion of curd-like brain fragments into epidural space was specifically described. The description by Pope et al. (15), is suggestive of an appearance more analogous to the shrunken dura in Fig. X-24 in the textbook by Spitz and Fisher (4), rather than the appearance demonstrated in our case.

An example of what might be more accurately inferred by the term “shrunken brain,” described as the size of a “miniature orange” and “hard as stone” occurred in an embalmed body which was recovered after burial at sea nearly a year previously (16). The authors suggest that this unusual postmortem artifact resulted from penetration of hypertonic sea water into the cranial vault. A second unusual example of brain tissue shrinkage, in this instance demonstrating disproportionately greater shrinkage of brain tissue than of overlying dura mater, has been recently described in imaging studies of a human mummified corpse found in an icefield in the Tyrolean Alps (17). These remains are believed to be from an individual who had lived during the Copper Age, more than 5000 years ago. An appearance similar to that of the latter two unique cases of “brain shrinkage” has not, to our knowledge, been described as due to thermal injury.

In summary, this case illustrates postmortem, thermally-induced differential relative shrinkage of dura mater and brain in a decapitated man’s head, resulting in extrusion of the compressed brain tissue through a dural defect into the epidural space. The differential shrinkage of dura and brain was reproduced in a simple experiment by boiling each in saline. Literature on the subject is reviewed, and several conditions apparently necessary for the occurrence of this uncommon postmortem artifact are set forth.

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