

Characteristics of Vertebral Body Augmentation in Human Skeletal Remains

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ABSTRACT: Vertebral body compression fractures are extremely common in adults in the United States, particularly postmenopausal women. Vertebral body compression fractures are associated with increased mortality and morbidity and often require medical intervention. Vertebral augmentations such as percutaneous vertebroplasty and kyphoplasty are routinely used to treat vertebral body compression fractures. Here we present two unrelated case studies of willed-body donors exhibiting gross dry bone vertebral augmentations consistent with percutaneous vertebroplasty and kyphoplasty. Vertebrae on both donors exhibit characteristics associated with vertebral body compression fractures, such as decreased vertebral height, as well as protruding areas of a hard, off-white colored substance, which was determined to be bone cement. Additionally, radiographic imaging of the affected vertebrae of both donors exhibits the internal presence of bone cement throughout much of the vertebral bodies. Understanding this medical procedure as well as its morphological characteristics permits forensic anthropologists to correctly recognize these vertebral augmentations and associated abnormalities. Additionally, knowledge of these procedures could assist in the identification process of unknown individuals expressing these characteristics.

KEYWORDS: vertebroplasty, kyphoplasty, pathology, trauma, identification, death, investigation

Introduction

Vertebral body compression fractures (VCFs) are common and primarily occur due to osteoporosis, however trauma and pathologies (e.g., Schmorl's nodes, tumors, infections) may also cause VCFs. Roughly 1.5 million adults in the United States are diagnosed with a VCF every year (Alsoof et al. 2022; Hyot et al. 2020; Lindquester et al. 2020). Approximately 25% of all postmenopausal women will experience a VCF, and ~40% women will experience a VCF by age 80 (Alexandru & So 2012). This is largely due to postmenopausal hormonal changes leading to osteoporosis and decreased bone mineral density (Alexandru & So 2012). Having one VCF increases the risk of future VCFs; Lindsay

et al. (2001) found that almost 20% of postmenopausal women with one VCF experienced another within one year, arguing for the importance of medical care and, potentially, medical intervention. Additionally, VCFs are associated with increased mortality and morbidity (Lindsay et al. 2001).

The diagnosis of a VCF is based on the observation of at least a 20% loss of vertebral body height in the anterior, middle, or posterior craniocaudal dimensions (Lenchick et al. 2004). VCFs may result in chronic pain, immobilization, kyphosis, pulmonary deterioration due to pain and kyphotic deformity, and subsequently depression (Jay & Ho Ahn 2013). Clinically, VCFs are often treated with analgesics, bed rest, and external bracing, however approximately one-third of patients require additional treatment with a percutaneous vertebroplasty or kyphoplasty to relieve pain and improve mobility (Jay & Ho Ahn 2013).

Percutaneous vertebroplasty and kyphoplasty are well-accepted and minimally invasive approaches used to stabilize vertebral bodies experiencing a VCF. These augmentation procedures are similar. For a vertebroplasty, a trocar (i.e., hollow needle) is inserted into the vertebral body, typically through one pedicle, and bone cement is injected and allowed to harden (Hide & Gangi 2004). Bone cement is typically polymethyl methacrylate (PMMA), which is injected percutaneously under imaging guidance, typically fluoroscopy (Jay & Ho Ahn 2013). The injected volume of cement varies but is typically between 3.5 and 5.0 mL,

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depending on the size of the vertebra (Jay & Ho Ahn 2013; Kallmes et al. 2009). PMMA has a curing time of approximately nine minutes and, once cured, has a composition similar to concrete, which reinforces the vertebral body from further collapse, improves mobility, and reduces pain (Belkoff et al. 2001; Fletcher et al. 2021).

The primary difference between vertebroplasty and kyphoplasty is that vertebroplasty stabilizes the vertebral body as it is, while kyphoplasty attempts to restore height to the vertebral body and reduce kyphosis. For kyphoplasty, the trocar is inserted into each pedicle, and bone tamps (i.e., balloons) are fed down the trocar into the vertebral body. The bone tamps, capable of sustaining high pressure, are then inflated to create a cavity within the vertebra to restore height to the vertebral body. These inflated cavities are then filled with the bone cement (Kasper 2010). Small amounts of cement can leak from the vertebral body prior to hardening. If leakage occurs in the spinal canal, this can result in neuropathies (Shen & Kim 2006).

Here we present the dry bone characteristics of two individuals exhibiting evidence of vertebral augmentations from Western Carolina University's (WCU's) willied body donation program (George et al. 2022). WCU's willied body donation program operates in support of its human decomposition facility, the Forensic Osteology Research Station (FOREST). Along with the legally required paperwork for willied body donation, WCU requests living pre-donors and the surviving next-of-kin of deceased donors to complete an antemortem biological questionnaire inquiring about donor life circumstances, including medical histories. Given that individuals rarely maintain detailed personal medical histories, these forms frequently do not include significant medical procedures such as hip or knee replacements (or vertebroplasties). The biological questionnaires on the individuals examined in this report, for example, did not denote having had a vertebral augmentation procedure.

Case 1

Case 1 represents an elderly adult female. The individual had consented to destructive taphonomic research, so after intake at WCU, the remains took part in a controlled burn as part of a continuing education course in 2022 (George et al. 2024). After the thermal alterations, the individual decomposed in the FOREST and was subsequently cleaned and curated in WCU's John A. Williams Human Skeletal Collection. During processing for curation, abnormal characteristics were observed on the first lumbar vertebra (Figs. 1 and 2). This vertebra presented as abnormally heavy with a collapsed vertebral body, where portions of the superior vertebral body's cortical bone were absent and a hard, off-white substance was protruding in some areas. This individual did not note any previous medical

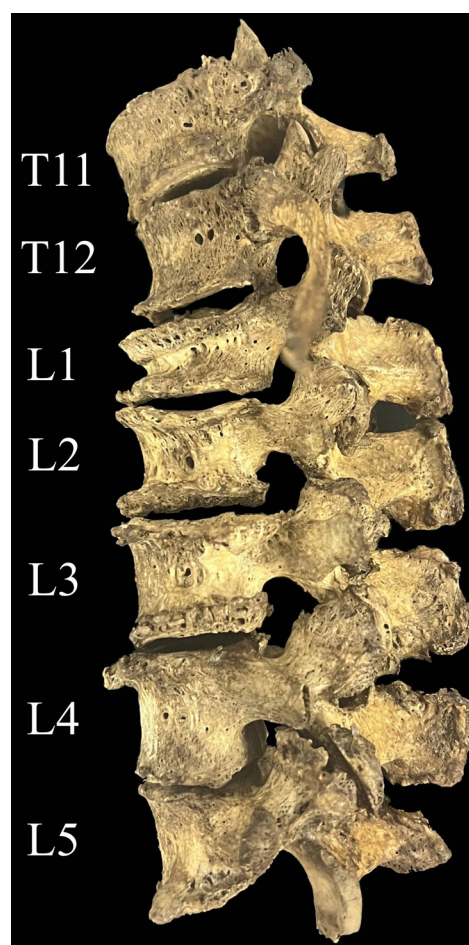


FIG. 1—Lateral view of the vertebrae of Case 1. Note compressed body of the first lumbar vertebra.

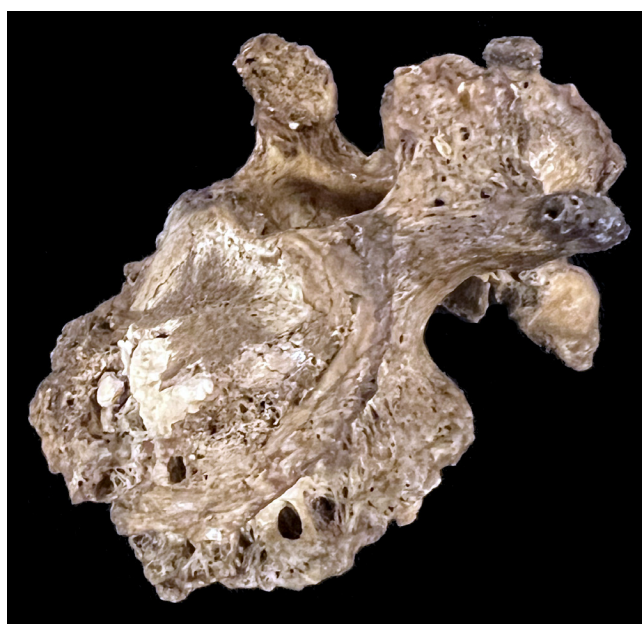


FIG. 2—Oblique view of first lumbar vertebra of Case 1. Note off-white substance protruding from superior surface of the vertebra body.



FIG. 3—Radiograph of superior view of lumbar vertebra from Case 1.

procedures on their optional donation paperwork, so the cause of the abnormality was unclear with multiple possible origins initially hypothesized (e.g., antemortem neoplasm, antemortem surgical augmentation, postmortem fungal growth).

Laboratory analyses were performed to investigate the abnormal vertebra. Gross observation of the vertebra did not locate any obvious areas of antemortem needle insertion; however, the cortical bone of the vertebra was porous, which may have obscured surgical defects. The cortical bone on the superior vertebral body was thin and fragile, suggesting that the absent portions of bone in this area may have occurred postmortem during decomposition outside. Radiography of the vertebra demonstrated that the unknown substance was present throughout the inside of the vertebral body (Fig. 3). The unknown substance was analyzed using Fourier Transform Infrared Spectrometry (FTIR). The resulting spectrum showed the presence of PMMA and barium sulfate, consistent with bone cement (Fig. 4). Based on these results, the compressed vertebral body and presence of bone cement are indicative of vertebral augmentation; due to a lack of medical history for this donor, the pathogenesis and age at surgical intervention are unknown. It is unclear if this augmentation represents a vertebroplasty or kyphoplasty, but a vertebroplasty seems more plausible as there does not appear to be any indications of inflation of the vertebral body from a kyphoplasty procedure (e.g., increases in vertebral body height, voids within the vertebral body where the bone cement did not fully infill).

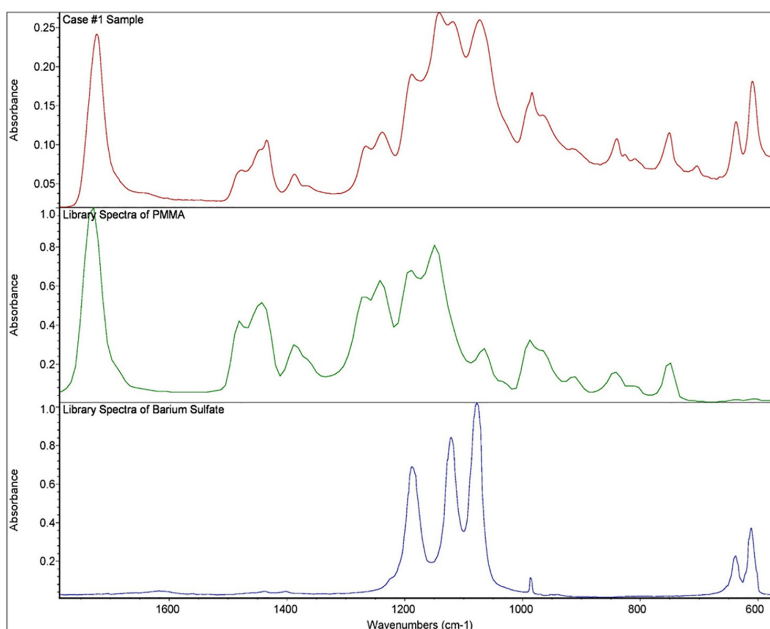


FIG. 4—FTIR spectra of (a) substance inside L1 of Case 1, (b) library spectra of pure PMMA, and (c) library spectra of pure barium sulfate showing the presence of PMMA and barium sulfate in substance inside L1 of Case 1.

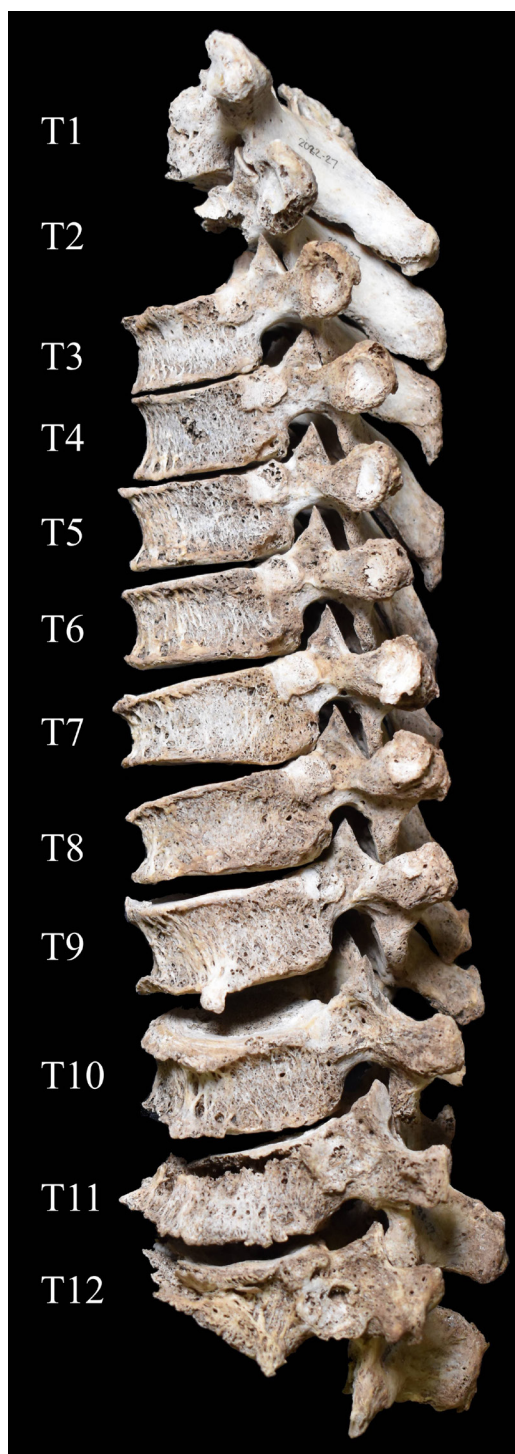


FIG. 5—Lateral view of thoracic vertebra of Case 2. Note compressed vertebral bodies of T11 and T12.

Case 2

Case 2 represents an elderly adult male individual. Similar to Case 1, this individual was donated to WCU's Forensic Anthropology Program and decomposed in the FOREST prior to awareness of any vertebral abnormalities. Also



FIG. 6—Lateral view of lumbar vertebrae of Case 2.

similarly, after decomposition, this individual was cleaned and curated at WCU, and it was during this process that vertebral abnormalities were observed. Unlike Case 1, which had only one abnormal vertebra, this individual exhibited partially or fully collapsed vertebral bodies on thoracic vertebrae 11–12 and lumbar vertebrae 1–5, as well as associated surgical augmentations on thoracic vertebra 12 and lumbar vertebrae 1–5 (Figs. 5–7). In this case, leakage of the bone cement was observable on multiple vertebrae (e.g., coming out of the superior aspect of the vertebral body of L5). Again, radiography was used to document the internal presence of bone cement (e.g., Figure 8).

Unlike the previous case, some antemortem medical information was provided for this individual, however it consisted entirely of “back surgery—2022” and “fractured vertebrae in his back.” Assuming the back surgery mentioned in the donor information relates to these vertebral augmentations, then they would have occurred less than one year prior to death. It is unclear if these surgical augmentations represent vertebroplasties, kyphoplasties, or some mix of both. However, kyphoplasty seems more plausible, at least for lumbar vertebrae 2–4, due to the extra cortical bone deposition on the lateral aspect of the vertebral bodies and the radiographically observable separation of the pockets of bone cement in the vertebral bodies, indicating bilateral injections. The

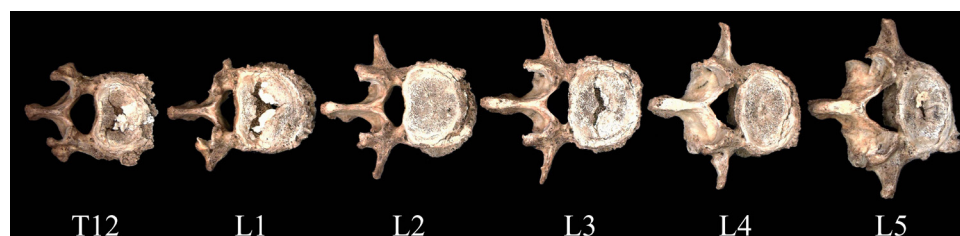


FIG. 7—Superior view of T12–L5 of Case 2. Note protruding bone cement on multiple vertebrae.

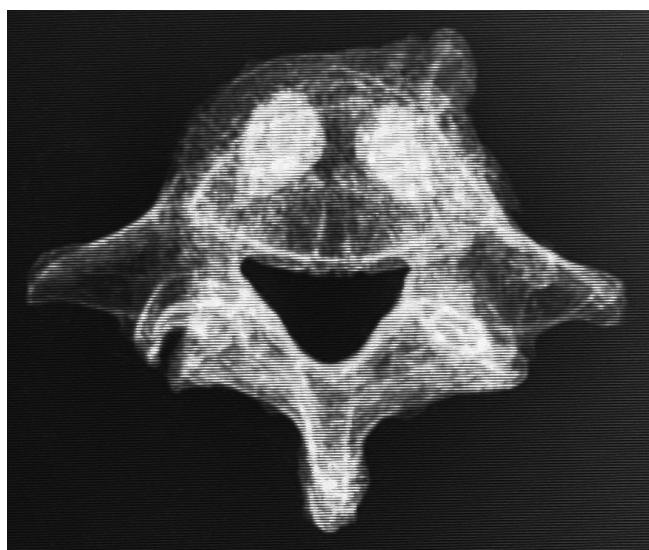


FIG. 8—Radiograph of superior view of fifth lumbar vertebra from Case 2.

abnormal bone deposition could be the result of changes in vertebral body height due to the VCF decreasing the vertebral body height prior to a kyphoplasty attempting to increase the vertebral body height through inflation of bone tamps.

Discussion/Conclusions

According to Laratta (2017), 81,690 patients had vertebroplasty procedures and 169,413 patients had kyphoplasty procedures in the United States between 2006 and 2014. Lindquister et al. (2020) noted that there were ~70,000 kyphoplasty procedures for Medicare patients in 2018 alone. Considering the large quantity of vertebral compression fracture procedures performed every year, forensic anthropologists are likely to encounter evidence of these medical interventions occasionally in their casework and research. While anyone suffering from a VCF may have vertebral augmentation performed, such interventions are much more likely to be found in elderly individuals, especially females.

Understanding this medical procedure, as well as its radiographic and dry bone characteristics, can assist forensic anthropologists in correctly recognizing these vertebral abnormalities, which may otherwise be confounding.

Additionally, knowledge of these procedures could potentially assist in the identification process of unknown individuals expressing these characteristics. Individuals with vertebral body augmentations likely have antemortem radiography available for comparison as a result of these medical interventions. Not only does the bone cement provide highly variable and individualizing radiographic features for comparisons in support of an identification, but in some circumstances, voids may be left unfilled by the cement, which can also be used to support a radiographic identification.

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