A32 Early Signs of Direct Fracture Repair and Indirect Intramembranous Fracture Repair Without Indications of Endochondral Ossification in the Ribcage

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After attending this presentation, attendees will better understand the early stages of osseous healing and their macroscopic manifestation on dry skeletal material.

This presentation will impact the forensic science community by highlighting the need to carefully examine all fractures, including minute incomplete fractures associated with major fractures, for slight irregularities indicative of short-term survival after a traumatic event.

Partially skeletonized human remains were discovered beneath a structure that had collapsed several months prior. Associate Medical Examiner Dr. Kyle Shaw of Florida's District 5 Medical Examiner's Office evaluated the scene and remains; he referred the latter to the University of Florida C.A. Pound Human Identification Laboratory (CAPHIL) for additional analysis. Assessments at the CAPHIL indicated that the remains were those of a middle- to older-aged adult female of primarily European ancestry. Analyses also revealed the presence of several complete and incomplete fractures of the anterior rib cage. All fractures to right ribs 2-7 and left ribs 2-5 were consistent with an anterior loading (compression) event. These fractures were examined under 7-80x magnification using a stereoscope. Although most complete fractures revealed no indications of healing and were consistent with peri-mortem trauma, several incomplete fractures, including those directly associated with a complete fracture, revealed indications of very early osseous repair. Small spicules of new bone were present adjacent to larger incomplete fractures and bridge smaller incomplete fractures. In both cases, bony spicules were oriented perpendicularly to the long axis of fracture. The large majority of new bone present cannot be visualized on plain film radiography.

While there is extensive literature on the cellular and molecular changes underlying early fracture repair, there is a dearth of literature addressing the gross, anatomical appearance of early fracture healing in human skeletal material. Immobilized, highly mechanically stable fractures, including stress fractures and incomplete fractures, may demonstrate a high degree of direct healing and indirect intramembranous ossification.[1] For both direct repair and indirect intramembranous repair, bone formation at fracture sites begins prior to (and on rare occasions, in lieu of) endochondral ossification of a soft callus.[2] In direct healing, the cells in the local cortical bone build new lamellar bone and Haversian systems without intermediary woven bone.[3] This type of repair occurs only at fracture gaps of less than ~1mm with low interfragmentary strain (i.e., fractures that do not require calluses for stabilization).[3] In indirect healing, the intramembranous hard callus is deposited without a precursor onto the existing bone surface from the subperiosteal layer and forms adjacent to fracture margins before progressing toward the fracture line.[4] In non-human animal studies, intramembranous bone deposition usually begins by day three post-fracture.[5] In contrast, woven bone deposition in endochondral ossification may not begin until ~14 days post-fracture.[6]

Despite the mix of fractures with and without indications of healing in the rib cage of the forensic case examined by the CAPHIL (a mix observed even along the margins of a single fracture area), it is likely most of the fractures occurred as a result of a single, compressive event. Death occurred after the body initiated direct and intramembranous fracture healing at the incomplete (mechanically stable) fracture locations, but prior to any endochondral ossification at the complete (mechanically unstable) fracture sites. Although individual variation and a lack of studies on timing of these fracture repair stages in humans render an exact timetable difficult to establish, these findings suggest the individual died very shortly, but not immediately, after injury. In this particular case, these findings may have implications for cause of death. This case study illustrates the importance of careful examination of *all* fracture surfaces via light microscopy. Further, this case study highlights the need for future studies/autopsy series designed to elucidate macroscopic changes associated with fracture repair and the timing of ossification in human adults. Such findings would not only aid forensic scientists reconstructing the last days of someone's life, but would augment clinical understandings of human skeletal repair as well. In addition, because bone is one of the few truly regenerative tissues, better understanding of the initiation of bone regeneration in humans could have an important impact on tissue engineering.

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