General discussion
In this thesis, the diagnostic value of bone scintigraphy in daily practice has been assessed. In addition, the results of bone scintigraphy have been compared with clinical outcome and the observer variation of bone scintigraphy has been established. Furthermore, the role of acute MR imaging in suspected scaphoid fractures and the observer variation of MR imaging have been determined. Finally, the function of the wrist and strength measurements have been assessed for their use in the diagnostic strategy of suspected scaphoid fractures.

It was established that bone scintigraphy is reliable and consistent in the diagnostic strategy of suspected scaphoid fractures. In contrast, acute MR imaging is not superior to bone scintigraphy. Finally, function of the wrist and strength measurements are useful in the diagnostic strategy for suspected scaphoid fractures. They can rule out a suspected scaphoid fracture and consequently, no further investigation is needed and the patient can be functionally treated.

In comparison with the literature, these results are innovative. Especially as MR imaging is currently often being advocated and is even deemed the most appropriate investigation in imaging acute scaphoid trauma by the American College of Radiology. The prominent role of MR imaging should therefore be reassessed as this thesis presents the largest study population to date comparing MR imaging with bone scintigraphy. In addition, the results regarding the strength measurements are unique. Consequently, this thesis implies a novel diagnostic strategy for suspected scaphoid fractures in daily practice.

Implications for daily practice

Based on the results, each suspected scaphoid fracture mandates further investigation. The diagnostic strategy to be followed, in case of a suspected scaphoid fracture, is presented in the following steps (Figure 9.1).

1. In case of a suspected scaphoid fracture, **scaphoid radiographs** should be performed. Postero-anterior and lateral views are essential and at least 1 additional scaphoid radiograph is required. When a scaphoid fracture is evident on 1 of the scaphoid radiographs, treatment should be started.
   If no scaphoid fracture is evident on any of the scaphoid radiographs, further assessment is required.

2. **Strength measurements and / or impaired function of the wrist help** the clinician in ruling out a suspected scaphoid fracture. Function of the wrist, supination strength, pronation strength and grip strength have clear cut off values above which no scaphoid fracture is present. In general, if flexion or extension is more
than 76% with respect to the contra-lateral side, this suggests no fracture. If the patient has either a supination strength, a pronation strength or a grip strength of more than 40% with respect to the contra-lateral side, this suggests no scaphoid fracture. These cut off values of 76 and 40% exclude approximately 25% of patients from having a scaphoid fracture with 100% sensitivity that no scaphoid fracture is undetected. Consequently, no further investigation is required and the patient can be functionally treated. If these tests are not available, if the function of the wrist is less than 76% or if one of the strength measurements is less than 40% of the contra-lateral side, further investigation is required.

3. At this stage, adequate **immobilisation** is vital in order to minimise the chance of complications in patients with a scaphoid fracture. This thesis demonstrates that MR imaging in the acute setting is not reliable as it fails to identify up to 20% of

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**Figure 9.1**
Flow chart displaying the diagnostic strategy for suspected scaphoid fractures.
scaphoid fractures. To date, bone scintigraphy (3 to 5 days after the trauma) is the most appropriate investigation to confirm or rule out a scaphoid fracture. Consequently, patients should be treated according to the outcome of bone scintigraphy.

Critical remarks

Despite the unique study design, the novel results and implications for daily practice, some critical remarks should be made. In this thesis, a standardised algorithm consisting of bone scintigraphy, MR imaging and clinical follow-up has been used as a gold standard. The sole use of either bone scintigraphy or MR imaging as a gold standard would certainly affect the final results in this thesis. Clinical follow-up received a prominent place in order to access the true diagnostic value of bone scintigraphy and to evaluate those patients having a discrepancy between bone scintigraphy and MR imaging. Clinical follow-up was consistent with a scaphoid fracture if one clinical sign of a scaphoid fracture was present. Other studies have revealed the sensitivity and specificity of both a tender anatomic snuffbox and pain with axial compression of the thumb. Both clinical signs have, independent from each other, a sensitivity approximating 100%. Clinically, the main point that no scaphoid fracture is missed is therefore guaranteed. There is however, less equivocal evidence regarding their specificity. According to the literature, the specificity of anatomic snuffbox tenderness varies between 9 and 98%. There is a comparable wide variation for axial compression tenderness. When combining the clinical signs it is known that the specificity will increase to approximately 70%.

In this thesis, the hypothesis was that if a scaphoid fracture is present there will be remaining clinical signs for at least 2 weeks after the trauma. Consequently, if there were no more clinical signs of a scaphoid fracture after 2 weeks, no scaphoid fracture had occurred. This 2 week period will hence be discussed. To date, no literature has addressed this issue. In the Netherlands, the average period of cast immobilisation is 11 weeks. The literature describes that a number of scaphoid fractures are consolidated after 6 weeks. Scaphoid fractures can therefore heal within 6 weeks. Accordingly, a number of scaphoid fractures will no longer have clinical signs of a scaphoid fracture after 6 weeks of immobilisation. Experience indicates that it is unlikely that scaphoid fractures will heal within 2 weeks after trauma. The conservative 2 week timeframe chosen as the gold standard in this thesis may lead to over-treatment of suspected scaphoid fractures. In contrast, it is highly unlikely that a scaphoid fracture was missed.
The use of CT in the gold standard for patients with a discrepancy between the outcome of bone scintigraphy and MR imaging could have been useful. When designing the study however, data regarding CT were very limited and MR imaging was advocated by the American College of Radiology. Therefore, CT has not been evaluated in this thesis.

In order to determine the most appropriate investigation, the combined gold standard used in this thesis is one of the closest to the absolute truth. It is a conservative approach that might have overestimated the true number of scaphoid fractures. But overestimating the number of scaphoid fractures is still clinically preferred as to leaving scaphoid fractures undetected. There is no absolute standard for diagnosing a scaphoid fracture. Even an ‘open inspection of the scaphoid’ should not be considered as a certainty, as it depends on personal judgement.

Finally, the study performed is by far the largest undertaken to date evaluating the diagnostic value of clinical tests, bone scintigraphy and acute MR imaging. One hundred patients were included to detect a difference in correct diagnosis between MR imaging and bone scintigraphy, with a power of 0.80. No significant differences have been noticed in this thesis, but the trend is clear. One might consider investigating more patients to either increase the power of this thesis, validate the results and / or achieve a statistical difference.

Future perspectives

To date, the recommended strategy for suspected scaphoid fractures is bone scintigraphy in combination with clinical follow-up.

Acute MR imaging could not fill the void in the diagnostic strategy of suspected scaphoid fractures. Computed Tomography has not yet been properly evaluated, but studies at the Medical Centre Haaglanden and the Leiden University Medical Centre currently address the role of CT. These prospective studies compare the value of acute MR imaging, CT and delayed bone scintigraphy in patients with a suspected scaphoid fracture. Moreover, more clinical tests are being evaluated for their use in the diagnostic strategy of suspected scaphoid fractures. These are the first and main issues in line with this thesis which need to be addressed.

Subsequently, more research is needed to answer other issues surrounding scaphoid fractures. Major aspects requiring further studies include:

- Cost-effectiveness studies for the diagnostic strategy of scaphoid fractures are currently being established at the Medical Centre Haaglanden and Leiden University Medical Centre;
• Evidence based cast immobilisation. The possibilities of randomised controlled trials are currently being investigated. They address the different types and time frame of immobilisation. The main difficulty is to randomise patients with identical fractures to the different immobilisation groups. Based on preconceived definitions, fractures should be divided into proximal, middle and distal thirds;
• Evidence based operative management. Currently, randomised controlled trials are being established to compare immobilisation with operative management for a number of indications. This is being performed for patients with a stable scaphoid fracture. In these trials patients with identical fractures are being randomised.

**Conclusions**

The following conclusions have been established. Firstly, suspected scaphoid fractures are common and mandate further investigation. Secondly, function of the wrist and strength measurements improve the diagnostic strategy for suspected scaphoid fractures. Thirdly, MR imaging fails to identify up to 20% of scaphoid fractures. Fourthly, the observer variation of bone scintigraphy is less than the observer variation of MR imaging. Finally, bone scintigraphy in combination with clinical follow-up is the standard for suspected scaphoid fractures to date.
Chapter 9

General discussion