Scaphoid fractures: anatomy, diagnosis and treatment

Buijze, G.A.

Publication date
2012

Chapter 1

Introduction & Outline

Buijze GA

Introduction

Fractures of the scaphoid are common, especially in young and active adults. They account for up to 90% of carpal fractures and up to 7% of all fractures.[1,2] Annual incidences of scaphoid fractures are estimated between 29 and 43 per 100.000 people.[3-5] However, the exact incidence remains unknown, as many patients either do not seek medical attention or present years or decades after fracture and nonunion. In the Netherlands, fractures of the carpals are suspected in over 24.000 patients a year. The scaphoid has a pivotal role in the functioning of the wrist. Nonunion and deformities can therefore lead to serious pain and impairment. Both biological and clinical factors contribute to the development of nonunion.[6] Biological factors include the degree of fracture displacement, the tenuous vascular supply of the scaphoid, and its complex anatomy.[7-10] Clinical factors include the lack of an accurate diagnosis, delayed treatment, and inadequate treatment (e.g. incompliance with immobilization).[6,11]
Historically, fractures of the scaphoid have not been recognized for very long in comparison to other injuries. It was not until the end of the nineteenth century that the pathology was first described.[12,13] The topic rapidly gained popularity in the early twentieth century because of the unfavorable prognosis and relative frequency.[14] At that time, scaphoid fractures were considered an unsolvable and important economic problem. Treatment had been the subject of long controversy in the medical literature. Advancements in treatment took a leap in 1954, when McLaughlin introduced open reduction and internal fixation of the scaphoid.[15] He founded some of the main treatment principles of the current practice. Notably he concluded that "with perfections of operative technique, internal fixations may become the treatment of choice for displaced and unstable fractures of the carpal navicular." That prediction closely reflects the current practice.

Current Issues

The current issues in the management of scaphoid fractures are inaccurate diagnosis, inadequate treatment, delayed treatment, and overtreatment. The primary goals of contemporary research on scaphoid fractures are to improve functional outcome and to reduce the rate of nonunion. It has been extensively documented that an early accurate diagnosis and adequate treatment ensure high predictable healing rates approaching 100% and good wrist function.[16,17]
Inadequate treatment is closely related to inaccurate diagnosis. Over 20% of non- and minimally displaced fractures are not visible on radiographs (at least initially), and these missed fractures may be at risk for nonunion.[6,18] On the other hand, many fractures that are diagnosed on radiographs can be misdiagnosed as nondisplaced scaphoid fractures — i.e. they seem nondisplaced on radiographs but are displaced

on computed tomography (CT). Radiographs are not as reliable as CT or MRI in diagnosing displacement (usually defined as a gap or translation between the fracture fragments).[16,19] Nonoperative treatment of displaced fractures has been associated with a risk of nonunion up to 55%.[8-10] Therefore, there is a clear need for a reliable and readily available diagnostic method to ensure adequate treatment.

Delayed treatment can be caused by either patient-related factors or physician-related factors. Failure to seek medical attention after a fracture (for instance, assuming it's just a sprain) is considered a risk factor for scaphoid nonunion.[18,20] To reduce the risk, it is advised to examine the wrist clinically and radiographically as soon as possible but at most within 4 weeks after injury.[6] If the wrist is clinically suggestive of a fracture (e.g. tenderness in the anatomical snuffbox) but radiographs are negative, we speak of a suspected scaphoid fracture. In order to prevent delay in treatment, suspected scaphoid fractures are immobilized in a below-elbow cast until a fracture is ruled out. Additional diagnostics are required and can include a repeat clinical examination or advanced imaging such as CT, MRI or bone scintigraphy. The development of a clinical prediction rule might improve the diagnostic performance characteristics of radiological tests by decreasing the number of suspected fractures and thereby increasing the prevalence of true fractures.

Overtreatment is the resultant shortcoming of the careful management of suspected scaphoid fractures. Patients with suspected scaphoid fractures are generally immobilized in a cast for up to 2 weeks but the vast majority of patients have no fracture.[21] Overtreatment results in high and unnecessary costs for hospital visits and imaging studies. It also leads to unnecessary disability to perform manual labor in a generally young active population as the involved limb is immobilized for weeks until a fracture is definitely ruled out. The functional consequences of long cast immobilization of the wrist are substantial stiffness and muscle atrophy. It is important to investigate if functional outcome can be improved by minimizing immobility such as surgical fixation, shorter periods of cast immobilization or leaving the thumb free in the cast.

Aims of the Thesis

Firstly, the aim is to improve our understanding of the anatomy of the scaphoid bone and ligaments. *Secondly*, the aim is to improve the current knowledge on diagnosing true scaphoid fractures among suspected scaphoid fractures, as well as reliably diagnosing displacement and union. *Thirdly*, the aim is to improve treatment of acute scaphoid fractures.

Outline of the Thesis

This thesis is structured to address the whole spectrum of scaphoid fracture issues from the basics to the specifics with the final objective to improve the outcome of patients who sustain such fractures. Therefore, the structure is best explained by the "top-down" model: In order to improve the outcome it is essential to improve treatment (*Part IV*). Treatment of scaphoid fractures is highly dependent on the injury characteristics; hence diagnostic methods need to be improved first (*Part III*). And to understand the complexity of the diagnosis, the primary step is to acquire more knowledge regarding the precise anatomy (*Part II*). So this thesis is structured from the anatomy and diagnosis to treatment.
In the final part (*Part V*) all chapters will be put in perspective in a general discussion and summary.

ANATOMY

The scaphoid has a pivotal role in the functioning of the wrist as it articulates with 5 adjacent bones and forms a mechanical linkage between the carpal rows.[22] The ligaments that attach to the scaphoid play an essential role in carpal stability of both normal and injured wrists.[22] However, the literature on scaphoid ligaments is controversial and confusing. In this part of the thesis, the aim is to improve our understanding of the osseous and ligamentous anatomy of the scaphoid.

Anatomy of the Scaphoid: *Controversial Literature*

There is no consensus among authors on the anatomic description of the ligaments that have scaphoid attachments and their function in normal kinematics. This controversy increases when the discussion focuses on fractures or ligament pathologies such as scapholunate dissociation. In Chapter 2, all anatomical studies on scaphoid ligaments are systematically reviewed. The purpose of this study is to clarify and unify different concepts and classifications of the wrist ligaments and to describe the ligaments related to the scaphoid.

Anatomy of the Scaphoid: *3D Imaging*

No previous study on scaphoid anatomy has provided a detailed description of the three dimensional (3D) location and area of all scaphoid ligament attachments. In chapter 3, the anatomy of the scaphoid ligaments are described using 3D imaging of eight cadaveric wrists. The aim of this study is to provide a quantitative and more accurate description of the 3D geometrical aspects of the scaphoid ligaments.

DIAGNOSIS

Adequate treatment of true and suspected scaphoid fractures depends highly on reliable diagnostic methods. In this part of the thesis the diagnostic methods for true scaphoid fractures, displaced scaphoid fractures and united (healing) scaphoid fractures are investigated.

Latent Class Analysis

There is no gold standard for diagnosing scaphoid fractures. One way to deal with a lacking reference standard in diagnostic studies is to apply latent class analysis. This statistical method identifies unobserved or latent classes (factors associating with one another) in data.[23] In chapter 4, a comparison is made of the diagnostic performance test characteristics calculated using latent class analysis and standard formulas based on a reference standard.

Predictors of Scaphoid Fractures

An important step to improve the diagnostic performance characteristics of the imaging modalities available would be to increase the prevalence of true scaphoid fractures among suspected fractures. In chapter 5, the primary aim is to develop clinical prediction rules for true acute scaphoid fractures that incorporate demographic and clinical factors predictive of a fracture. The secondary aim is to determine the diagnostic performance characteristics of the clinical signs tested using latent class analysis and Bayesian statistical methods.

Displacement and Instability: *CT vs Radiography*

The current hypothesis is that displaced fractures are unstable and therefore susceptible to healing problems such as delayed union and nonunion. However, there is no evidence to support the fact that radiologically nondisplaced scaphoid waist fractures are stable and that displaced fractures are unstable.[24] In chapter 6, this hypothesis is tested using arthroscopy. The diagnostic performance characteristics of radiographs and CT in diagnosing displacement and instability of scaphoid waist fractures are evaluated using intra-operative visualization as the reference standard.

Displacement and Instability: *Predictors*

A relationship between fragment instability and location has been found in scaphoid nonunions.[25-28] Previous studies show that nonunions located distal of the apex (on the dorsal ridge of the scaphoid) were unstable and that nonunions located proximal of the apex were stable. If the same proved true for acute scaphoid fractures, fracture location might be a relative indication for surgery. In chapter 7, the aims are to assess

the relationship between fracture location relative to the apex and arthroscopically-determined displacement/ instability, and to assess other potentially associated factors.

Displaced Scaphoid Fractures

While the diagnosis of displacement is a critical factor of the management of scaphoid fractures, three previous methodological studies showed poor to moderate levels of inter-observer reliability for diagnosing displacement.[19,29,30] In chapter 8, the aim is to test if training can improve inter-observer reliability for the diagnosis of scaphoid fracture displacement on radiographs and CT.

United Scaphoid Fractures

Another important issue in scaphoid fracture management is to diagnose union in a reliable way as this affects the decision whether or not to discontinue cast immobilization. Radiographic and clinical signs of union have limited reliability.[31-33] In chapter 9, the aim is to determine the inter-observer reliability and diagnostic performance characteristics of CT for the diagnosis of union in scaphoid waist fractures.

TREATMENT

The lacking consensus on optimal treatment of acute scaphoid fractures is an important issue that needs to be addressed to improve functional outcome and reduce the rate of nonunion. In this part of the thesis, the best available evidence on the various treatment methods of scaphoid fractures is investigated.

Surgical versus Conservative Treatment

Currently, there is a trend in orthopedic practice towards early open reduction and internal fixation (ORIF) for fractures that had traditionally been treated conservatively.[34-36] Recent reports advocate surgical treatment for nondisplaced scaphoid fractures.[37-39] However, this trend towards early ORIF is not evidence based. In chapter 10, the aim is to evaluate the evidence from randomized controlled clinical trials comparing surgical to conservative treatment for acute nondisplaced and minimally displaced fractures of the scaphoid.

Conservative Treatment Methods

Consensus regarding the type of conservative treatment is also lacking. Cast immobilization techniques vary according to inclusion of the elbow,[40,41] inclusion of the thumb,[42,43] materials,[44,45] and duration of immobilization.[46] In chapter 11, the aim is to evaluate the evidence from randomized controlled trials comparing various conservative treatment methods for acute scaphoid fractures.

Cast Immobilization: *Thumb vs No Thumb*

Most surgeons worldwide immobilize the thumb when treating a patient with a scaphoid fracture, although there are regions, particularly in the UK where a below-elbow cast without immobilization of the thumb is preferred.[47-49] In chapter 12, the aim is to evaluate whether there is difference in union or arm-specific disability between patients with nondisplaced scaphoid waist fractures who are randomized either to treatment in a cast including the thumb or treatment in a cast excluding the thumb.

Scaphoid Nonunion Management

Despite advancements in treatment of acute scaphoid fractures, a small percentage fails to heal. It seems that untreated nonunion will lead to degenerative wrist arthritis.[50-52] However, it is not clear that surgery can change the natural history even if union is obtained. In chapter 13, the current concepts of management of scaphoid nonunions are reviewed. Surgical treatment options vary from percutaneous fixation to ORIF with vascularized or non-vascularized bone grafting and salvage procedures involving excision and/or arthrodesis of the carpals.

References

1. Beeres FJ, Rhemrev SJ, Hogervorst M, den Hollander P, Jukema GN. Scaphoid fractures: diagnosis and therapy. Ned Tijdschr Geneeskd 2007;151(13):742-7.
2. van der Molen AB, Groothoff JW, Visser GJ, Robinson PH, Eisma WH. Time off work due to scaphoid fractures and other carpal injuries in The Netherlands in the period 1990 to 1993. J Hand Surg Br 1999;24(2):193-8.
3. Duckworth AD, Jenkins PJ, Aitken SA, Clement ND, Court-Brown CM, McQueen MM. Scaphoid fracture epidemiology. J Trauma Acute Care Surg 2012;72(2):E41-5.
4. Hove LM. Epidemiology of scaphoid fractures in Bergen, Norway. Scand J Plast Reconstr Surg Hand Surg 1999;33(4):423-6.
5. Brondum V, Larsen CF, Skov O. Fracture of the carpal scaphoid: frequency and distribution in a well-defined population. Eur J Radiol 1992;15(2):118-22.
6. Wong K, von Schroeder HP. Delays and Poor Management of Scaphoid Fractures: Factors Contributing to Nonunion. J Hand Surg Am 2011;2011:29.
7. Gelberman RH, Menon J. The vascularity of the scaphoid bone. J Hand Surg Am 1980;5(5):508-13.
8. Eddeland A, Eiken O, Hellgren E, Ohlsson NM. Fractures of the scaphoid. Scand J Plast Reconstr Surg 1975;9(3):234-9.
9. Cooney WP, 3rd, Dobyns JH, Linscheid RL. Nonunion of the scaphoid: analysis of the results from bone grafting. J Hand Surg Am 1980;5(4):343-54.
10. Szabo RM, Manske D. Displaced fractures of the scaphoid. Clin Orthop Relat Res 1988(230):30-8.
11. Langhoff O, Andersen JL. Consequences of late immobilization of scaphoid fractures. J Hand Surg Br 1988;13(1):77-9.
12. Callender. Fracture of the Carpal End of the Radius, and of the Scaphoid Bone. Trans Path Soc London 1866;XVII, 221.
13. Stokes W. Clinical Note on a Case of Fracture of the Carpal Scaphoid. Br Med J 1900;1(2053):1075-1082 2.
14. Soto-Hall R, Haldeman KO. Treatment of acute lunate and perilunate dislocations. J Bone Joint Surg Am 1934;16:822-828.
15. Mc Laughlin H. Fracture of the carpal navicular (scaphoid) bone; some observations based on treatment by open reduction and internal fixation. J Bone Joint Surg Am 1954;36-A(4):765-74.
16. Bhat M, McCarthy M, Davis TR, Oni JA, Dawson S. MRI and plain radiography in the assessment of displaced fractures of the waist of the carpal scaphoid. J Bone Joint Surg Br 2004;86(5):705-13.
17. Geoghegan JM, Woodruff MJ, Bhatia R, Dawson JS, Kerslake RW, Downing ND, et al. Undisplaced scaphoid waist fractures: is 4 weeks' immobilisation in a below-elbow cast sufficient if a week 4 CT scan suggests fracture union? J Hand Surg Eur Vol 2009;34(5):631-7.
18. Osterman AL, Mikulics M. Scaphoid nonunion. Hand Clin 1988;4(3):437-55.
19. Lozano-Calderon S, Blazar P, Zurakowski D, Lee SG, Ring D. Diagnosis of scaphoid fracture displacement with radiography and computed tomography. J Bone Joint Surg Am 2006;88(12):2695-703.
20. Pao VS, Chang J. Scaphoid nonunion: diagnosis and treatment. Plast Reconstr Surg 2003;112(6):1666-76; quiz 1677; discussion 1678-9.
21. Mallee W, Doornberg JN, Ring D, van Dijk CN, Maas M, Goslings JC. Comparison of CT and MRI for diagnosis of suspected scaphoid fractures. J Bone Joint Surg Am 2011;93(1):20-8.

22. Berger RA. The anatomy of the scaphoid. Hand Clin. 2001;17(4):525-32.

23. Hui SL, Walter SD. Estimating the error rates of diagnostic tests. Biometrics 1980;36(1):167-71.

24. Herbert TJ, Fisher WE. Management of the fractured scaphoid using a new bone screw. J Bone Joint Surg Br 1984;66(1):114-23.

25. Oka K, Moritomo H, Murase T, Goto A, Sugamoto K, Yoshikawa H. Patterns of carpal deformity in scaphoid nonunion: a 3-dimensional and quantitative analysis. J Hand Surg Am 2005;30(6):1136-44.

26. Moritomo H, Viegas SF, Elder KW, Nakamura K, Dasilva MF, Boyd NL, et al. Scaphoid nonunions: a 3-dimensional analysis of patterns of deformity. J Hand Surg Am 2000;25(3):520-8.

27. Moritomo H, Murase T, Oka K, Tanaka H, Yoshikawa H, Sugamoto K. Relationship between the fracture location and the kinematic pattern in scaphoid nonunion. J Hand Surg Am 2008;33(9):1459-68.

28. Leventhal EL, Wolfe SW, Moore DC, Akelman E, Weiss AP, Crisco JJ. Interfragmentary motion in patients with scaphoid nonunion. J Hand Surg Am 2008;33(7):1108-15.

29. Desai VV, Davis TR, Barton NJ. The prognostic value and reproducibility of the radiological features of the fractured scaphoid. J Hand Surg Br 1999;24(5):586-90.

30. Bernard SA, Murray PM, Heckman MG. Validity of conventional radiography in determining scaphoid waist fracture displacement. J Orthop Trauma 2010;24(7):448-51.

31. Dias JJ, Taylor M, Thompson J, Brenkel IJ, Gregg PJ. Radiographic signs of union of scaphoid fractures. An analysis of inter-observer agreement and reproducibility. J Bone Joint Surg Br 1988;70(2):299-301.

32. Esberger DA. What value the scaphoid compression test? J Hand Surg Br 1994;19(6):748-9.

33. Waizenegger M, Barton NJ, Davis TR, Wastie ML. Clinical signs in scaphoid fractures. J Hand Surg Br 1994;19(6):743-7.

34. Canadian Orthopaedic Trauma Society. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. J Bone Joint Surg Am 2007;89(1):1-10.

35. Handoll HH, Huntley JS, Madhok R. External fixation versus conservative treatment for distal radial fractures in adults. Cochrane Database Syst Rev 2007(3):CD006194.

36. Jawa A, McCarty P, Doornberg J, Harris M, Ring D. Extra-articular distal-third diaphyseal fractures of the humerus. A comparison of functional bracing and plate fixation. J Bone Joint Surg Am 2006;88(11):2343-7.

37. McQueen MM, Gelbke MK, Wakefield A, Will EM, Gaebler C. Percutaneous screw fixation versus conservative treatment for fractures of the waist of the scaphoid: a prospective randomised study. J Bone Joint Surg Br 2008;90(1):66-71.

38. Bond CD, Shin AY, McBride MT, Dao KD. Percutaneous screw fixation or cast immobilization for nondisplaced scaphoid fractures. J Bone Joint Surg Am 2001;83-A(4):483-8.

39. Bedi A, Jebson PJ, Hayden RJ, Jacobson JA, Martus JE. Internal fixation of acute, nondisplaced scaphoid waist fractures via a limited dorsal approach: an assessment of radiographic and functional outcomes. J Hand Surg Am 2007;32(3):326-33.

40. Alho A, Kankaanpaa. Management of fractured scaphoid bone. A prospective study of 100 fractures. Acta Orthop Scand 1975;46(5):737-43.

41. Gellman H, Caputo RJ, Carter V, Aboulafia A, McKay M. Comparison of short and long thumb-spica casts for non-displaced fractures of the carpal scaphoid. J Bone Joint Surg Am 1989;71(3):354-7.

42. Clay NR, Dias JJ, Costigan PS, Gregg PJ, Barton NJ. Need the thumb be immobilised in scaphoid fractures? A randomised prospective trial. J Bone Joint Surg Br 1991;73(5):828-32.

43. Karantana A, Downs-Wheeler MJ, Webb K, Pearce CA, Johnson A, Bannister GC. The effects of Scaphoid and Colles casts on hand function. J Hand Surg Br 2006;31(4):436-8.

44. Sjolin SU, Andersen JC. Clinical fracture of the carpal scaphoid–supportive bandage or plaster cast immobilization? J Hand Surg Br 1988;13(1):75-6.

45. Cohen AP, Shaw DL. Focused rigidity casting: a prospective randomised study. J R Coll Surg Edinb 2001;46(5):265-70.

46. Rhemrev SJ, van Leerdam RH, Ootes D, Beeres FJ, Meylaerts SA. Non-operative treatment of non-displaced scaphoid fractures may be preferred. Injury 2009.

47. Haisman JM, Rohde RS, Weiland AJ. Acute fractures of the scaphoid. J Bone Joint Surg Am 2006;88(12):2750-8.

48. Grewal R, King GJ. An evidence-based approach to the management of acute scaphoid fractures. J Hand Surg Am 2009;34(4):732-4.

49. Petheram TG, Garg S, Compson JP. Is the scaphoid cast still alive? A survey of current UK practice in conservative management of scaphoid fractures. J Hand Surg Eur Vol 2009;34(2):281-2.

50. Hooning van Duyvenbode JF, Keijser LC, Hauet EJ, Obermann WR, Rozing PM. Pseudarthrosis of the scaphoid treated by the Matti-Russe operation. A long-term review of 77 cases. J Bone Joint Surg Br 1991;73(4):603-6.

51. Stark A, Brostrom LA, Svartengren G. Scaphoid nonunion treated with the Matti-Russe technique. Long-term results. Clin Orthop Relat Res 1987;214(214):175-80.

52. Jiranek WA, Ruby LK, Millender LB, Bankoff MS, Newberg AH. Long-term results after Russe bone-grafting: the effect of malunion of the scaphoid. J Bone Joint Surg Am 1992;74(8):1217-28.