Three-Dimensional Ultrasound Reconstruction of Sonographic Callus: A Novel Imaging Modality for Early Evaluation of Fracture Healing

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Purpose: Sonographic callus may enable assessment of fracture healing. The aim of this study was to establish a reliable method for 3-dimensional reconstruction of sonographic callus.

Methods: Patients who underwent nonoperative management of displaced midshaft clavicle fractures and intramedullary nailing of tibia fractures were prospectively recruited and followed to union. Ultrasound scanning was performed at periodical time points following injury. Infrared tracking technology was used to map each image to a 3-dimensional lattice. Criteria were first established for 2-dimensional bridging callus detection in a pilot study. Using echo intensity of the ultrasound image, semi-automated mapping was used to create an anatomic 3-dimensional representation of fracture healing. Agreement on the presence of sonographic bridging callus was assessed using the kappa coefficient and intraclass correlation coefficient (ICC) between observers.

Results: 112 clavicle fractures and 10 tibia fractures completed follow-up at 6 months. Sonographic bridging callus was detected in 62.5% (n = 70 of 112) of the clavicles at 6 weeks post-injury. If present, union occurred in 98.6% of the fractures (n = 69 of 70). If absent, nonunion developed in 40.5% of cases (n = 17 of 42) (73.4% sensitive and 100% specific to predict union). Out of 10 tibia fractures, 7 had bridging callus of at least 1 cortex at 6 weeks and when present all united. Of the three patients lacking sonographic bridging callus, one went on to nonunion (77.8% sensitive and 100% specific to predict union). Figure 1 shows medial tibia cortex bridging callus with extensive remodeling at 3 months post-injury in a patient who united. The ICC for sonographic callus between four reviewers was 0.82 (95% confidence interval 0.68-0.91).

Conclusion: Three-dimensional ultrasound reconstruction of bridging callus has the potential to identify impaired fracture healing at an early stage in fracture management.