Chapter 1

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General introduction

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Scaphoid fractures: diagnosis and therapy
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Background

The scaphoid bone has a pivotal role in the functioning of the hand and wrist. Deformities can, therefore, lead to serious impairment. Fractures of the scaphoid bone mainly occur in young adults and constitute 2-7% of all fractures. In the Netherlands, a carpal fracture is suspected in more than 24,000 cases per year. Of all carpal fractures in the Netherlands, 90% is a scaphoid fracture. The exact incidence of scaphoid fractures is, however, not known.

The specific blood supply in combination with the demanding functional requirements can easily lead to a disturbed fracture healing. An incorrect or delayed treatment may lead to serious complications, such as delayed union, pseudo-arthrosis, avascular necrosis, instability and ultimately osteoarthritis. This is also true for occult scaphoid fractures that, contrary to popular belief, are not uncommon. Consequently, there is a clear need for a fast and reliable diagnostic tool in order to initiate the appropriate treatment as quickly as possible.

Despite its common occurrence, the severe complications and the vast amount of research performed, the diagnostic strategy and therapeutic management of scaphoid fractures are still surrounded by controversy.

Scaphoid fractures often remain undetected. Initial scaphoid radiographs detect about 80% of all scaphoid fractures. Repeated radiographs do not lead to improved diagnosis of scaphoid fractures since the added sensitivity is low. Bone scintigraphy has often been advocated as the gold standard in the diagnostic management of scaphoid fractures. It has a known sensitivity of 95% and a specificity varying between 60 and 95%. Nuclear imaging, however, requires intravenous radioactive isotopes and a delay of at least 72 hours after injury. Alternative imaging techniques are therefore being investigated.

Magnetic Resonance (MR) imaging and Computed Tomography (CT) can obviate the disadvantages of bone scintigraphy. CT has been claimed a useful technique, however, CT is less sensitive compared with bone scintigraphy. Further data regarding CT is limited. Due to a high sensitivity (95-100%) and specificity (100%) MR imaging, is often advocated as the diagnostic modality of choice. In addition, the American College of Radiology currently deems MR imaging and radiographs as the most appropriate investigation in imaging acute scaphoid trauma. The value of MR imaging in the detection of suspected scaphoid fractures, has not been evaluated properly. In particular, acute MR imaging has not been compared with bone scintigraphy. This flaw is underlined by the United Kingdom’s Royal College of Radiology as they give equal weight to bone scintigraphy, MR
imaging and CT in the imaging of suspected scaphoid radiographs. Moreover, the lack of univocal scientific evidence is confirmed in a recent international survey of hospital practice that revealed a marked inconsistency in the imaging of acute scaphoid injury.

‘Imaging the scaphoid problem’ is therefore an important and contemporary question that needs to be addressed.

**Anatomy of the scaphoid**

Destot was the first to describe a scaphoid fracture in 1905. The scaphoid is boat shaped and the word ‘scaphoid’ is derived from the Greek word ‘skaphos’, meaning ‘boat’. Because of this shape, it can articulate with 5 surrounding bones (lunate, capitate, trapezium, trapezoid and distal radius) (Figure 1.1). The scaphoid consists for 80% of cartilage. Consequently, there is only limited space for blood vessels to enter the scaphoid bone.

![Figure 1.1](image)

The anatomical localisation of the scaphoid bone (right hand, dorsal view).
The scaphoid has a retrograde blood supply, mainly through the arteria radialis. A dorsal branch enters the scaphoid through the foramina and provides 75% of the scaphoid blood supply. A palmar branch enters through the distal tubercle of the scaphoid (Figure 1.2). The distal pole and the tubercle have an independent vascularisation, while the proximal pole is completely dependent on blood supply running from the distal pole, through the scaphoid bone, to the proximal pole. This means that disruption of the blood supply is likely if the scaphoid fractures.

Clinical signs and symptoms of scaphoid fractures

The typical mechanism of injury is impact to the palm with extended wrist, usually as a result of a fall on the outstretched hand. During a fall, hyperextension of the wrist counteracts the force on the radial side and the force is transferred to the ulnar side. Through this mechanism 3 structures are at risk: the distal radius, the scaphoid-lunatum (SL) ligament and the scaphoid bone. The specific mechanism of injury can predict the structure that is most likely to give way. If the injury occurs with the wrist in radial deviation, the proximal two third of the scaphoid impacts against the distal radius causing a fracture in the middle of the scaphoid bone. If injury occurs with the wrist in a neutral position, a smaller portion of the proximal pole is involved meaning an increased chance of a proximal pole fracture.

Unfortunately, there are neither good nor reliable clinical tests to prove or to rule out a scaphoid fracture. Loss of concavity of the anatomic snuffbox increases the chance of a scaphoid fracture. A tender anatomic snuffbox, a tender tubercle and pain when applying axial pressure on the thumb each have a sensitivity of 100%. The specificity is respectively 9, 30 and 48%. Other studies show a higher specificity (up to 57%) for a tender tubercle. Diminished grip strength by more than 50% (compared to the contra-lateral side) suggests a scaphoid fracture.
Scaphoid fractures mainly occur in patients between 20 and 40 years of age. They are rare in children under the age of 15 years and in elderly due to a relative weakness of the distal radius compared to the scaphoid.

Diagnostic methods of scaphoid fractures

Scaphoid fractures often remain undetected. Initial scaphoid radiographs detect about 80% of all scaphoid fractures. There is no consensus regarding the different types of scaphoid radiographs. Anterior-posterior and lateral radiographs are standard. An additional number of up to 4 radiographs are often performed. Repeated radiographs do not lead to improved diagnosis of scaphoid fractures since the added sensitivity is low. In addition to bone injuries, it is important to evaluate the carpal relations (scaphoid-lunate, peri-lunate). Bone scintigraphy has a higher sensitivity (95%) than scaphoid radiographs (80%). Nuclear imaging, however, is invasive and is not routinely available. In addition, bone scintigraphy requires intravenous radioactive isotopes and a delay of at least 72 hours after injury. Finally, bone scintigraphy has a low specificity, varying between 60 and 95%. 

MR imaging and CT can obviate the disadvantages of bone scintigraphy. Due to a high sensitivity (95-100%) and specificity (100%) MR imaging is often advocated as the diagnostic modality of choice for the detection of occult scaphoid fractures. The role of MR imaging for suspected scaphoid fractures, has not been evaluated appropriately. In particular, acute MR imaging has not been compared with bone scintigraphy. Recently, a comparative study between MR imaging and CT showed that CT is superior in imaging the cortical surface of the scaphoid bone. MR imaging, however, is preferred for detecting occult scaphoid fractures. There are also studies that underline the value of high-spatial-resolution sonography to detect occult scaphoid fractures, especially if MR imaging or CT is not possible.

In patients with a suspected scaphoid fracture and no supporting radiological evidence, further diagnostic investigation is required. No univocal scientific evidence exists regarding the preferred supplemental diagnostic tool. To date, bone scintigraphy remains the gold standard.

Classification of scaphoid fractures

Three main classification systems for scaphoid fractures exist. The Mayo Clinic-classification divides scaphoid fractures into the proximal (30% of fractures), middle (65% of fractures) and distal (5% of fractures) thirds. Within the distal third, the Mayo Clinic-classification distinguishes between the distal articular surface and the distal tubercle. The localisation of the fracture influences both the
tendency and timeframe for healing. The chance of union in proximal, middle and distal third scaphoid fractures is respectively 64, 80 and 100%.\textsuperscript{30}

The Herbert classification is based on stability.\textsuperscript{33} Unstable fractures are those with a dislocation of more than 1mm, angulation more than 15°, additional fractures and trans-scaphoid-perilunate dislocations. Proximal pole fractures are also classified as unstable due to the increased chance of non-union. Conservative cast treatment of an unstable fracture likely influences the position of healing, increases the length of the period to heal and the chance of developing non- and mal-union. The degree of instability is essential for the choice of therapy as unstable fractures have a 50% chance of non-union, while stable fractures have a chance of 15%.

The third classification is the anatomical classification of Russe.\textsuperscript{33} This anatomical classification can be used to predict the tendency to heal. Russe classified scaphoid fractures as horizontal oblique, transverse, or vertical oblique. The vertical oblique type accounts for only 5% of the fractures. This fracture pattern results in the most shear forces across the fracture site, thus making it the most unstable. Horizontal oblique types have the most compressive forces across the fracture site and consequently have the best tendency to heal. Transverse fractures are the most common, have a combination of compressive and shear forces and have an average tendency to heal.

Figure 1.3
(a) Initial scaphoid radiographs, made at the Emergency Department, of the left hand of a patient with a suspected scaphoid fracture without radiological evidence of a scaphoid fracture.
(b) MR imaging in the acute phase (less than 24 hours after trauma) showing a scaphoid fracture.
(c) Bone scintigraphy (more than 72 hours after trauma) showing a scaphoid fracture.
Chapter 1 General introduction

Fracture treatment

The aim of fracture treatment is to achieve consolidation, rapid recovery of function, prompt return into society and prevention of previously mentioned complications, such as non- and mal-union. Therapeutic possibilities are a functional treatment, a conservative cast treatment or operative management.

Functional treatment
With functional treatment the patient is allowed to mobilise according to his or her pain. This method of treatment is advocated by several authors in patients with a suspected scaphoid fracture, which is undetected on either scaphoid radiographs or other diagnostic methods. When a scaphoid fracture is proven, functional treatment is inadequate due to the high chance of non-union (Figure 1.4).

Conservative cast treatment
Scaphoid fractures are difficult to immobilise because nearly every motion of the hand, wrist and forearm moves the bone. Ninety percent of all scaphoid fractures, however, are being

Figure 1.4
(a) Initial scaphoid radiographs, made at the Emergency Department, of the left hand of a patient with a suspected scaphoid fracture without radiological evidence of a scaphoid fracture. Because no fracture was visible, no further diagnostics were performed and the patient was treated functionally.
(b) Scaphoid radiographs of the same patient 1 year after presentation at the Emergency Department. The patient complained of persistent pain in hand and wrist. No new injury had taken place. A non-union and pseudo-arthritis are clearly visible.
treated conservatively with a cast immobilisation. Nevertheless, with prolonged cast immobilisation, the average chance of non-union is 10% for non-dislocated and 25-50% for dislocated scaphoid fractures. The indication for a cast immobilisation depends on the localisation and the stability of a scaphoid fracture. All stable distal and middle third scaphoid fractures are eligible for cast immobilisation. In the Netherlands, the average cast immobilisation is 11 weeks. According to standard protocols, the time of immobilisation varies between 6 and 20 weeks. In the literature, a 4 to 6 week period of immobilisation is advocated for distal scaphoid fractures, 6 to 12 weeks of casting are being recommended for middle third fractures and a 12 to 20 weeks of immobilisation is being suggested for proximal pole fractures. Other protocols advocate an immobilisation period of 6 weeks which can be prolonged with 2 week intervals in case of persistent clinical signs of a scaphoid fracture.

It is unclear which joints should be immobilised and in what position. Different opinions exist regarding the position of the wrist. The current trend is the neutral position. Immobilisation of the thumb eliminates the effects of the abductor pollicis longus and brevis muscles. Immobilisation of the thumb, which is common practice in the Netherlands, has no added value. Immobilisation of the elbow mainly eliminates the strain on the extrinsic and intrinsic carpal ligaments on the scaphoid during pro- and supination. Consequently, the chance of union increases and the period to heal decreases. Temporary treatment with an “above the elbow” cast can present a solution for those patients requiring operative treatment but are not eligible for surgery. Finally, a bone stimulator can aid treatment of fresh scaphoid fractures.

Operative management
Operative treatment is indicated for dislocated fractures (more than 1 mm or more than 15° angulation), proximal pole fractures, fractures comprising of complex hand injuries, carpal instability due to perilunate fractures and non-unions. Patients who require rapid return into society can undergo elective surgery. Advantages of surgery are an accurate and stable reposition and early mobilisation. An additional advantage is that patients can quickly return to society, which makes operative management an attractive economic option. The key to success is reaching an anatomic repositioning, a rigid fixation and an early mobilisation. The main risk in surgery of a scaphoid fracture is a non-optimal placement of the screw and a suboptimal compression of the fracture fragment that may lead to a mal- or non-union. There is also a chance of misplacement of the screw, which can lead to cartilage damage in the non-affected region of the scaphoid, distal radius or other carpal bones. The scaphoid bone can be approached both from dorsal and volar. Proximal pole fractures require a dorsal approach while distal pole fractures require a volar approach. Middle third fractures may be approached from both sides. In addition it is possible to perform either open or percutaneous surgery (Figure 1.5).
Clinical outcome

Conservatively treated non-dislocated scaphoid fractures have an approximate 10% chance of non-union. For dislocated scaphoid fractures, chances increase to approximately 50%. Seven years after a consolidated (conservatively treated) scaphoid fracture, 11% of patients were complaining of loss of strength, 10% of pain when moving, 6% of loss of functionality and 3% of pain in rest. In another group of patients, 7 years after operative treatment, 89% of patients were consolidated, 60% of patients were free of complaints with complete strength recovery and 73% did have a complete range of motion. These results are compatible with other studies. There is also evidence of better results due to operative treatment. Concerning the treatment of non-dislocated scaphoid fractures, it can be concluded that there is insufficient evidence that operative management is superior to conservative cast treatment. Operative management should only be recommended if previously mentioned indication criteria have been met.

Outline of this thesis

As outlined in the introduction, the diagnostic and therapeutic management of scaphoid fractures is still surrounded by controversy. An incorrect or delayed treatment may lead to serious complications. In order to initiate the appropriate treatment as quickly as possible, an accurate diagnostic management of scaphoid fractures is mandatory.

Many clinical tests have been developed to diagnose a scaphoid fracture. However, not all tests are equally practical, and their sensitivity and specificity are not always known, or are very low. Therefore, there is a need to evaluate new and practical clinical tests that have the capability of proving or ruling out a scaphoid fracture.

In addition, there is insufficient scientific evidence for the preferred imaging of acute scaphoid trauma. Radiographs lack sensitivity, bone scintigraphy has a varying
specificity, little is known regarding CT and the results of MR imaging are promising. No prospective study, however, has compared the different diagnostic modalities with a true gold standard, nor have they been assessed in the acute setting. Nevertheless, there is a call for a routine and univocal diagnostic strategy in the acute setting for suspected scaphoid fractures. Consequently, new research is required that can fill this void.

The aim of this thesis was, therefore, to answer the following questions in patients suspected of a scaphoid fracture but with no evidence of a fracture on scaphoid radiographs.

1. Are there new clinical tests that can aid in the diagnostic strategy of suspected scaphoid fractures?
2. What is the true diagnostic value of bone scintigraphy for suspected scaphoid fractures?
3. What is the role of bone scintigraphy if scaphoid radiographs show other fractures in the carpal region?
4. What is the observer variation of bone scintigraphy and MR imaging?
5. Is MR imaging in the acute setting superior to bone scintigraphy in diagnosing a scaphoid fracture?

Outline of the scientific chapters

Tests to improve the clinical diagnosis of a suspected scaphoid fracture are addressed in chapter 2. The diagnostic value of the function of the wrist and of a number of strength measurements is evaluated. This is important as these ‘simple’ tests might improve the value of physical examination. During a 30 months period, 78 consecutive patients with a suspected scaphoid fracture but no evidence of a fracture on scaphoid radiographs were enrolled in a prospective study at the Emergency Department.

The diagnostic value of bone scintigraphy in daily practice for clinically suspected scaphoid fractures is determined in chapter 3. All patients attending the Emergency Department over a 24 months period with clinical signs of a scaphoid fracture were evaluated.

While determining the value of bone scintigraphy for suspected scaphoid fractures, a diagnostic strategy for suspected scaphoid fractures in the presence of other fractures in the carpal region was developed in chapter 4.

Bone scintigraphy had proven to be a sensitive diagnostic tool for suspected scaphoid fractures, but the results had to be interpreted with care. Therefore, the results of bone scintigraphy were prospectively compared with clinical outcome in chapter 5. Fifty consecutive patients with signs of a suspected scaphoid fracture were included in a prospective study during an 18 months period.
In order to further evaluate the role of bone scintigraphy, the observer variation was determined in Chapter 6. One hundred subsequent bone scans of patients with a suspected scaphoid fracture but negative initial radiographs were prospectively investigated to calculate the inter- and intra-observer variation.

Meanwhile, the first MR scans of patients with a suspected scaphoid fracture were performed. Chapter 7 evaluates the observer variation of MR imaging of suspected scaphoid fractures. Seventy-nine consecutive MR scans of patients with a suspected scaphoid fracture were prospectively analysed to determine the inter- and intra-observer variation.

Chapter 8 answers one of the primary questions, is MR imaging superior to bone scintigraphy for suspected scaphoid fractures? To evaluate this hypothesis, 100 consecutive patients were included in a prospective study.

This thesis concludes with a general discussion (Chapter 9). The general discussion addresses the implications of this thesis for daily practice, together with some critical remarks and an outline of future perspectives. Finally, a number of conclusions are made.

This thesis is completed with a summary (Chapter 10), samenvatting (Dutch summary, Chapter 11), list of references, imaging protocols, list of publications and a curriculum vitae of the author. The imaging protocols contain the standardised protocols used for scaphoid radiographs, bone scintigraphy and MR imaging.