The novel application of high resolution peripheral quantitative ct imaging in distal radius and scaphoid fractures

Summary thesis Anne Daniels

'The novel application of High Resolution peripheral Quantitative CT imaging in distal radius and scaphoid fractures'

In this thesis, we studied the association of patient characteristics, bone mineral density (BMD, measured by Dual Energy X-ray Absorptiometry (DXA)), bone microarchitecture and calculated bone strength (by High Resolution peripheral Quantitative Computer Tomography (HR-pQCT)) with the pattern complexity and secondary displacement of distal radius fractures. Subsequently, we studied the novel application of HR-pQCT for detection of scaphoid fractures, compared to current diagnostic modalities such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Bone Scintigraphy (BS).

Chapter 1 sets out the background and outline of this thesis and presents an overview of the epidemiology, classification and treatment of distal radius and scaphoid fractures.

In ***chapter 2*** we have investigated the association of patient characteristics, BMD, bone microarchitecture and bone strength (assessed with HR-QCT) with the pattern complexity of distal radius fractures. In a cohort of 251 patients aged 50-90 years, we have demonstrated that age (Odds ratio (OR) 1.11, 95% CI 1.03-1.19) and male gender (OR 8.48, 95% CI 1.75-41.18) were independently associated with the pattern complexity of distal radius fractures. Other factors known to be associated with fracture risk, including body mass index, BMD, number and severity of prevalent vertebral fractures, smoking and alcohol use were not associated with distal radius fracture pattern complexity. In addition, bone microarchitecture and bone strength were not associated with fracture pattern complexity. This indicates that, besides age and gender, trauma mechanism may also be an important determinant for distal radius fracture pattern complexity.

Chapter 3 described the association of patient characteristics, BMD, bone microarchitecture and strength with secondary displacement of distal radius fractures based on radiographic alignment parameters. In our cohort of 251 patients, the most important determinant for secondary displacement of a distal radius fracture was primary reduction (OR 22.00, 95% CI

2.27-212.86). While age, gender, bone mineral density measured by dual-energy X-ray absorptiometry and prevalent vertebral fracture status were not associated with secondary fracture displacement, lower total (OR 0.16, 95% CI 0.04-0.68) and cortical volumetric bone mineral density (OR 0.19, 95% CI 0.05-0.80) and lower cortical thickness (OR 0.13, 95% CI 0.02-0.74) at the distal radius were independently associated with secondary displacement of a distal radius fracture. This implies that besides primary reduction, poor cortical bone quality may be important for the risk of secondary displacement of distal radius fractures.

In chapter 4 to 7, we studied the application of HR-pQCT for detection of scaphoid fractures. As there were no data available in literature regarding the feasibility of HR-pQCT imaging of the scaphoid bone, we performed a prospective cohort study in 91 consecutive patients, ≥ 18 years with a clinically suspected scaphoid fracture. In the emergency department (ED), conventional radiographs of the scaphoid bone were made. Independent of the diagnosis on these initial radiographs, cast immobilization was applied and reassessment at the outpatient clinic was performed within 7 to 14 days after trauma. Conventional CT and HR-pQCT of the scaphoid bone were scheduled immediately following reassessment.

In *chapter 4* we compared a fully automated and a semi-automated contouring procedure of the scaphoid bone and evaluated the microarchitectural indices in good- and poor- quality scans. We found that it was necessary to extend the standard cast with an additional (removable) thumb part in order to reduce motion artifacts. After this modification, the proportion of poor-quality stacks was similar to distal radius and tibia scans and automatic contouring starting from course hand-drawn pre-contours appeared to be appropriate in good and bad quality scans. We concluded that In vivo HR-pQCT scanning of the scaphoid bone is feasible in patients with a clinically suspected scaphoid fracture when using a cast with thumb part.

Based on the findings in chapter 4, we investigated the interobserver agreement of the diagnosis and classification of scaphoid fractures, in a randomly selected subgroup of 31 out of the 91 patients, in *chapter 5*. We found an interobserver agreement of 91% for the identification of a scaphoid fracture of (κ = 0.91, 95% CI 0.76-1.00) and 80% for the identification of other fractures of (κ = 0.80, 95% CI 0.72-0.87). Additionally, the mean intra-

class correlation coefficient for the classification of a scaphoid fracture in the seven patients diagnosed with scaphoid fracture by all four observers was 73% (95% CI 0.42-0.94). We concluded that the diagnosis of scaphoid and other fractures using HR-pQCT is reliable in patients with a clinically suspected scaphoid fracture.

To investigate whether the use of HR-pQCT increased scaphoid fracture detection, we compared this technique to conventional CT in our cohort of 91 patients with a clinically suspected scaphoid fracture in *chapter 6*. The number of patients diagnosed with a scaphoid fracture was 60% higher when using HR-pQCT (N=24) compared to CT (N=15). The correlation between CT and HR-pQCT was high for the Herbert classification of scaphoid fractures (Kendall rank correlation coefficient (W) 0.793, $p<0.001$) and very high (W 0.955, $p<0.001$) for scaphoid fracture location (proximal, waist, distal). We therefore concluded that scaphoid fracture detection with HR-pQCT is superior compared to conventional CT and that HR-pQCT could be a promising novel application for the detection of scaphoid fractures.

In *chapter 7* the performance of conventional radiographs (at first presentation at the ED) and clinical reassessment (after 7-14 days) for the diagnosis of scaphoid fractures was compared to HR-pQCT. The accuracy of conventional radiographs at the ED was fair (AUC 0.76) and clinical reassessment failed (AUC 0.50) compared to HR-pQCT, indicating that the value of initial radiographs and especially clinical reassessment is limited in diagnosing scaphoid fractures.

Chapter 8 provides a general discussion with conclusion following from this thesis.