

## **Preoperative bone density measurements from computed tomography (CT) scans predict 3-month healing of surgically treated scaphoid nonunions: A multicenter cohort study**

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**INTRODUCTION:** As 10% or more of scaphoid nonunions fail surgical treatment, there is a need to understand which scaphoid nonunions are likely to heal. Relative bone density (RBD) of the proximal and distal scaphoid poles relative to the triquetrum has been shown to predict nonunion in nonoperatively managed subacute scaphoid fractures. We hypothesized that RBD would predict 3-month healing of scaphoid delayed unions or nonunions treated by open reduction and internal fixation (ORIF).

**METHODS:** We identified a retrospective cohort of non-united scaphoid fractures treated with ORIF between 6 weeks and 2 years after injury at two academic medical centers between January 1, 2003 and December 10, 2021 (N=73). Included patients were  $\geq 18$  years old with a pre-operative CT scan within 18 weeks of ORIF and no vascularized bone grafting, trans-scaphoid perilunate fracture dislocation, radiocarpal osteoarthritis, previous scaphoid surgery, open fracture, large central cyst, or proximal pole collapse. Bone density was measured in each radiographic plane by 2 observers from pre-operative CT scans using standard clinical radiology software. Inter-observer reliability was assessed using intraclass correlation coefficients (ICC). RBD was calculated as the ratio of mean bone density in the fracture fragments relative to the triquetrum for each fragment and the difference between proximal and distal fragments. Predictive accuracy for healing at the scheduled 3-month visit using optimal RBD cutoffs was described using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and c-statistic.

**RESULTS:** 64 of 73 patients (88%) included in the cohort had a recorded outcome at the 3-month visit and 12 of 64 (18.8%) were classified as non-healing. Inter-observer reliability for bone density measurements was higher in the coronal and sagittal planes (ICC range 0.87-0.99) than the axial plane (ICC range 0.63-0.98); thus, the axial plane was not used for prediction. Predictive characteristics in the coronal and sagittal planes were similar. PPVs for healing ranged from 0.82-0.92 and NPVs ranged from 0.18-0.33 for all predictors. The highest PPV was obtained using the difference between RBD of the proximal and distal fragments (coronal, sagittal planes: PPV 0.87, 0.92; NPV 0.22, 0.25; c-statistic 0.50, 0.72). Using this predictor in the coronal plane, 22 of 52 fractures in the healing group had difference RBDs below the cut point (42.3%), and 10 out of 12 fractures (83.3%) in the non-healing group had difference RBDs above the cut point.

**DISCUSSION AND CONCLUSION:** The difference in RBD between the proximal and distal fragments performs well in identifying fractures that are very likely to have healing at 3 months; using either the coronal or sagittal plane, the probability of 3-month healing progression for fractures with difference RBDs below the cutoff is 87% or higher. RBD is not predictive for fractures above the cutoff, possibly reflecting the role of surgical technique and fixation quality in healing.