Choosing a Strategy for the Diagnostic Management of Suspected Scaphoid Fracture: A Cost-Effectiveness Analysis

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To assess the cost-effectiveness of various strategies for the diagnostic management of clinically suspected scaphoid fracture, a decision-analytic model was built to evaluate three strategies and to compare them with a (clairvoyant) reference diagnostic management strategy. **Methods:** Evaluated strategies were: (A) repeated radiography up to 2 wk; (B) repeat radiography up to 6 wk; and (C) radiography, followed by bone scintigraphy in patients with negative initial radiographs. Therapy consisted of 12 wk of immobilization for a radiographically or scintigraphically proven fracture. Diagnostic costs, therapeutic costs, period of immobilization and nonunion rate were calculated for all three strategies. Estimates were derived from a descriptive management study using bone scintigraphy and available literature. Sensitivity analyses were performed. **Results:** Overall costs were 273.7, 317.7 and 316.1 European Currency Units (ECU) for Strategies A, B and C, respectively (1 ECU = 1.15 U.S. dollar). Strategy B led to the longest average period of immobilization (8.6 wk), while Strategy A resulted in the highest nonunion rate (4.7%). The costs per nonunion saved for the additional use of bone scintigraphy (Strategy C) was ECU 2618 when compared to Strategy A. **Conclusion:** The use of bone scintigraphy in the diagnostic management of scaphoid fractures is accurate, convenient for patients and cost-effective.

Key Words: bone scintigraphy; scaphoid fracture; cost-effectiveness analysis; diagnostic management; complication rate

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Nonunion of the scaphoid is a major cause of wrist disability following injury. A frequency of nonunion of up to 88% has been reported in scaphoid fractures that were not recognized within 4 wk (*1,2*). This complication occurs in 5%–12% of promptly and adequately treated fractures (*1,3,4*). Scaphoid radiography is the first diagnostic procedure in an acute situation. It is generally accepted that patients with positive radiographs are immobilized for 12 wk. In these patients, radiography is only required to determine fracture-healing. In patients with negative radiographs and persistent symptoms, radiography may be repeated up to 6 wk after injury in order to confirm a scaphoid fracture. These patients are usually treated in a plaster cast as long as the complaints persist. It is well known that not all fractures of the scaphoid can be identified using radiography (*5–7*). In addition, the sensitivity of repeated radiographs is low (*8*) and inter-observer variability is high (*9*), rendering this procedure unreliable. To increase the accuracy and reliability of the diagnosis of fractures of the scaphoid and other carpal bones, early bone scintigraphy has been advocated (*9–14*).

The primary aim of our study was to evaluate the cost-effectiveness and adequacy of treatment (as measured by expected nonunion rate) of three commonly employed diagnostic-therapeutic management strategies for clinically suspected scaphoid fracture. Second, we wanted to assess the social consequences in terms of the immobilization period. For this purpose, a decision-analytic model was built in which we used results from a previously reported management study and additional research on the costs of diagnosis and treatment.

METHODS

Patients

A consecutive series of patients with clinically suspected fracture of the scaphoid after carpal injury was studied using a uniform management protocol. Informed consent was obtained from all patients. If a fracture of the scaphoid was recognized on initial radiographs, the patient was immobilized for 12 wk in a below-elbow plaster cast with the wrist in slight dorsiflexion and the thumb in a position of opposition. If a scaphoid fracture was not identified on initial x-rays, a plaster cast was applied and the patient was referred for three-phase bone scintigraphy. Immobilization was discontinued if a negative bone scan result was obtained. If the bone scan was positive, specific treatment was continued or adjusted. Radiographs were repeated after 2 and 6 wk. A long-term follow-up study was performed after a minimum period of 1 yr, including patient's history, physical examination and scaphoid radiographs. Nonunion was defined as a persistent fracture line on scaphoid radiographs after 6 mo of conservative treatment. Therapy for nonunion consisted of surgery followed by 12 wk of immobilization.

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Radionuclide Bone Scintigraphy

Bone scintigraphy was performed at least 72 hr following injury using 200 MBq of ^{99m}Tc-methyldiphosphonate (MDP). Images were recorded immediately, after 2–5 min and after 2–3 hr. Anterior and lateral static views were obtained in a preset time of 5 min. The bone scan was considered to be positive if focally increased activity (a hot spot) in the scaphoid region was seen on both the dynamic and static images. A hot spot in both images in another carpal region was considered to be another fracture. All other bone scan results were judged to be unrelated to a fracture. Criteria for normal bone scintigraphy were symmetrical activity in both wrists with the same activity in the distal ends of the radius and ulna and diffuse activity in the area of the palm of the hand (*15*).

Evaluated Strategies

Three theoretical strategies were derived from patient data and compared in this analysis. In all strategies, patients with radiographically or scintigraphically proven scaphoid fractures were immobilized for a total of 12 wk. Strategy A consisted of treatment of all patients with a suspected scaphoid fracture on the initial radiographs; at 2 wk repeated radiography was performed and if no fracture could be demonstrated, the cast was removed. Strategy B was similar to Strategy A, but the patient was treated with a plaster cast for up to 6 wk; if repeated radiography at both 2 and 6 wk did not demonstrate a fracture, the plaster was removed. In Strategy C, patients with negative initial radiographs underwent bone scintigraphy. If the bone scan showed focal increased activity in the scaphoid region, the patient was treated for 12 wk, while a normal bone scan led to removal of plaster and mobilization. Furthermore, an imaginary diagnostic strategy, which identifies all fractures correctly without diagnostic costs, was used for reference ("clairvoyant").

Outcome Measures

The following results were evaluated: adequacy of therapy as measured in nonunion rates; mean costs of diagnostic procedures, treatment and overall management; and average number of weeks in a plaster cast. These results were used to measure the cost-effectiveness for each strategy in terms of incremental direct medical costs per nonunion saved.

Estimates of Effectiveness

The majority of estimates were based on a previously published study (*13*). In this study, using a combination of radiography and bone scintigraphy, a prevalence of scaphoid fracture of 44% was reported. First-day radiographs proved to be reliable with a sensitivity of 59%, while repeated radiographs at 2 wk and 6 wk showed a sensitivity of 31% and 30%, respectively (*13*). The specificity of the radiograph-series was assumed to be 100%. The diagnostic properties of bone scintigraphy in the setting of an acute carpal injury were evaluated in previous studies (*8,10–12*). A sensitivity of 100% was repeatedly described (*10–12*). Furthermore, a specificity of three-phase bone scintigraphy in acute carpal injury was approximately 98% (*8*). Thus, sensitivity and specificity were set at 100% and 98%, respectively, for baseline analysis.

An incidence of nonunion of 5%–12% has been described in promptly and adequately treated patients, who were diagnosed using only repeated radiography (*1,3,4*). In patients in whom bone scintigraphy was used, a nonunion rate of 0% was reported (*13*). Furthermore, in patients in whom the diagnosis was not immediately made, a nonunion rate of up to 88% was reported (*2*). We estimated incidence rates of nonunion to be 7% and 20%, respectively, in adequately and inadequately treated patients. The baseline estimates are summarized in Table 1.

TABLE 1
Estimates Used in Analysis

Variables	Estimates	Range (sensitivity analysis)
Prevalence	44%	35%–50%
Radiography		
Sensitivity		
First series	59%	45%–80%
Two weeks	31%	10%–60%
Six weeks	30%	10%–60%
Specificity	100%	77%–100%
Bone scintigraphy		
Sensitivity	100%	77%–100%
Specificity	98%	88%–100%
Nonunion rate		
Adequate therapy	7%	0%–12%
Inadequate therapy	20%	10%–50%

Cost Estimates of Diagnostic and Therapeutic Procedures

The direct medical costs of the diagnostic procedures were calculated in European Currency Units (1 ECU = 1.15 U.S. $ = 0.68 UK £ = 1.97 DM) by a health economist. These included the costs of materials, personnel and analysis. Costs of scaphoid radiography and bone scintigraphy were ECU 28 and ECU 164, respectively. Costs for application of a plaster cast were ECU 50. We assumed that plaster casts were applied or renewed at day 1, 2 wk and 6 wk, if necessary. Costs of surgery for nonunion of the scaphoid with hospitalization of 3–5 days followed by a period of 12 wk immobilization (plaster cast) amounted to ECU 2325 per patient. Indirect costs, as a result of immobilization, were not included in this analysis.

Sensitivity Analysis

To assess the effects of plausible changes in values of the various parameters, one-way sensitivity analyses were performed, varying one variable each time. In addition, a probabilistic sensitivity analysis was carried out. In this analysis, all parameters were simultaneously varied over a range described in Table 1 using Monte Carlo simulations (*16*).

RESULTS

Patients

A total of 160 patients was included. In 35 patients, the initial radiographs showed evidence of a scaphoid fracture. These patients were treated with a below-elbow plaster cast for 12 wk. The remaining 125 patients with normal radiographs underwent three-phase bone scintigraphy which demonstrated a scaphoid fracture in 35 patients. In 21 of these patients, radiography confirmed a fracture. The plaster cast was removed in patients with a normal bone scan result.

Reference Diagnostic Management Strategy

All three diagnostic management strategies in the diagnosis of scaphoid fracture were compared with the refer-

TABLE 2
Results of Cost-Effectiveness Analysis Using Baseline Estimates*

Strategies†	Diagnostic costs (ECU)	Therapeutic costs (ECU)	Overall costs (ECU)	Nonunion rate (%)	Immobilization (mean, wk)
Ref. strategy	0	137.6	137.6	3.1	5.6
A	48.7	225.0	273.7	4.7	5.7
B	67.9	249.8	317.7	4.2	8.6
C	149.4	166.7	316.1	3.1	6.9

*Costs in European Currency Units; average per patient.
†Reference strategy: all patients correctly identified and treated: Strategy A: repeated radiography up to 2 wk; Strategy B: repeated radiography up to 6 wk; Strategy C: bone scintigraphy if negative initial radiography.

ence (imaginary) strategy (Table 2). This "clairvoyant" diagnostic management strategy assumed that, without using any diagnostic methods, only patients who have a scaphoid fracture are immobilized for 12 wk. Using a prevalence of 44%, the mean overall (therapeutic) costs (immobilization and expected surgery) were ECU 137.6 (Table 2).

Diagnostic Costs

In all three strategies, first-day radiographs were obtained. Mean diagnostic costs for Strategy A, using repeated radiographs at 2 wk after injury, were ECU 48.7; while in Strategy B, using radiographs up to 6 wk after trauma, they were ECU 67.9. Diagnostic costs increased to ECU 149.4 in Strategy C (Table 2).

Therapeutic Costs

Therapeutic costs consisted of application of a plaster cast on Day 1 with renewal of the plaster after 2 and 6 wk combined with costs of expected surgery for nonunion. These were ECU 225.0, 249.8 and 166.7 for Strategies A, B and C, respectively (Table 2).

Overall Cost

Strategy A has the lowest total costs of ECU 273.7 per patient due to the low diagnostic costs. The addition of radiographs at 6 wk after injury (Strategy B) increased the overall costs to ECU 317.7 per patient. The overall costs of Strategy C were ECU 316.1.

Mean Period of Immobilization

Using the reference strategy, 44% of the patients were immobilized in a plaster cast for a 12-wk period, i.e., only those with a scaphoid fracture, leading to an average period of immobilization of 5.6 wk. Mean periods of immobilization amounted to 5.7, 8.6 and 6.9 wk for Strategies A, B and C, respectively.

Nonunion Rate

A nonunion rate of 3.1% could be obtained with the "clairvoyant" strategy. A similar result was obtained with Strategy C, whereas the nonunion rates of Strategies A and B were 4.7% and 4.2%, respectively.

Incremental Costs Per Nonunion Saved

Compared to Strategy A, the incremental costs per nonunion saved with the use of Strategy B was valued at ECU 8,973 (10,319 U.S. $). In Strategy C these incremental costs amounted to ECU 2,618 (3,011 U.S. $).

Sensitivity Analysis

We performed multiple sensitivity analyses varying the prevalence of scaphoid fractures, sensitivity and specificity of scaphoid radiography at day 1, after 2 wk and 6 wk, respectively, sensitivity and specificity of bone scintigraphy, and nonunion rates in adequately or inadequately treated patients.

Costs of the various strategies were not influenced by variation of any of the parameters: in all analyses, Strategy A was associated with the lowest costs and shortest immobilization period, but with the highest nonunion rate. Strategy C consistently showed the lowest nonunion rate in all ranges. This result was confirmed in the probabilistic sensitivity analysis: in 96% of the simulations, Strategy A had the lowest costs, while Strategy C was associated with the lowest nonunion rate in 98% of the cases.

DISCUSSION

In this study, we considered the consequences of three different diagnostic management strategies for patients with clinically suspected scaphoid fracture that are presently used in medical practice. Our analysis assessed the costs and nonunion rates of these strategies using published data for diagnostic accuracy and complication rates.

When considering which strategy should be selected for clinical use, the present analysis may provide two important guidelines. First, no or minimal use of objective diagnostic techniques for the detection or exclusion of a scaphoid fracture results in a large proportion of unrecognized scaphoid fractures, leading to a high incidence of pseudoarthrosis. Second, presently an adequate diagnostic management strategy should include bone scintigraphy in patients with initial negative radiographs. Such a strategy is associated with a nonunion rate that is optimal: it is identical to what can be obtained if all patients are correctly diagnosed.

Although implementation of the bone scan in the diagnostic management of scaphoid fractures leads to an increase of diagnostic costs from ECU 48.7 (Strategy A) to ECU 149.4 (Strategy C), therapeutic costs are reduced from ECU 249.8 to ECU 166.7 in Strategy C. For this reason, overall costs between strategies differ marginally (ECU 273.7, ECU 317.7 and ECU 316.1 in Strategies A, B and C, respectively).

The average period of immobilization is longest in Strategy B (8.6 wk) and shortest in Strategy A (5.7 wk). The prolonged period of immobilization in Strategy C (6.9 wk) can be explained by the optimal sensitivity of the bone scan, leading to 12 wk of immobilization of 44% of patients, i.e., those with a scaphoid fracture.

Since it is generally accepted that simple, noninvasive and cheap methods are initially preferred, the optimal timing of bone scintigraphy becomes clinically relevant. As our analysis suggests, the benefit of performing bone scintigraphy is greatest for patients in whom initial radiography yielded a nondiagnostic or a normal test outcome.

Analysis of the incremental costs incurred to save one nonunion showed that the use of bone scintigraphy in patients with negative initial radiographs costs approximately one-third of the price of using repeated radiography up to 6 wk after injury, and is therefore more cost-effective. Implementation of additional carpal box radiography (*17*) may improve the sensitivity of the radiographs, leading to a better cost-effective option, but this needs further clinical evaluation before it can be included in a cost-effectiveness analysis.

In conclusion, this cost-effectiveness analysis suggests that, at present, the most efficient approach appears to be a combination of first-day scaphoid radiography and bone scintigraphy. The initial investigation should be scaphoid radiography. In case of a recognized scaphoid fracture, the patient should be treated in a plaster cast for 12 wk. If the initial radiographs are negative or inconclusive, the patient is immobilized and bone scintigraphy is indicated. A normal bone scan rules out scaphoid fractures and plaster treatment may be discontinued. In patients with a positive bone scan, we advocate continuation of treatment for a period of 12 wk.

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EDITORIAL

Diagnosis of Scaphoid Fractures: The Role of Nuclear Medicine

The scaphoid is the most commonly fractured carpal bone; accounting for almost 90% of all carpal fractures in many series (*1,2*). Falling on the outstretched hand is the most common mechanism of injury (*1,3*), and pain in the anatomic "snuff box" is the classical clinical symptom (*4*). The scaphoid acts as a multifunctional link between the proximal and distal carpal rows. Major alterations in the kinematics of the wrist occur when fractures of this carpal bone do not heal properly (*5,6*). This accounts for the continued interest in early, accurate diagnosis, cost-effective management and therapeutic algorithms.

In this issue of the *Journal*, Tiel-van Buul et al. present a cost-based analysis of several different theoretical diagnostic management strategies for patients with suspected scaphoid fracture (*7*). We believe that their main conclusion implying that routine ". . . use of bone scintigraphy in the diagnostic management of scaphoid fractures is. . . cost effective" is not justified and is based on incomplete and biased assumptions, a selective use of the literature and a failure to incorporate significant knowledge regarding the anatomy, physiology, biomechanics and natural history of scaphoid fracture (*5*). In this editorial,

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