The added value of routine radiographs in wrist and ankle fractures

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Citation

Gerven, P. van. (2022, November 2). *The added value of routine radiographs in wrist and ankle fractures*. Retrieved from https://hdl.handle.net/1887/3485208

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Reduction of routine use of radiography in patients with ankle fractures leads to lower costs and has no impact on clinical outcome: an economic evaluation

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BMC Health Services Research. 2020;20:893-905

ABSTRACT

Objective

To evaluate the cost-effectiveness of a reduction in the number of routine radiographs during the follow-up of patients with ankle fractures.

Methods

We performed an economic evaluation alongside the multicentre, randomized WARRIOR trial. Participants were randomized to a reduced imaging follow-up protocol (i.e., radiographs at weeks 6 and 12 follow-up made only for a clinical indication) or routine care (i.e., routine radiography made at weeks 6 and 12). The Olerud-Molander Ankle Score (OMAS) was used to assess ankle function and the EuroQol-5 Dimensions-3 Levels (EQ-5D-3L) was used to estimate quality-adjusted life-years (QALYs). Costs and resource use were assessed with use of self-reported questionnaires and medical records and analysed from a societal perspective. Multiple imputation was used for missing data, and data were analysed with use of seemingly unrelated regression analysis and bootstrapping.

Results

In total, 246 patients had data available for analysis (reduced imaging=118; routine care=128). Fewer radiographs were made in the reduced imaging group (median=4) compared with the routine care group (median=5). Functional outcome was comparable for both groups. The difference in QALYs was –0.008 (95% confidence interval [CI], –0.06 to 0.04) and the difference in OMAS was 0.73 (95% CI, –5.29 to 6.76). Imaging costs were lower for the reduced imaging group (–€48; 95% CI, –€72 to –€25). All other cost categories did not statistically differ between the groups. The probability of the reduced imaging protocol being cost-effectiveness was 0.45 at a willingness to pay of €20,000 per QALY.

Conclusions

Reducing the number of routine follow-up radiographs has a low probability of being cost-effective compared with routine care. Functional outcome, health-related quality of life and societal costs were comparable for both groups, whereas imaging costs were marginally lower for the reduced imaging group. Given this, a reduced imaging follow-up protocol for those with routine ankle fractures can be followed without sacrificing quality of care and may result in reduced costs.

INTRODUCTION

Ankle fractures are common and account for about 9% of all fractures in the UK.[1] The incidence of ankle fractures around the world is reported to lie between 71 and 187 per 100,000 persons per year and has risen over the last decade as a result of aging of the population and increased participation in athletic activities.[2-5] Routine imaging during the follow-up of ankle fractures is associated with relatively high healthcare costs.[6, 7] Healthcare costs are expected to rise in coming decades.[8] This has led to an increased interest in the effectiveness of imaging in clinical decision-making.[9-12] Despite increased costs, both national and international trauma protocols dictate that routine radiographs should be made at regular intervals during the follow-up of patients with an ankle fracture, although there is little scientific evidence to support this position.[4, 13, 14] For both nonoperatively and operatively managed patients, it is recommended that 4 outpatient clinic visits including radiographs, are to be conducted after a follow-up of 1, 2, 6, and 12 weeks.[13] The goal of these radiographs is to monitor the position of the fracture fragments, the position of fixation material, the alignment of the joint, and the bone-healing process.

In the Netherlands, with a population of over 17 million, approximately €5 million is spent annually on radiography for patients with ankle fractures. This estimate is based on an incidence of 30,000 per annum,[15] with 3 to 4 follow-up radiographs,[16] at a cost of €50 per radiograph.[17] Various studies have questioned the value of routine radiographs made at the first outpatient clinic visit and at intermediate-to-late follow-up (i.e., after the initial 3 weeks) of operatively managed ankle fractures.[18, 19] A recent retrospective analysis, involving a cohort of 528 patients with an ankle fracture, demonstrated that as few as 1.2% (11/928) of routine radiographs made after 3 weeks of follow-up led to a change in the treatment strategy.[16] These results suggest that current imaging protocols for the follow-up of ankle fracture patients might not be cost-effective.

METHODS

Aim

The aim of the present study was to evaluate the cost-effectiveness of a protocol with reduced numbers of routine radiographs during the follow-up of ankle fractures, in comparison with the current routine care.

Setting and Design

This economic evaluation was conducted alongside a multicentre, randomized controlled trial (RCT). The methods of this trial, including its sample size calculation, are described in detail elsewhere.[20] 7 hospitals in the Netherlands participated in the study, including 3 university hospitals and 4 large teaching hospitals. Patients were enrolled between July 2014 and October 2017.

Both a cost-effectiveness and cost-utility analysis were performed from a societal perspective. The time horizon of the economic evaluation was 12 months. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) guidelines were followed in preparing this report.[21, 22]

Inclusion and Exclusion Criteria

Patients could participate in the study if they provided written informed consent, were over 18 years of age, had a fracture of the ankle (Lauge Hansen classification types supination-adduction 2, supination-external rotation 2 to 4, pronation-external rotation 1 to 4, or pronation-abduction 1 to 3),[23] and were able to independently complete the Dutch questionnaires. Distortions or isolated Danis-Weber type A fractures[24] were not included. Exclusion criteria were the presence of fractures to multiple extremities, pathologic, or open fractures (Gustilo grades 2 and 3). If patients were deemed unable to comply with follow-up they were also excluded.

Randomization

Patients were informed about the study both verbally and by means of an information letter. All participants had to provide written informed consent. Participants were randomized by means of computerised allocation, with use of an online registration and randomization program (ProMISe; Project Manager Internet Server; https://www.msbi.nl/promise-/ProMISe.aspx)

Participants were assigned in a 1:1 ratio to either the intervention group or the control group. Randomization was carried out with use of a stratified, randomly varying block design (each block size containing 2 to 6 allocations). The tables were internally pregenerated within the secure data management system stratified by hospital and the initial treatment strategy.

Control Group – Routine Care

Patients randomized to the routine care group were monitored at the outpatient clinic and received routine follow-up radiographs at 1, 2, 6, and 12 weeks of follow-up.

Additional follow-up moments with or without the use of radiographs could be scheduled at any time if deemed necessary by the treating physician.

Intervention Group – Reduced Imaging

In the reduced imaging group, radiographs were routinely made after 1 and 2 weeks. Radiographs could be made later in the follow-up if a specific clinical indication was present or could be made at the discretion of the treating physician. Reasons for doing so included an additional trauma to the affected ankle, a pain score of 6 or higher on a 11-point Numerical Rating Scale (NRS), a decrease in Range-Of-Motion (ROM), or neurovascular abnormalities. Motivations to make additional radiographs were required to be logged in the medical file. Aside from the modified imaging protocol at follow-up, all aspects of treatment and follow-up were similar for both groups.

Outcome measures

Measurements at baseline included potential confounders,[25] such as age, sex, medical history, smoking habits, alcohol intake, functional status, health-related quality of life (HRQoL), and socioeconomic status. Follow-up questionnaires assessing the patients' clinical outcomes as well as their resource use were administered after 6, 12, 26, and 52 weeks. The questionnaires could be completed either online or by post. The recall period of these questionnaires varied from 6 weeks at the follow-up moment at week 6 to 26 weeks at the follow-up moment at week 52.

Functional status of the affected ankle was evaluated with use of the Olerud-Molander Ankle Score (OMAS). This is a 9-item questionnaire assessing both pain and disability related to the affected ankle. The OMAS was calculated for all of the measurement points separately, ranging from 0 to 100 with a score of 100 equalling no pain or disability.[26] HRQoL was assessed with use of the Dutch version of the EuroQol-5 Dimensions-3 Levels (EQ-5D-3L). At baseline, participants were asked to complete the EQ-5D-3L for their health state just prior to their trauma. At all other time points, they were asked to consider their current health status. Utility scores per time point were estimated with use of the Dutch EQ-5D-3L tariff.[27, 28] Quality-adjusted life-years (QALYs) per patient were estimated with use of linear interpolation of the utility scores for the different time points. As the patients' utility score right after the trauma was not available (i.e., the patients' "true" baseline utility score), we assumed their utility score at baseline to be equal to the score at 6 weeks of follow-up.

Cost measures

Resource use questionnaires were used to measure the patients' use of primary and secondary healthcare, medication, informal care, as well as their levels of unpaid productivity losses, absenteeism, and presenteeism. Costs of the intervention (i.e., costs for the radiographs) were gathered from electronic patient records. Primary healthcare use included the patients' number of general practitioner consultations, visits to a company medical officer, physiotherapy treatments, and visits to other specialised therapists. All these visits were required to be associated with the ankle fracture. Information on the use of secondary healthcare services was gathered from electronic patient records and included admissions to hospital, nursing home or rehabilitation centre, outpatient clinic visits, all imaging other than plain radiographs (e.g., CT- or MRI-scans of the ankle), and re-operations. These services also included the initial admission right after the trauma occurred and the primary intervention if applicable. All healthcare costs were valued according to Dutch standard costs[29] or, if unavailable, tariffs. Medication costs were calculated as costs-per-day for each medication, which was based upon the standard dosage per day and unit prices of the Royal Dutch Society of Pharmacy.[30] Total medication costs were calculated by multiplying this cost per day with the total days of use. If the duration was not specified, we assumed patients used a certain medication during the complete recall period. Unpaid productivity losses (i.e., volunteer work, caregiving, or domestic activities patients could not perform because of their fracture) and informal care (i.e., care provided by relatives, friends, or volunteers) were valued at €14.13 per hour, a shadow price that is recommended by the Dutch National Healthcare Institute.[29] Absenteeism was defined as the number of days of absence because of the ankle fracture. The Friction Cost Approach was used to value absenteeism, which assumes that costs are limited to the time it takes to replace an absent worker (in the Netherlands: 12 weeks).[29] The participants' number of presenteeism days were estimated by multiplying the number of days worked (i.e., workable days – sickness absence days) by a self-reported score reflecting their productivity level when they were present at work ranging from 0 (equalling no productivity) to 10 (equalling full productivity). Days of absenteeism and presenteeism were valued with use of gender-specific price weights.[29] The trial's follow-up was 12 months and discounting of costs and effects was, therefore, not necessary. All costs were converted to Euros 2016 with the help of consumer price indices.[31]

Statistical Analysis

Analyses were performed in accordance with the intention-to-treat principle. Missing data were multiply imputed with use of STATA (Version 12 SE, Stata Corp, College station, TX). The imputation model included utility scores, the OMAS, and all available cost values at baseline, 6, 12, 26, and 52 weeks as well as the baseline variables fracture classification, Body-Mass-Index (BMI), American Society of Anaesthesiologists (ASA) classification, smoking habits, alcohol intake, hospital, age, sex, randomization result, and whether the fracture was managed operatively or nonoperatively. These baseline variables were added because they were regarded as possible confounders, because they differed between groups at baseline, and/or because they were predictive of the 'missingness' of data. 5 complete datasets were generated in order for the loss-of-efficiency to be lower than 5%.[32] Each dataset was analysed separately, and estimates were pooled with use of Rubin's rules. This method takes into account both imputation variability within each dataset, as well as imputation variability between the separate datasets.[32] Seemingly unrelated regression analyses (SUR) were used to estimate total cost differences (ΔC) and effect differences (ΔE). The advantage of SUR is that ΔC and ΔE are modelled simultaneously so that their possible correlation can be accounted for.[33] For the OMAS, the patients' follow-up scores at week 52 were used as dependent variable. For total costs and QALYs, the patients' total costs and QALYs during follow-up were used as dependent variable, respectively. Analyses of the OMAS were adjusted for the patients' baseline OMAS and other possible confounders measured at baseline (Table I). In contrast to the recommendation of Manca et al.,[34] we decided not to adjust QALYs for baseline utility scores, as a "true" utility score was lacking in the current study. That is, the baseline utility value in the present study described the patients' utility value prior to their fracture, instead of right after their fracture. The incremental cost-effectiveness ratio (ICER) was estimated by dividing the cost difference by the effect difference ($\Delta C/\Delta E$). To estimate the uncertainty around the ICER and to estimate 95% confidence interval (95% CI) surrounding the cost differences, bias-corrected and accelerated bootstrapping was performed with 5,000 replications. For all 5,000 replications the cost and effect pairs were plotted on a cost-effectiveness plane to graphically illustrate the uncertainty surrounding the ICER.[35] A summary measure of the joint uncertainty surrounding costs and effects was provided by constructing cost-effectiveness acceptability curves (CEACs). These curves give an indication of the probability that the reduced imaging protocol for ankle fractures is cost-effective for a range of willingness to pay values. CEACs were pooled with use of a combination of Rubin's rules and the incremental net monetary benefit approach. For all statistical tests, significance was assumed at $p < 0.05$.

Sensitivity Analyses

A total of 6 sensitivity analyses were planned. In the first sensitivity analysis, only data of participants with complete data were used (SA1). The second sensitivity analysis (SA2) made use of the measured utility score at baseline (prior to the fracture), instead of the value derived from the utility score at 6 weeks. The third sensitivity analysis (SA3) used the Human Capital Approach to calculate productivity losses instead of the Friction Cost Approach. The Human Capital Approach assumes that productivity losses occur during the complete period of absence instead of being limited to the friction period. For the fourth sensitivity analysis (SA4), costs were assessed from a healthcare perspective. A healthcare perspective regards only costs accruing to the formal Dutch healthcare system, meaning that costs of informal care, absenteeism, presenteeism, and unpaid productivity losses were disregarded. The fifth (SA5) and sixth sensitivity analysis (SA6) only included patients with either a nonoperative or an operative management, respectively.

RESULTS

Participants

We enrolled 312 participants in the study (Fig. 1). 6 were excluded after randomization, because an exclusion criterion was present that was not identified before randomization (Fig. 1). Of the remaining 306 participants, 156 were randomized to routine care and 150 to reduced imaging. In total, 60 patients, 28 in the routine care group (18%) and 32 in the reduced imaging group (21%) did not return any of the follow-up questionnaires

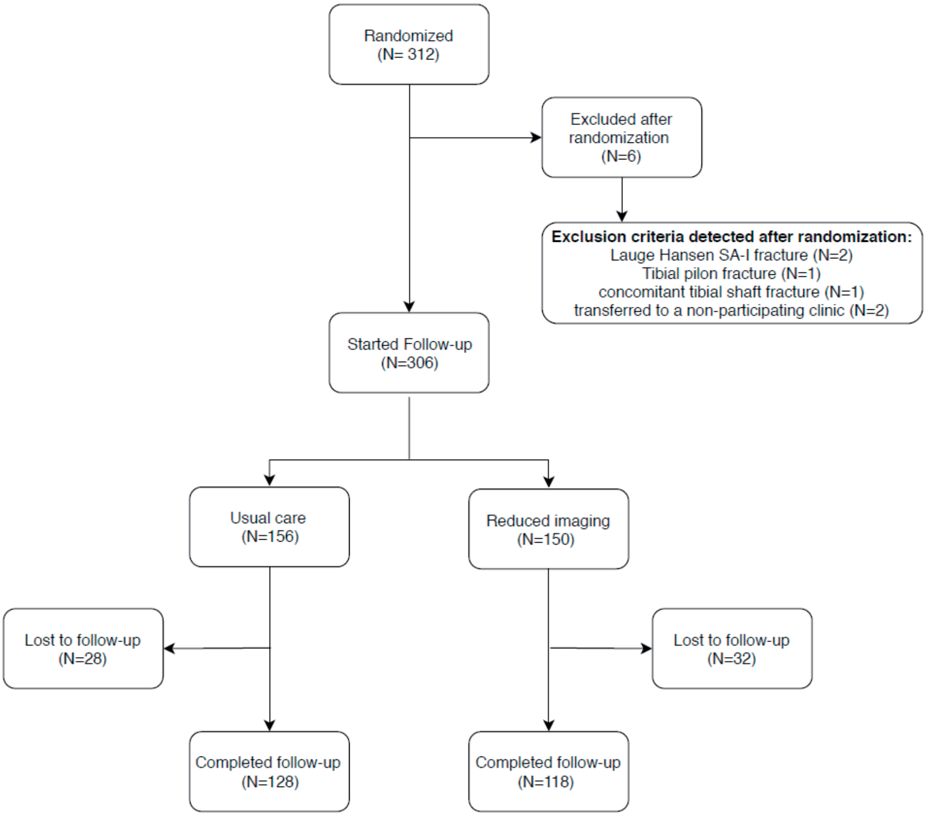

Figure 1. Flowchart of participants

and were lost to follow-up. Thus, 246 participants were included in the analysis (128 in the routine care group and 118 in the reduced imaging group).

Aside from a higher mean BMI for the reduced imaging group, no meaningful differences were observed between groups at baseline (Table I). Surgery was performed in 60% of participants in the routine care group (77/128) and in 65% of participants in the reduced imaging group (76/118). Out of a total of 1,230 (246*5) baseline and follow-up questionnaires, 1,096 were returned by the participants (89%).

Table I. Patient characteristics by treatment allocation

		Routine care (n=128)	**Reduced imaging** (n=118)	***p*-value**
Male sex,	n (%)	69 (53.9)	58 (48.7)	0.42
Age	mean (SD)	47.7 (18.5)	50.8 (18.2)	0.18
BMI	mean (SD)	25.8 (4.3)	27.3 (6.0)	**0.02**
Alcohol >10 U/week	n (%)	22 (17.2)	16 (13.4)	0.42
Smoking >10/day	n (%)	10 (7.8)	9 (7.6)	0.94
Operative treatment	n (%)	77 (60.2)	76 (64.4)	0.46
Lauge-Hansen classification SA	n (%)	2 (1.6)	2 (1.7)	0.60
SE		94 (73.4)	94 (79.0)	
PA/PE		31 (24.2)	23 (19.3)	
missing		1 (0.8)	0 (0.0)	
Weber classification A	n(%)	2 (1.6)	2 (1.7)	0.49
B		93 (72.7)	94 (79.0)	
C		27 (21.1)	21 (17.6)	
missing		6 (4.7)	2 (1.7)	
Malleolar involvement Uni-	n(%)	66 (51.6)	64 (53.8)	0.79
Bi-		27 (21.1)	21 (17.6)	
Tri-		35 (27.3)	34 (28.6)	
ASA classification 1	n(%)	53 (41.4)	47 (39.5)	0.83
2		60 (46.9)	55 (46.2)	
≥3		15 (11.7)	12 (7.7)	

Legend for Table I:
SD: Standard deviation
SA: Supination-adduction
SE: Supination-external rotation
PA: Pronation-adduction
PE: Pronation-eversion
BMI: Body Mass index
ASA: American Society of Anesthesiologists
Bold = a significant difference between groups ($p < 0.05$)

Effects

There was no significant difference in the OMAS (0.73; 95% CI, −5.3 to 6.8) and QALYs (−0.008; 95% CI, −0.04 to 0.03) between groups. An overview of the patients' OMAS and EQ-5D-3L score per follow-up moment can be found in the Appendix.

Costs and Use of Resources

As a result of the intervention, patients randomized to the reduced imaging group had fewer radiographs taken of their ankle fracture than patients randomized to routine care, equalling a median number of radiographs of 4 (Interquartile Range [IQR] 3 to 5) for the reduced imaging group versus a median of 5 (IQR 4 to 6) for the routine care group. This resulted in a significant reduction in imaging costs in favour of the reduced imaging group (–€48 per patient; 95% CI, −72 to −25). All other costs, including total societal costs, were not significantly different between groups (Table II).

Table II. Mean cost (in euros) per participant in the intervention and control group and mean cost differences between groups during follow-up

Cost category	Routine care (n=128) mean (SEM)	Reduced imaging (n=118) mean (SEM)	Cost difference (β) adjusted mean (95%CI)
Intervention	266 (9)	222 (9)	**-48 (-72 to -25)**
Primary care	967 (154)	1266 (387)	137 (-277 to 1018)
Secondary care	7435 (971)	7803 (1176)	-169 (-2230 to 2178)
Medication	36 (9)	27 (7)	-8 (-27 to 12)
Informal care	671 (121)	647 (131)	-46 (-373 to 262)
Absenteeism	976 (212)	1218 (312)	306 (-373 to 1109)
Presenteeism	4903 (627)	4373 (605)	-29 (-1503 to 1408)
Unpaid productivity loss	789 (152)	757 (184)	-12 (-437 to 427)
Total	16046 (1419)	16314 (1741)	130 (-2975 to 3723)

Legend
Bold = a significant difference between groups ($p < 0.05$)

Cost-effectiveness

For QALYs, the intervention was dominated by the control, based on a cost difference (ΔC) of €131 and an effect difference (ΔE) of −0.008 QALY. The ICER for functional outcome was 178, based on the same ΔC of €131 and a ΔE of 0.73 points on the OMAS (Table III). The CE-plane for QALYs shows that the cost-effect pairs were scattered across all 4 quadrants of the CE-plane (Fig. 2). The CEAC in Fig. 3 indicates that if decision-makers are willing to pay €20,000 per QALY gained, the probability of reduced imaging being cost-effectiveness compared with routine care was 0.45. This probability reduced with increasing values of willingness to pay to about 0.37 at a willingness to pay of €80,000

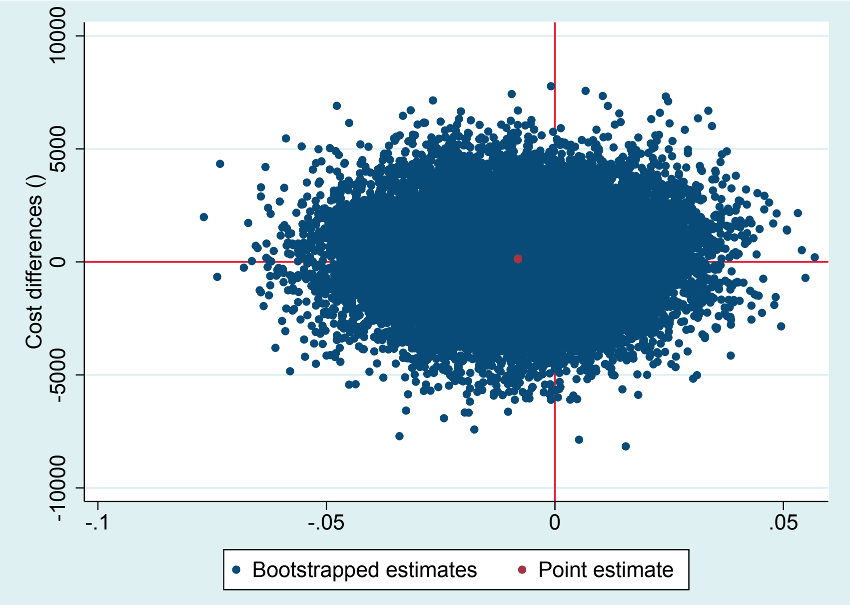

Figure 2. Cost-effectiveness plane for QALYs representing the results from the 5000 bootstrapped replications, and the point estimate.. Higher on the Y-axis corresponds to costlier than routine care, more right on the X-axis corresponds to more effective than routine care.

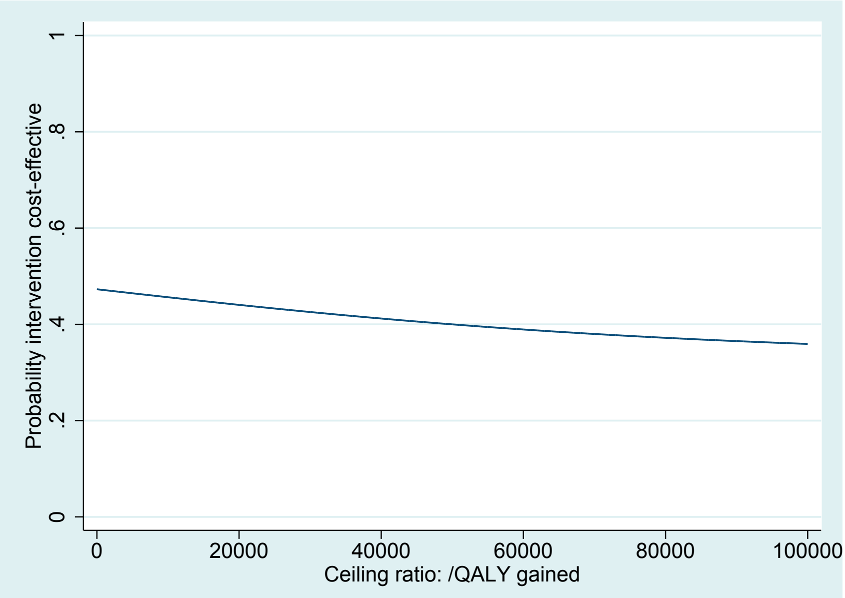

Figure 3. Cost-effectiveness acceptability curve for QALYs, showing the probability of the intervention being cost effective at a certain willingness to pay value per QALY.

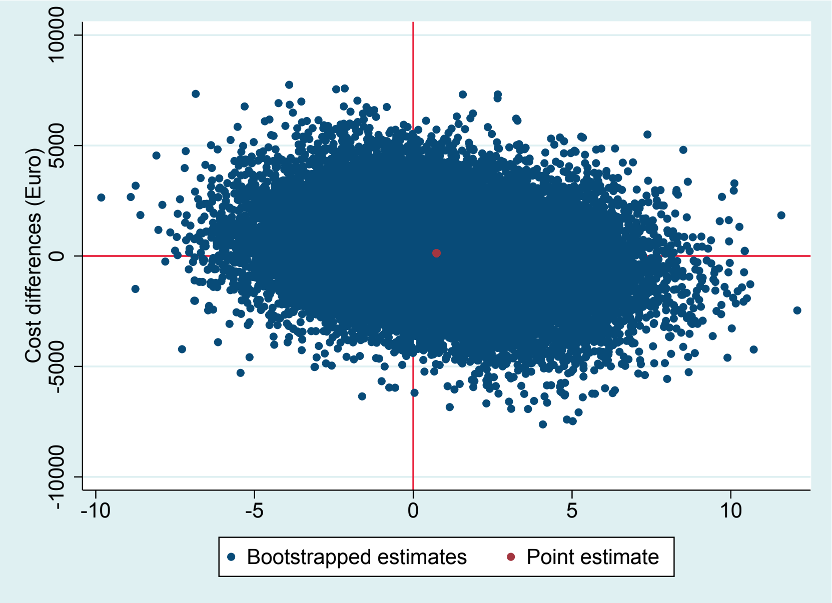

Figure 4. Cost-effectiveness plane for the OMAS, representing the results from the 5000 bootstrapped replications, and the point estimate. Higher on the Y-axis corresponds to costlier than control, more right on the X axis corresponds to more effective than control.

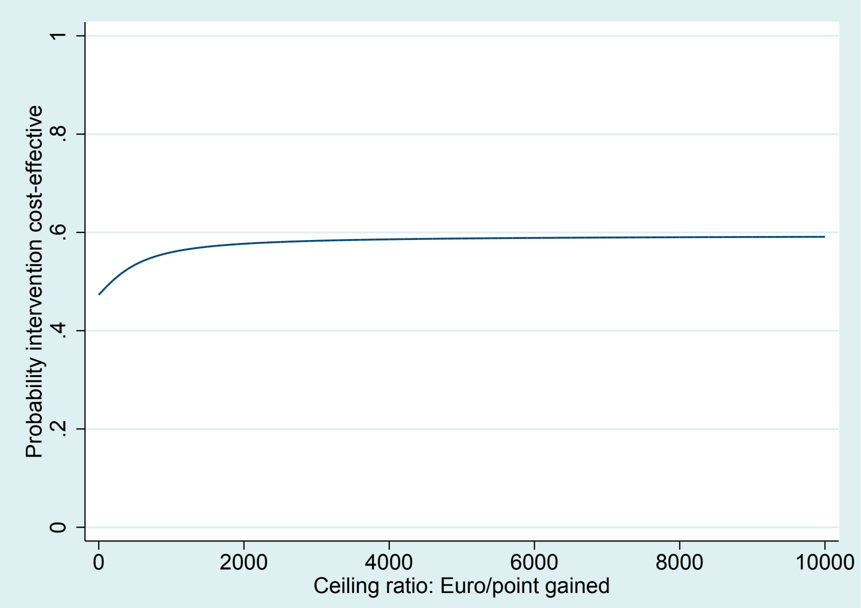

Figure 5. Cost-effectiveness acceptability curve for the OMAS, showing the probability of the intervention being cost effective at a certain willingness to pay value per point increase of the OMAS.

per QALY. The CE-plane for the OMAS also shows that the cost-effect pairs were scattered across all 4 quadrants of the CE-plane (Fig. 4). For the OMAS, the CEAC indicates that if decision-makers are not willing to pay anything per point improvement, the probability of reduced imaging being cost-effectiveness compared with routine care was 0.47. This probability increased with increasing values of willingness to pay to about 0.59 at a willingness to pay of €5,000 per point improvement (Fig. 5).

Sensitivity Analyses

In total, 6 sensitivity analyses (SA) were performed. Outcomes of the sensitivity analyses demonstrated many similarities with those of the main analysis (Table III). Except for SA6, differences in QALYs were in favour of the routine care group. Cost per category for the nonoperatively and operatively treated subgroup are reported separately in the Appendix. Except for SA5, the OMAS was higher for the reduced imaging group than for the routine care group and except for SA4 and SA5, total costs were higher for the reduced imaging group. However, all these differences in costs and effects were not significant. It is important to note that the relatively large differences in ICERs between the main analysis and some of the sensitivity analyses were because of small between-group differences in QALYs and the OMAS.

DISCUSSION

The reduced imaging follow-up protocol resulted in a significant decrease in the number of radiographs as well as the associated cost compared with routine care. Other cost categories, including total healthcare costs and total societal costs, did not statistically differ between groups. Furthermore, no significant differences were found between groups for QALYs and the OMAS. This indicates that functional outcome and HRQoL were unaffected by reducing the number of radiographs performed at 6 and 12 weeks of follow-up. The probability of the reduced imaging protocol being cost-effective compared with routine care was relatively low (0.45) at a willingness to pay threshold of €20,000 per QALY. In the Netherlands, this is deemed an acceptable cost-per-QALY for interventions for diseases/disorders with a relatively low disease burden.[36] For the OMAS, it is currently unknown how much decision-makers are willing to pay per unit of effect gained, so it is not possible to draw any firm conclusions for this outcome. Sensitivity analyses confirm these findings. Literature on the (cost-)effectiveness of omitting routine extremity radiography is scarce. This is discussed in our retrospective review[37] and has been confirmed by researchers investigating the usefulness of an additional shoulder radiograph.[38] Results from the present study, however, were consistent with results from our study which examined the cost-effectiveness of reduced imaging in

Table III: Differences in pooled mean costs and effects, incremental cost-effectiveness ratios, and the distribution of incremental cost-effect pairs around the quadrants of the cost-effectiveness planes for reduced imaging compared to routine care

	Routine care	**Reduced imaging**	**Outcome measure**	**ΔC** € (95% CI)	**ΔE** Points (95% CI)	**ICER** €/point	**Distribution CE-plane** (%)			
							NE	SE	SW	NW
Main analysis	128	118	QALYs (Range: 0 - 1)	131 (-3039 to 3928)	-0.008 (-0.04 to 0.03)	-16198	17.4	14.4	32.1	36.0
			OMAS (Range: 0 – 100)	131 (-3039 to 3928)	0.73 (-5.29 to 6.76)	178	21.4	31.8	15.0	25.8
SA1 *– Complete cases*	29	23	QALYs (Range: 0 - 1)	1242 (-7949 to 6447)	-0.014 (-0.06 to 0.04)	-86988	46.0	7.5	10.9	35.6
			OMAS (Range: 0 – 100)	1242 (-7949 to 6447)	3.04 (-5.82 to 11.89)	409	70.1	16.2	2.8	10.8
SA2 *– QALY 1 VS QALY 2*	128	118	QALYs (Range: 0 - 1)	131 (-3039 to 3947)	-0.013 (-0.05 to 0.02)	-10394	8.3	15.9	30.8	45.0
SA3 *– Human capital approach*	128	118	QALYs (Range: 0 - 1)	383 (-2900 to 4365)	-0.008 (-0.04 to 0.03)	-47311	19.2	13.2	29.8	39.9
			OMAS (Range: 0 – 100)	383 (-2900 to 4365)	0.73 (-5.29 to 6.75)	527	30.6	28.9	13.2	27.4
SA4 *– Healthcare perspective*	128	118	QALYs (Range: 0 - 1)	-89 (-2386 to 3287)	-0.008 (-0.04 to 0.03)	11052	14.3	17.2	36.4	32.1
			OMAS (Range: 0 – 100)	-89 (-2386 to 3287)	0.73 (-5.29 to 6.75)	-121	23.6	36.2	17.4	22.8
SA5 – *Conservative treatment*	51	41	QALYs (Range: 0 - 1)	-2425 (-9691 to 1223)	-0.03 (-0.09 to 0.02)	74883	3.7	8.1	66.2	22.0
			OMAS (Range: 0 – 100)	-2425 (-9691 to 1223)	-1.60 (-10.49 to 7.30)	1519	6.2	28.5	45.5	19.8
SA6 – *Operative treatment*	77	77	QALYs (Range: 0 - 1)	1432 (-3007 to 6706)	0.001 (-0.04 to 0.04)	1504404	39.0	15.5	14.7	30.9
			OMAS (Range: 0 – 100)	1432 (-3007 to 6706)	1.51 (-5.07 to 8.08)	951	50.6	24.7	4.3	20.4

Legend for Table III:
SA: Sensitivity analysis
QALYs: Quality Adjusted Life Years
OMAS: Olerud and Molander Ankle Score
ΔC: Difference in cost
ΔE: Difference in effect
ICER: Incremental Cost Effectiveness Ratio
CE-plane: Cost Effectiveness plane.
NE: North east part of the CE-plane (representing an intervention that is more costly, but more effective)
SE: South east part of the CE-plane (representing an intervention that is cheaper, and more effective)
SW: South west part of the CE-plane (representing an intervention that is cheaper, but less effective)
NW: North west part of the CE-plane (representing an intervention that is both more costly and less effective)

distal radius fractures.[39] In that study we also saw no difference in functional outcome, but a significant reduction in cost for radiographic imaging for the reduced imaging group.

Strengths and Limitations

This economic evaluation was performed alongside a pragmatic RCT. Therefore, our results are likely to have a high internal validity, while their external validity is improved by the pragmatic nature of the trial. Of course, the present study has limitations as do all studies. First, the sample size calculation was based upon a margin of noninferiority[40] for the OMAS, rather than a meaningful difference in societal costs or QALYs. Wide confidence intervals surrounding the aggregate and disaggregate cost differences suggest that the study was underpowered to detect a meaningful difference in cost between groups. This is common for economic evaluations as powering to detect a meaningful difference in societal costs would have required many more participants. This would have been neither feasible nor ethical. Second, the number of radiographs omitted was lower than anticipated. This was because of a high number of protocol violations for the reduced imaging group. The protocol was adhered to (i.e., no routine radiograph made at both 6 as well as 12 weeks of follow-up) in just 59 of 118 participants (50%) in this group. We have reported on this in more detail in an earlier report.[41] Third, self-reported questionnaires were used to query the effect, and some costs. These questionnaires had a maximum recall period of 26 weeks, which might have introduced recall bias. However, as the recall period was similar for both groups, we assume that if present, this bias was similar for both groups. Fourth, 79% (195/246) of the participants had at least 1 missing item on at least 1 of the questionnaires. The number of participants with complete cost and effect data was 242 at baseline (100%), 227 at week 6 (92%), 216 at week 12 (88%), 206 at week 26 (84%), and 201 at week 52 (82%). Multiple imputation was used to deal with missing data. In an economic evaluation, multiple imputation is considered the gold-standard for dealing with missing data.[32] Moreover, a sensitivity analysis with use of data of complete cases showed similar results as the main analysis, i.e., no significant differences between groups for costs, the OMAS, and QALYs. Finally, the patients' EQ-5D-3L health status directly following the fracture was not assessed. It was only assessed prior to the fracture and at the various follow-up measurement points. To deal with this issue, we assumed the patients' EQ-5D-3L health state at week 6 to be representative for the complete period between the occurrence of the fracture and the follow-up moment at week 6 and used this value for calculating QALYs. We opted for this strategy, instead of using their pre-injury EQ-5D-3L health state, as most patients would have had a cast, or nonweightbearing mobilisation during these 6 weeks. We do not expect this to have biased our outcomes, as a sensitivity analysis with use of the patients' EQ-5D-3L health state before the occurrence of the fracture showed similar results as the main analysis.

CONCLUSION

Reducing the number of routine follow-up radiographs (on average 1 per patient) has a relatively low probability of being cost-effective compared with routine care. However, functional outcome, HRQoL, and societal costs were comparable for both groups whereas imaging costs were lower for the reduced imaging group. In the light of these findings and the potential for further reduction of the number of routine follow-up radiographs in daily clinical ankle fracture care, we advise a reduced imaging follow-up protocol for patients with ankle fracture.

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APPENDICES

Appendix 1: outcome scores per treatment allocation per time point.

		Routine care n=128 Median (IQR)	**Reduced imaging** n=118 Median (IQR)
OMAS	*BL*	100 (100-100)	100 (100-100)
	W6	40 (25-60)	45 (25-65)
	W12	65 (45-80)	65 (46-80)
	W26	85 (68-95)	80 (65-95)
	W52	90 (80-100)	90 (80-100)
EQ-5D	*BL*	1.0 (0.9-1.0)	1.0 (0.84-1.0)
	W6	0.78 (0.57-0.81)	0.78 (0.65-0.86)
	W12	0.83 (0.78-1.0)	0.81 (0.78-1.0)
	W26	1.0 (0.81-1.0)	0.84 (0.78-1.0)
	W52	1.0 (0.84-1.0)	1.0 (0.81-1.0)

Appendix 2: Mean cost (in euros) per operatively treated participant in the reduced imaging and routine care group, and mean cost differences between groups during follow-up

Cost category	**Routine care** n=128 mean (SEM)	**Reduced imaging** n=118 mean (SEM)	**Cost difference** (β) mean (95%CI)
Intervention	264 (11)	231 (12)	**-40 (-71 to -11)**
Primary care	1110 (161)	1575 (589)	101 (-476 to 1470)
Secondary care	10064 (908)	11469 (1679)	249 (-2733 to 3775)
Medication	35 (10)	32 (11)	-5 (-33 to 26)
Informal care	747 (143)	824 (202)	33 (-384 to 516)
Absenteeism	923 (256)	1335 (443)	551 (-335 to 1746)
Presenteeism	5451 (794)	5012 (885)	257 (-1618 to 2301)
Unpaid productivity loss	753 (175)	1058 (284)	287 (-278 to 980)
Total	**19346 (1330)**	**21536 (2420)**	**1432 (-2596 to 6998)**

Legend for appendix 2
Bold = a significant difference between groups (*p* <0.05)

Appendix 3: Mean cost (in euros) per nonoperatively treated participant in the reduced imaging and routine care group, and mean cost differences between groups during follow-up

Cost category	**Routine care** n=128 mean (SEM)	**Reduced imaging** n=118 mean (SEM)	**Cost difference** (β) mean (95%CI)
Intervention	271 (17)	205 (13)	**-54 (-96 to -16)**
Primary care	752 (259)	708 (177)	63 (-448 to 564)
Secondary care	3465 (1936)	1169 (272)	-1194 (-5891 to 574)
Medication	37 (14)	18 (7)	-13 (-39 to 6)
Informal care	557 (203)	328 (135)	-161 (-728 to 145)
Absenteeism	1058 (384)	1006 (510)	-42 (-1119 to 1213)
Presenteeism	4076 (949)	3217 (957)	-405 (-2838 to 1613)
Unpaid productivity loss	846 (278)	214 (88)	**-619 (-1524 to -175)**
Total	11063 (2665)	6865 (1267)	-2425 (-9471 to 1162)

Legend for appendix 3
Bold = a significant difference between groups (*p* <0.05)