Diagnostic modalities for the occult scaphoid fracture

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Chapter 1

Introduction and outline of this thesis

Introduction

The discussion about diagnostic modalities for scaphoid fractures seems to be a never-ending story. The dilemmas and challenges are illustrated by the fact that a Pubmed search (dd 12-08-2017) on "scaphoid AND diagnosis'' results in more than 3000 hits. On average, at least one relevant paper on the topic is published every two weeks. The diagnosis of a scaphoid fracture is still subject of debate and probably will be for the next decades.

The aim of this thesis is to add new data and to review the current literature per specific part of the discussion. This thesis will summarize existing statements and provide evidence based new ones. Moreover will it be a guide towards a consensus in the diagnostic work up for occult scaphoid fractures.

The incidence of scaphoid fractures varies between 1,5 to 121 per 100.000 persons and the fracture predominantly occurs in young active males.(1) The scaphoid plays a central role in wrist function and is easily injured.(2) Of the patients visiting the emergency department with a clinical suspected scaphoid fracture after a fall on the outstretched hand, 21 to 28% are diagnosed with a scaphoid fracture.(3-5) Between 10 to 20% of these fractures are not visible on the initial scaphoid radiographs and are so called the ''occult scaphoid fracture''.(6,7)
Because of the limited and partially retrograde blood supply, in combination with the multidirectional forces applied on the bone during wrist movement, the scaphoid bone has a low tendency to heal.(8,9) Therefore a scaphoid fracture can result in a non-union, avascular necrosis, carpal instability and osteoartritis.(10-13)
Scaphoid fractures have a non-union rate of 15% and displacement of 2 mm seems to be the predictor for developing a non-union.(14,15) If a scaphoid fracture is not displaced, proximal pole have worse outcome than midwaist and distal pole fractures because of the predominantly retrograde blood supply.(16,17) To improve outcome, these displaced and proximal pole fractures can be treated with internal fixation.(15) Non-displaced fractures can safely be treated with cast immobilisation and union rates are up to 100%.(15) However, a tendency arises to also treat these fractures operatively.(18) Benefits are early return to work and avoidance of cast immobilisation. However long term outcome does not differ and complication rates of operative treatment are up to 30% (mostly minor wound problems).(10,11,19,20)
Most studies concerning non-unions after scaphoid fractures, included fractures that were visible on initial scaphoid radiographs. Occult fractures, diagnosed with techniques like CT, MRI or bone scintigraphy in patients with a clinically suspected scaphoid fracture and no fracture on scaphoid radiographs, are mostly treated with cast immobilisation and non-unions are not described in literature. There is no data available if these fractures also could lead to adverse outcome without treatment. However, as there are relatively high percentages of occult fractures and the consequences of a non-union, it is believed there is place for advanced diagnostic methods.(21,22) There is however controversy what is the best diagnostic modality to detect these occult fractures.

The remarkable wide incidence ranges (between 1,5 and 121 per 100.000) published in literature may well result from different definitions used for (occult) scaphoid fractures. The absence of a 100% reliable reference standard on the diagnosis of a scaphoid fracture is one of the main reasons for this difficulty in defining true scaphoid fractures. In other words, depending on the type of radiographic

modality that you use to diagnose scaphoid fractures, you will find difference in incidences. In literature different reference standards are being used. Some use repeated radiographs, others CT, MRI or bone scintigraphy. However these diagnostic modalities all have their specific advantages and shortcomings. These will be further investigated in this thesis.
The low prevalence of true scaphoid fractures among suspected fractures does not help either.(23) Low percentages of false positive outcomes will lead to many patients who will be overdiagnosed and consequently overtreated, as most patients will have no fracture. Furthermore prospective studies need large sample sizes to have a sufficient amount of fractures.

In the last decades much effort has been done to solve these diagnostic problems. Latent class analysis and clinical prediction rules are the latest developments in order to improve the clinical diagnosis of a scaphoid fracture.(24-28)

The research described in this thesis has started in 2010. Bone scintigraphy was then widely used as additional imaging in clinically suspected scaphoid fractures with no evidence of a fracture on radiographs. The estimated sensitivity and specificity was 100% and 90% respectively.(29-31) In addition to a specificity of 90%, bone scintigraphy was found to have other shortcomings. Nuclear imaging is time-consuming, invasive and the radiation exposure is around 4 mSv.(32) Moreover CT and MRI became more available for musculoskeletal imaging in isolated extremity trauma. In 2010 studies focused on the value of MRI. The accuracy of MRI was promising and the estimated sensitivity and specificity were 98% and 99% respectively.(23) However these results were not consistent and also lower sensitivities of around 80% have been described.(33) At that time, literature that evaluated the role of the CT in diagnosing occult fractures was scarce. Only three studies had been performed with small sample sizes.(34-36) CT however had the advantage of being quick and readily available in a daily clinical setting. A disadvantage of the CT scan was the radiation exposure.

In this thesis the diagnostic characteristics of CT, MRI, bone scintigraphy and SPECT/CT is investigated in patients with clinically suspected scaphoid fractures, that were not visible on standard scaphoid radiographs.

Outline and research questions of this thesis

Chapter 2

MRI is often being suggested to have the best diagnostic value for detecting occult scaphoid fractures. Therefor MRI is frequently being used as a reference standard. To date, no study has reported a specificity below 99% for MRI in diagnosis of scaphoid fractures.(23,31,37,38) If we know that the diagnosis is ''no fracture'' on beforehand, it is possible to study the specificity without a reference standard. Therefore we have used a group of healthy volunteers with no complaints and no history of trauma. The questions to be answered in this chapter are

- What is the specificity of MRI?
- Can MRI be used as a reliable reference standard?

Chapter 3

A missed scaphoid fracture can lead to serious complications. Therefor a diagnostic modality for the detection of an occult scaphoid fracture needs to be highly sensitive. Bone scintigraphy has proven to be a sensitive diagnostic modality.(34,36,37) CT has several advantages over bone scintigraphy: it is readily available, has probably less radiation exposure and is less time-consuming. In chapter 3 the diagnostic value of CT compared with bone scintigraphy is investigated. The question this chapter aims to answer is

- What is the diagnostic value of CT compared to bone scintigraphy?

Chapter 4

For a diagnostic modality to be accurate, the interobserver variability needs to be low. In chapter 4 we have studied interobserver agreement of radiologists evaluating CT's of patients with a clinical suspicion of a scaphoid fracture and no fracture on conventional radiographs. The main question to be answered in chapter 4 is

- What is the interobserver variability of CT's for the diagnosis of scaphoid fractures, not visible on conventional radiographs?

Chapter 5

An often suggested disadvantage of the CT is the radiation exposure. There is controversy around the harmfulness of low dose radiation exposure.(39)

So far, only indirect measurements of radiation exposure concerning a CT of the wrist, are known in the literature.(40) In chapter 5 the radiation exposure of a CT of the wrist, including scatter radiation, is quantified using a phantom (direct measurements). Moreover the difference in radiation exposure of scanning with -and without a plaster cast is evaluated. The questions to be answered in this chapter are

- What radiation exposure does a CT of the wrist induce?
- Is there a difference in radiation exposure during CT of the wrist with and without a plaster cast of the wrist?

Chapter 6

MRI, CT and bone scintigraphy all have advantages and disadvantages. To date, no other study has been performed comparing these three diagnostic modalities in the same patient group. In chapter 6 an unique comparative prospective cohort study is presented in which MRI, CT and bone scintigraphy

are compared in diagnosing occult scaphoid fractures. The questions to be answered in this study are

- Are MRI, CT and bone scintigraphy comparable in diagnosing occult scaphoid fractures?
- What are the discrepancies in these advanced diagnostic methods and how should they be interpreted?

Chapter 7

Recently, SPECT/CT has become a more commonly used imaging tool in orthopedic trauma surgery. (41) Chapter 7 is a pilot study investigating the role of SPECT/CT in the diagnostic work up for scaphoid fractures. Moreover the role of SPECT/CT as reference standard is being investigated.

- Does SPECT/CT have place in the diagnostic work up for scaphoid fractures?
- Could SPECT/CT serve as a reference standard in future studies?

In **Chapter 8** the outcome of this thesis is being discussed, the latest literature is being reviewed and future perspectives are being evaluated.

Chapter 9 presents the summary of this thesis in English.

Chapter 10 presents the summary in Dutch.

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