Costs analysis and comparison of usefulness of acute MRI and 2 weeks of cast immobilization for clinically suspected scaphoid fractures

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Background and purpose — **Fractures of the scaphoid are often not detected on initial plain radiographs. Conventional management of clinically suspected scaphoid fractures is cast immobilization for 2 weeks and then reassessment. Early MRI is a diagnostic alternative. We compared the cost and usefulness of the early MRI diagnostic strategy with that of conventional management.**

Patients and methods — **This prospective pseudo-randomized study included patients between 18 and 49 years of age who attended Bergen Accident and Emergency Department, Bergen, Norway during 1 year in 2009–2010, after sustaining an acute wrist trauma in the previous week and with a clinically suspected scaphoid fracture. 61 patients were investigated with acute MRI, while 63 patients received standard treatment as a control group. We used cost-minimization analysis to estimate the cost of the 2 patient groups.**

Results — **Concerning cost, there were no statistically significant differences in the total direct medical costs or in indirect costs between the groups. Concerning usefulness, patients in the MRI group without a fracture (n = 35) used a cast for fewer days (mean 1 day) than patients in the control group with no fractures (n = 52) (mean 14 days; p < 0.001). They had less than half the number of days on sick leave than patients in the control group (mean 7 days vs. 15 days; p = 0.002).**

Interpretation — **In a Norwegian setting, an early MRI was of value in patients with clinically suspected scaphoid fracture and normal plain radiographs.**

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Initial plain radiographs have a sensitivity of 65–93% for scaphoid fractures. (Tiel-van Buul et al. 1993, Hunter et al.

1997, Dorsay et al. 2001). Conventional management of occult scaphoid fractures involves a temporary wrist cast, and a review in approximately 2 weeks for repeated clinical and radiographic assessment. Previous studies have shown that only 20% of patients treated with cast immobilization for clinically suspected scaphoid fractures—who initially have negative radiographs—are finally diagnosed with scaphoid fractures. Thus, 4 in 5 patients are immobilized unnecessarily (Hunter et al. 1997, Dorsay et al. 2001, Brydie et al. 2003, Pillai and Jain. 2005, Jenkins et al. 2008).

Acute MRI of wrist and hand injuries has become an increasingly better tool for diagnosing or ruling out injuries that are otherwise often missed or over-treated (Hunter et al. 1997, Brydie et al. 2003, Khalid et al. 2010, McCullough et al. 2011, Bergh et al. 2012, Jorgsholm et al. 2013). Previous studies have shown that early MRI gives a reduction in immobilization time in patients with suspected scaphoid fractures, and facilitates a faster return to work (Kumar et al. 2005, Hansen et al. 2009, Patel et al. 2013). There has been disagreement in previous studies about whether early MRI in clinically suspected scaphoid fractures is cost-saving compared with conventional management (Gooding et al. 2004, Brooks et al. 2005, Nikken et al. 2005, Jenkins et al. 2008, Hansen et al. 2009, De Zwart et al. 2012, Patel et al. 2013). Furthermore, direct and indirect costs vary between countries, different healthcare systems, and different institutional settings. National studies are therefore important in order to find out the relevance for a particular country.

We estimated and compared the direct, indirect, and overall costs of a diagnostic strategy involving early MRI and of the traditional conservative management in the treatment
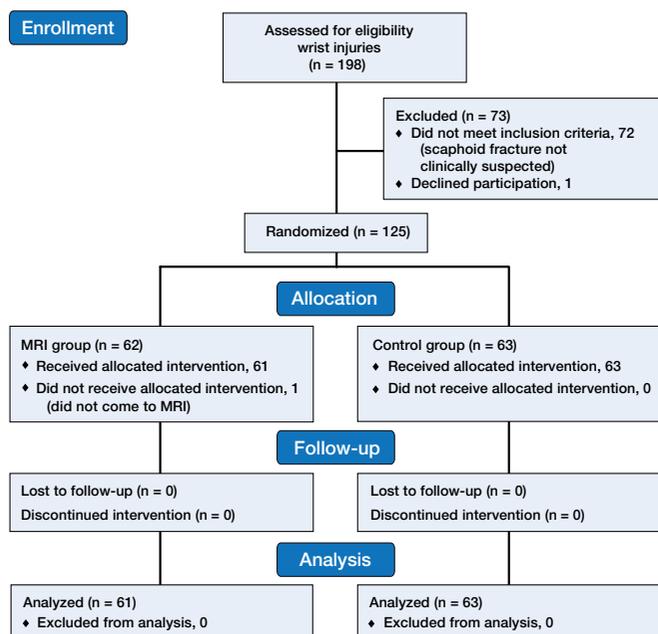
Figure 1. Flow diagram of patients enrolled in this study.

of clinically suspected scaphoid fractures with normal plain radiographs in a Norwegian setting. We also compared the benefits and disadvantages of the 2 diagnostic strategies for the patients.

Patients and methods

This prospective study was conducted at Bergen Accident and Emergency (A&E) Department, Norway from November 5, 2009 to November 4, 2010. Bergen A&E is an outpatient clinic that treats almost all minor injuries in Bergen, which is the second largest city in Norway. Annually, 100,000 patients attend the A&E, 40,000 of whom are injured.

Patients aged 18–49 years who attended the A&E within a week after sustaining an acute wrist trauma requiring radiographic examination were assessed for eligibility in the study. Only clinically suspected scaphoid fractures were included.

The exclusion criteria were radiographically identified fractures or dislocations, as well as patients with previous wrist fractures, rheumatoid arthritis, and contraindications for MRI such as pregnancy, metal implants, and claustrophobia (Figure 1).

Patients were examined with 3 commonly used clinical tests for suspected scaphoid fractures. We constructed a clinical scaphoid score (CSS) by grading and adding the results of these tests: tenderness in the anatomical snuffbox with the wrist in ulnar deviation, tenderness over the scaphoid tubercle with the wrist slightly extended, and pain upon longitudinal compression of the thumb (Bergh et al. 2014). The CSS is therefore a sum of the findings from these examinations. Both the clinical examination and the interpretation of the X-rays

were done by the doctors on call at the A&E, as part of their daily clinical practice.

Selection and randomization

This study was part of a larger project looking into different aspects of wrist injuries (n = 198) (Bergh et al. 2012, 2014). This leg of the study included 125 patients with clinical suspicion of a scaphoid fracture with a CSS of ≥ 3 and with normal plain radiographs. At the design stage of the study, CSS ≥ 3 was hypothesized to be an appropriate level for suspicion of a scaphoid fracture. Every other day for the entire study period, patients were allocated to 2 different groups based on diagnostic strategy—the early MRI group or the control group (Figure 1). Thus, 61 patients received intervention with acute MRI and treatment according to the MRI results, and 63 patients were controls who received the standard treatment (Table 1).

Follow-up of patients

The patients in the MRI group had MRI done as soon as possible (within mean 1 (0–7) day) after attending the A&E, and they had a follow-up consultation when the results of the MRI were available. They were treated according to the MRI results. The patients in the control group received conventional treatment with a below-elbow scaphoid cast for 2 weeks, after which they had a follow-up consultation with a repeat clinical examination, investigation, and treatment as with standard practice. Half of the patients in the control group had scaphoid fracture ruled out by clinical examination, with or without repeat radiographs after 2 weeks. In the remaining half of the control group, the doctor still suspected a scaphoid fracture at the 2-week assessment and MRI was requested (Figure 1).

Plain radiography and MRI

We used a standard protocol for radiography with extended wrist views and a series of 4 images including the distal part of the radius and the proximal part of the metacarpals (Bergh

Table 1. Demographic data and baseline characteristics of the MRI group and the control group

	MRI group	Control group	p-value
Age (95% CI) [a]	29 (27–31)	31 (29–33)	0.2
Sex, % [b]			
Female	51	40	0.2
Male	49	60	
Injured dominant wrist, % [b]	48	45	0.3
Injured non-dominant wrist, %	52	55	
Patients in paid work at the			
time of injury, % [b]	76	75	0.9
Patients not in paid work, %	24	25	
Occupational category, % [b]			
Blue-collar workers	70	81	0.2
White-collar workers	30	19	

[a] The p-value is based on t-test.
[b] The p-values are based on Pearson chi-square test.

et al. 2012). The MRI protocol included 4 different sequences and the MRI scans were performed in a 1.5 Tesla whole-body scanner with a wrist coil. An experienced musculoskeletal radiologist interpreted all the MRI results (Bergh et al. 2012). We had a preset treatment protocol to address possible pathological MRI findings; see Bergh et al. (2012).

Cost analysis

To our knowledge, no previous studies have demonstrated differences in patient outcome between these 2 diagnostic strategies. We assumed that there would be no difference in health outcome between the strategies, and therefore used cost-minimization analysis (CMA) (Robinson 1993, Drummond 2005). The cost perspective in this Norwegian study corresponds to the expenses for the National Social Security, including healthcare provider costs and sick leave benefits combined with the expenses for employers when employees are on sick leave.

We chose a time frame that would be sufficient to capture all major health and economic consequences, including both intended effects and unintended side effects. All the records at the A&E Department were reviewed 2 years after the inclusion of patients was completed. We also obtained sick leave data from the Norwegian Labor and Welfare Service (Ny arbeids- og velferdsforvaltning, NAV) from the start of the study until 6 months after inclusion was completed.

The direct and indirect costs were calculated for each patient in each group. Cost analysis was performed by comparing the cost of management of patients in the groups. We also calculated the costs for subgroups of patients within the groups: patients with scaphoid fractures, patients with all types of wrist fractures, and patients without fractures.

Direct costs

Direct costs included costs for consultations, radiographs, MRIs, plasters, and bandages (Table 3, see supplementary data). Information about each direct cost in 2010 (in Norwegian kroner (NOK)) was obtained from the Norwegian Health Economics Administration (HELFO; Helseøkonomiforvaltningen) and from the Norwegian Directorate of Health (Helsedirektoratet). Patients' co-payment was a part of the treatment-activities costs.

Indirect costs

Sick leave including self-certification was used as a measure of indirect costs. The employer covers 100% of an employee's income from day 1 to 16 of the sick-leave period. The Norwegian Labor and Welfare Service (NAV) gives compensation for all loss of income up to $6 \times G$ for the rest of the first year, where G is the Norwegian public pension base rate (on May 1, 2010, it was 9,600 euros).

We recorded whether patients were employees or self-employed, and their type of work. The patient's type of work was divided into 3 categories: blue-collar, white-collar, and other.

We calculated the number of days of sick leave for each patient using data from our own records and from the NAV. The NAV has all the data on the sick-leave period from day 17.

We also received information from medical certificates issued by general practitioners or other medical specialists. If the patient had a partial or graded sick leave over a certain period of time, we converted this to the equivalent number of whole days on sick leave. We assumed that employees worked full-time, if nothing else was stated in the medical records. We chose not to differentiate the wages according to occupation, but used an average salary for all employees in order to be able to generalize from a relatively small group of patients. The cost analysis would otherwise be very sensitive to those few patients with either a very high salary or a very low salary.

According to Statistics Norway (SSB), we calculated the average cost of sick leave per day to be 242 euros in 2010, which corresponds to an average daily personal income including payroll tax of 14%.

Statistics

Results for continuous variables are given as mean values with 95% confidence intervals. For continuous variables, t-test was used to compare mean values. If Levene's test showed significant differences in the variance estimates, Satherwaite's approach was used. For the cross-tabulations, chi-square tests were used. Any p-values less than 0.05 were considered statistically significant. IBM SPSS software version 21 was used for the statistical analyses.

Ethics

The study was approved by the Norwegian Ethics Committee for Medical Research (2009/869). The patients included gave their informed consent for participation in the study.

Results

The baseline characteristics of the MRI group and the control group showed balanced groups regarding prognostic factors (Table 1).

Fractures

We diagnosed 7 scaphoid fractures in the MRI group (n = 61) and 4 in the control group (n = 63). The number of other fractures was also higher in the MRI group than in the control group (22 as opposed to 8) (Table 2).

Healthcare provider resources

The numbers of consultations per patient were almost identical in the 2 groups. We found statistically significant differences between the numbers of radiographs, the numbers of MRIs, and the numbers of casts and elastic bandages used in the 2 groups (Table 3, see supplementary data).

Table 2. The different fracture locations identified. 3 patients had more than 1 fracture. None of the patients with scaphoid fractures had additional fractures

	MRI group	Control group
Scaphoid	7	4
Other fractures:		
Radius	7	4
Metacarpal	6	2
Capitate	4	0
Triquetrum	3	1
Trapezoid	1	0
Ulna	1	0
Trapezium	0	1
Fractures other than scaphoid	22	8

Usefulness

When patients were diagnosed as having either scaphoid fractures or other fractures, the number of days using a cast was similar (Table 4). The total number of days using a cast was fewer for patients in the MRI group (mean 12 days) than for those in the control group (mean 17 days) (mean difference 5 (−1 to 9) days) (p = 0.05). This difference was even more obvious for the mean number of days using a cast for patients without fractures in the MRI group (1 day as opposed to 14 days in the control group; mean difference 13 (11–15) days; p < 0.001). Mean length of time for a definite diagnosis was 1 (0–7) day for patients in the MRI group and it was 18 (13–68) days for the patients in the control group who received a MRI as part of the reassessment after 2 weeks or more. About half of the patients in the control group (n = 32) had few clinical symptoms at the reassessment after 2 weeks, and they were therefore discharged without MRI. 2 patients in the MRI group (but none in the control group) were referred to an orthopedic specialist, and neither of them received operative treatment.

The number of days of absence from work was not significantly lower in the MRI group than in the control group as a whole (Table 5, see supplementary data). However, for patients with no fractures, there were significantly fewer days of sick leave in the MRI group than in the control group (a mean of 7 days as opposed to a mean of 15 days; mean dif-

ference 8 (3–13) days; p = 0.002). All 11 patients who were diagnosed with scaphoid fractures in the study were treated with plaster. 8 of these patients were employed. 5 received a sick-leave certificate and 3 did not.

Blue-collar patients had more sick leave days (mean 17 days) than white-collar patients (mean 9 days) (mean difference 8 (0–15) days; p = 0.04).

Direct costs

We did not find any statistically significant difference in the sum of all direct costs of medical activities in the 2 groups: 30,160 euros in the MRI group and 27,997 euros in the control group (Table 3, see supplementary data).

In order to detect the 7 scaphoid fractures in the MRI group and the 4 scaphoid fractures in the control group, 61 MRI group patients and 63 control patients were investigated. Thus, we calculated that the average direct cost of detecting and treating a patient with an occult scaphoid fracture was 4,308 euros in the MRI group and 6,999 euros in the control group. The average direct medical cost of detecting and treating a patient with any occult wrist fracture was 1,160 euros in the MRI group (n = 26) and more than the double—2,545 euros—in the control group (n = 11).

Indirect costs

Three-quarters of the patients in both groups were wage earners (Table 1). Only patients in paid work and on sick leave generated indirect costs. We found similar indirect costs for the 2 groups (147,404 euros for the MRI group and 186,550 euros for the control group) (Table 5, see supplementary data). However, for patients in paid work with no fracture, the indirect cost in the MRI group was less than half of that in the control group (Table 5, see supplementary data).

Overall costs

Overall cost is the sum of direct and indirect costs. The overall costs were 177,564 euros in the MRI group and 214,548 euros in the control group. Neither the difference in direct costs nor the difference in indirect costs was statistically significantly different between the MRI group and the control group. However, for the MRI group the direct costs were slightly higher

Table 4. Usefulness; days with plaster treatment in subgroups of patients

| | MRI group | | Control | | Difference | |
	n	Days (mean)	n	Days (mean)	of mean (CI)	p-value [a]
All patients	61	12	63	17	4.6 (−0.5 to 9.3)	0.05
Patients without any fractures	35	1.3	52	14	13 (11–15)	< 0.005
Patients without scaphoid fracture	54	8.8	59	15	6.5 (3–10)	< 0.005
Patients with scaphoid fracture	7	40	4	43	2.4 (−18 to 22)	0.8
Patients with all types of fracture	26	27	11	30	2.7 (−7.5 to 13)	0.6

[a] t-test

while the indirect costs were slightly lower than in the control group. The difference in total costs between the MRI group and the control group was therefore marginal. The direct costs accounted for 15% of the overall cost and the indirect costs accounted for 85% of the overall cost.

Discussion

Usefulness, strengths and limitations

In this prospective pseudo-randomized controlled trial of adults with clinically suspected scaphoid fractures, patients who received early MRI used a cast for fewer days when any type of wrist fracture was ruled out than the control group (1 day as opposed to 14 days). This difference is in agreement with findings in earlier studies (Brydie et al. 2003, Brooks et al. 2005, Kumar et al. 2005, Hansen et al. 2009). Mean length of time for a definite diagnosis was 1 day in patients in the MRI group and 18 days for the patients in the control group who underwent MRI. About half of the patients in the control group (n = 32) had few clinical symptoms at the reassessment after 2 weeks, and were therefore discharged without MRI. Other studies have shown a similar reduction in the time until final diagnosis by using early MRI (Brooks et al. 2005, Raby 2001).

It could be considered a weakness of the present work that the examination procedure took the form of a pseudo-randomized controlled study rather than a blind, randomized controlled study. The patients included followed one of 2 different diagnostic strategies depending on the day of presentation. This procedure was found to be the most practical to follow in our busy accident and emergency unit. The doctor in charge knew which diagnostic strategy group the patient was allocated to (early MRI or control), but could not move the patient to the other group. We therefore consider the risk of selection bias to be small.

Another weakness of our study is that we do not know with certainty the number of occult fractures or soft tissue injuries that were present in the control group. About half of the patients in this group (n = 32) had few clinical symptoms at the reassessment after 2 weeks. MRI was therefore not requested, but theoretically, an occult wrist fracture could have become partially asymptomatic after 2 weeks of immobilization in a plaster. We checked all relevant medical records at our accident and emergency unit up to 2 years after the inclusion of patients was complete. Only 1 patient returned with signs of continued pain in the wrist. A volar wrist ganglion was diagnosed by MRI and probably caused his symptoms. This indicates that there was identical clinical outcome in these 2 groups.

The strength of our prospective study was that all patients were examined in a standardized manner with the 3 most commonly used clinical tests to identify scaphoid fractures.

Patients in the MRI group without any fracture had less than half the number of days of sick leave than patients in the control group with no fractures. Other studies have also found a reduction in time absent from work when using sub-acute MRI (Hansen et al. 2009), but this has been contradicted by others (Brooks et al. 2005). Blue-collar patients had more days of sick leave than white-collar patients, as has been found in other studies (Vinnars et al. 2007). Of the 11 patients in our study who were diagnosed with scaphoid fractures, 5 were given a sick leave certificate and 3 were not. Other studies have also found that some patients go to work in spite of their immobilized and cast scaphoid fracture (van der Molen et al. 1999, Fusetti 2003, Vinnars et al. 2007).

Costs

Our choice of using cost-minimization analysis required that the clinical endpoint after the 2 different diagnostic strategies should be identical. Our clinical endpoint was that the fracture was healed and the patient had returned to work. An indication that this assumption is correct was that none of the patients in the 2 groups were on sick leave for longer than 2 months after their acute wrist injury. None of the patients returned to our accident and emergency unit with a late-discovered scaphoid fracture during the 2 years that followed. The principle of this cost analysis could be transferred to other countries. However, direct costs, sick-leave rules, and possible payment of expenses from the insurance companies will vary from country to country. The effect of different direct activity costs can be estimated. In our model, it is possible to use a one-way sensitive analysis of one specific parameter (e.g. MRI) to access the impact of the output of the model.

Direct costs

Despite the relatively high cost of MRI, our overall estimation of direct costs in all patients was similar in the 2 groups. This was contrary to what we had assumed. Conventional treatment was only marginally cost-saving regarding direct costs, which is in agreement with other studies (Gooding et al. 2004, Brooks et al. 2005) yet contrasts with another study that found that the mean cost of management was marginally lower with early MRI management (Patel et al. 2013).

However, when we compared the average direct costs for detection and treatment of one occult scaphoid fracture, the cost was less in the MRI group (4,308 euros) than in the control group (6,999 euros). Moreover, the average direct medical cost per occult fracture was less than half in the MRI group than in the control group when the analysis was extended to diagnosing any wrist fracture, which is supported by other authors (Gooding et al. 2004). This difference in costs for identification of occult fractures was probably caused by the fact that early MRI identifies more fractures and that some fractures may have been missed in the control group. More importantly, we do not know the significance of these undiscovered fractures, but in our study none of the patients returned during the subsequent 2-year period with signs of avascular necrosis, non-union, or other complications. This calculation

is further complicated by the fact that a higher proportion of patients with known fractures in the MRI group would result in higher costs due to the fracture treatment. The question is really whether this cost is "unnecessary", as the patient actually receives a complete diagnosis and treatment as opposed to follow-up consultations, further reviews, and possibly subsequent investigations. In recent years, the cost of MRI has decreased in Norway. This has resulted in more frequent use of MRI at an early stage. The next development in the years to come will probably be a small, dedicated extremity scanner suitable for wrist examination, preferably located at the accident and emergency unit, which would be even cheaper and more time-saving than a conventional whole-body scanner with a wrist coil as used in the present study (Dorsay et al. 2001, Khalid et al. 2010).

Indirect costs

No statistically significant difference in indirect costs was found between the 2 groups. Patients in the MRI group who were employed, and who did not have any type of wrist fracture, had less than half the indirect costs of patients in the control group. This reflects that with early exclusion of pathology with MRI, the patient can be discharged and return to work. We found that the indirect costs for employees who were on sick leave represented 85% of the overall cost. This is in accordance with another study where the indirect cost accounted for 90% of the overall cost (Fusetti 2003).

Conclusion

By means of cost-minimization analysis, we found only a marginal difference in overall costs between the 2 groups of patients: one with early MRI for suspected occult scaphoid fracture and the other group following a conventional diagnostic strategy. However, from the point of view of usefulness, we found that patients receiving early MRI—which ruled out wrist fracture—had substantially fewer days in a cast unnecessarily and spent less than half the number of days on sick leave.

Supplementary data

Tables 3 and 5 are available at Acta's website (www.acta-orthop.org), identification number 7145.

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