Cost Consequence Analysis of Implementing the Low Risk Ankle Rule in Emergency Departments

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Study objective: Implementation of the Low Risk Ankle Rule can safely reduce radiographs for children with acute ankle injuries. The main objective of this study is to examine the costs and consequences of implementing the rule.

Methods: For children aged 3 to 16 years and with an acute ankle injury, we collected data on health care provider visits, imaging, and treatment at the index emergency department (ED) visit and days 7 and 28 post–ED discharge. This was done during 3 consecutive 6-month phases at 6 EDs. After the baseline phase 1, the Low Risk Ankle Rule was introduced in phases 2 and 3 in 3 intervention EDs, but not in the 3 pair-matched control EDs. We compared the effect of the Low Risk Ankle Rule on health care and patient-paid costs, the proportion of radiographs ordered, the proportion of missed clinically important fractures, and the follow-up use of health care resources.

Results: We enrolled 2,151 children with ankle injuries, 1,055 at the intervention and 1,096 at the control EDs. Health care costs were $36.93 less per patient at intervention compared with control sites (P=.02). Out-of-pocket costs to the patients were $2.09 more per patient at intervention sites (P=.30). In intervention versus control sites, the main contributor to cost reduction was the 22.9% reduction in ankle radiography. Furthermore, there were no significant differences in the frequency of missed clinically important fractures (0.1% versus 0.9%) or follow-up use of health care resources.

Conclusion: Widespread implementation of the Low Risk Ankle Rule may lead to reduction of unnecessary radiographs for children and result in cost savings. [Ann Emerg Med. 2015;■:1-9.]

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INTRODUCTION

Background

Pediatric ankle injuries result in more than 2 million emergency department (ED) visits in Canada and the United States each year.[1] Radiographs are ordered for 85% to 95% of these children,[1] although only 12% of these reveal a fracture.[2] Thus, radiographs may not be necessary for most children's ankle injuries, and these high rates may needlessly add to health care costs. There are 2 validated clinical decision rules that aim to reduce unnecessary ankle radiography in children: the Ottawa Ankle Rules and the Low Risk Ankle Rule. The Ottawa Ankle Rules have a high sensitivity for children[3] but a relatively low specificity, thereby limiting their capacity to reduce ankle radiographs by only approximately 10% to 15%.[2,4,5] In contrast, the Low Risk Ankle Rule has a comparably high sensitivity, but also has the potential to safely reduce imaging by 50% to 60%.[2,4] When the application of the Low Risk Ankle Rule suggests that no radiographs are needed, level 1 evidence demonstrated that any fractures that might be missed are clinically unimportant and can be safely and cost-effectively managed like an ankle sprain, with superior functional recovery.[6] Although the clinical implementation of the Low Risk Ankle Rule has been limited, it has been shown to have a high rating on the Ottawa Acceptability Score for clinical decision rules when tested on emergency physicians and compared with the Ottawa Ankle Rules.[7]

Importance

We recently implemented the Low Risk Ankle Rule at 3 of 6 diverse ED practice settings in Canada, using a multimodal knowledge translation strategy with the primary purpose of evaluating its effect on reducing the frequency of unnecessary radiography.[1] We found that use of the Low Risk Ankle Rule reduced ankle radiography use by approximately 23%, which was similar in both pediatric and general EDs. Furthermore, this reduction was achieved without an increase in the frequency of missed clinically

Editor's Capsule Summary

What is already known on this topic

The Low Risk Ankle Rule has been shown to significantly reduce unnecessary radiographs for children with acute ankle injuries without missing clinically significant fractures.

What question this study addressed

The costs and clinical consequences of implementing the Low Risk Ankle Rule in 3 Canadian emergency departments (EDs) is compared with that for 3 matched control EDs.

What this study adds to our knowledge

The Low Risk Ankle Rule appears to have modestly reduced health system cost (chiefly through a 22% reduction in radiography) without substantially increasing costs or adverse outcomes to patients.

How this is relevant to clinical practice

Although costs vary by health system, adoption of the Low Risk Ankle Rule appears to reduce radiograph use without increasing costs.

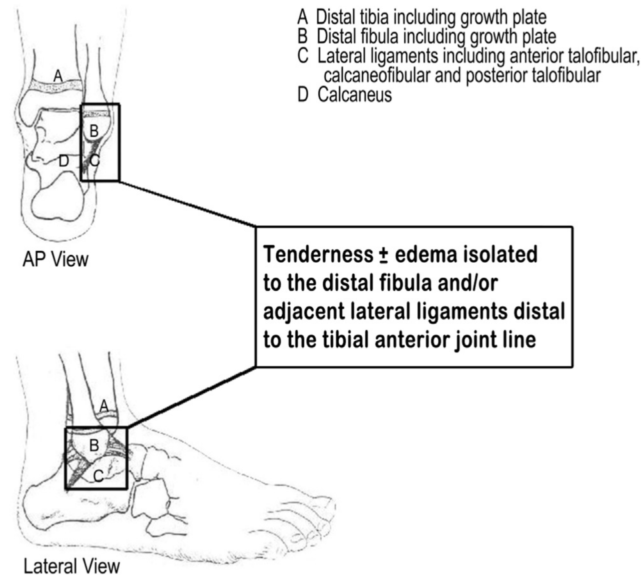

Figure 1. The Low Risk Ankle Rule: If a child presents with tenderness and swelling isolated to the distal fibula or adjacent lateral ligaments distal to the tibial anterior joint line (low-risk examination), then a radiograph may not be necessary for the detection of a clinically important ankle injury. Low risk ankle injuries that may not be detected if no radiography is obtained because of application of this rule include the following: nondisplaced Salter-Harris I and II and buckle fractures of the distal fibula and avulsion fractures of the distal fibula/lateral talus.

important fractures or decrease in physician or patient satisfaction. Although the Low Risk Ankle Rule was not primarily developed to reduce health care system or patient costs, a secondary consequence of its implementation might be either a reduction or unintended increase in costs.

Goal of This Investigation

The main objective of this study was to compare the costs and clinical consequences of managing pediatric ankle injuries after implementation of the Low Risk Ankle Rule at intervention sites versus standard care at control sites.

MATERIALS AND METHODS

The Low Risk Ankle Rule is demonstrated and defined in Figure 1. Children with these isolated findings have low risk ankle injuries, and radiographs do not contribute to management decisions because these injuries can be managed safely and effectively with supportive splinting and return to activities as tolerated by the patient.[6,8,9] Low risk ankle injuries include lateral ankle sprains, nondisplaced Salter-Harris I and II fractures of the distal fibula, and avulsion fractures of the distal fibula or lateral talus.[2,6] A high risk ankle injury includes any fracture of the foot, distal tibia, and fibula proximal to the distal physis, tibiofibular syndesmosis injury, osteochondral fractures, and ankle dislocations.[2]

Study Design, Setting, and Selection of Participants

The details of the design have been published.[1] In brief, the study occurred during an 18-month period at 6 Canadian EDs, using an interrupted time series with pair-matched control design. There were no changes made to usual practice at the 3 control sites during the entire 18-month study period. At the 3 intervention sites, there were 3 consecutive 26-week phases. Phase I did not include any interventions. Phase 2 introduced a multimodal intervention strategy consisting of educational initiatives for the Low Risk Ankle Rule. Phase 3 had a single intervention only (a computer decision support system). Participating sites included university-affiliated pediatric EDs in 2 children's hospitals, general EDs in 2 urban university-affiliated teaching hospitals, and community EDs in 2 suburban hospitals with a limited teaching or academic mandate. The study was approved by the research ethics boards at all participating sites.

Healthy children aged between 3 and 16 years who presented with an isolated acute (<72 hours) nonpenetrating ankle injury with no previous radiographs were eligible for participation. Children were excluded if they were developmentally delayed or at risk for pathologic fractures or had recent history of injury to the same ankle.

Methods of Measurement

The details of clinical data collection are reported elsewhere.[1] In summary, at all sites, the following variables were prospectively recorded: patient demographics, length of stay, imaging, final diagnosis, and treatment. To measure resource use, children at all sites were followed up by telephone at 7 and 28 days postinjury for the following information: health care visits, imaging, and any relevant change in diagnoses after the ED visit.[1] These data were collected at all sites in a consistent manner with an a priori–developed standardized forms.

Resource use data were abstracted from research implementation strategy documents, patient records, and scheduled follow-up telephone calls to patients' families on days 7 and 28 after the initial ED visit. Types of resources recorded were as follows: implementation strategies, consultations with health care professionals, imaging tests, surgeries, immobilization strategies, and use of crutches. Implementation strategies included physician education about the rule, on-site reminders that were both paper based and electronic (Table E1, available online at http://www.annemergmed.com).

We determined the cost of health care resources used and charges to patients during all phases at intervention and control sites (Table E2, available online at http://www.annemergmed.com). To minimize bias in assigning dollar values for each cost or charge, we subcontracted an economic evaluation team that was separate from the clinical research team, and this team independently determined prices and conducted the analysis. Individuals who determined prices were blinded to the study hypothesis and were provided only the quantity of resource use for each patient. Finally, the same unit prices were assigned to both arms, and thus cost differences were driven by differences in resource use rather than differences in costs. Costs and charges were assigned post hoc to represent more current values and assessed for 2013. When 2013 prices were not available, values for previous years were inflated, using the Canadian Consumer Price Index for Health and Personal Care.

The unit costs of physician services, procedures, and diagnostic imaging are standardized within provinces and, in Ontario, are determined from the Ontario Health Insurance Plan Schedule of Benefits for Physician Services. For costs that are not standardized across the province, there is variation in hospital-based charges from site to site. Given this variation, we used the standard economic evaluation practice for costing these items. We determined these costs from a hospital with a reliable costing system that can be considered representative of other hospitals in Canada[10] and from average costs determined from Web sites of health care supply stores.

The cost of managing each patient was estimated by applying relevant unit cost data to the resource profile compiled for each patient in the study. There were 3 categories of unit costs: (1) health care costs, which included health care visits, imaging, and treatment (surgery and health care provider–paid ankle support devices); (2) charges to patients for out-of-pocket or insurance-purchased ankle support devices and the physiotherapist's administration fee at first assessments; and (3) total costs, which were the sum of health care and patient-paid charges.

Outcome Measures

Our primary cost outcome was the mean health care provider costs. Secondary outcomes included mean patient-paid costs and total costs (health care and patient-paid costs). These outcomes were measured in Canadian dollars.

Our main clinical outcome for the primary clinical study analysis was the proportion of children who received ankle radiographs in the ED. Secondary clinical outcomes included median length of stay in the ED, proportion of clinically important fractures missed, proportion of children who received ankle radiographs after the initial ED visit, and median number of ED and fracture follow-up visits.[1]

Primary Data Analysis

Mean costs were estimated for phase 1 and phases 2 and 3 separately for intervention and control sites to allow the estimate of changes in mean costs by treatment group. A comparison of costs between intervention and control sites and between phases was conducted with a general linear model with a γ error to account for right skewing and with a compound symmetry error structure to account for the clustering of observations within sites. The compound symmetry was justified because of the exchangeability of patients within clusters (sites), and the observed intraclass correlation for patients within clusters was small (<0.002). The only variables in the general linear model were the dummy variables for intervention and phase, which established the contrast so that the change over time between treatment arms could be compared statistically. Using the γ distribution for the cost was justified because it yielded a better fit compared to normal, and this distribution for cost has been shown to be robust.[11] To demonstrate costs at all 6 sites through box plots, we took the log of each value and graphed and then transformed the axis labels to present data as a regular dollar scale.

Details of clinical analyses have been previously published.[1] In brief, analysis of the primary clinical outcome (proportion of radiographs) was performed with a general linear model with a compound symmetry error structure to account for the clustering of observations within sites. Analyses of the secondary outcomes (length of stay, proportion of missed clinically important fractures, proportion of follow-up visits/repeated imaging) were performed with the interrupted time series difference-in-difference method.[12-14] Analyses of the secondary outcomes (length of stay, proportion of missed clinically important fractures, proportion of follow-up visits/repeated imaging) were performed with the interrupted time series difference-in-difference method. Variables in the model included indicators of the 6 hospital types, study phase, and interactions between site and phase indicators. We implemented this analysis with a standard linear regression model and estimated the parameters of this regression model with ordinary least squares. Standard errors were estimated with methods that are robust to possible site-specific clustering and heteroscedasticity. For these secondary outcomes, the slope of the preintervention trend lines was similar in the treatment and control sites, satisfying a key requirement for the application of the difference-in-differences regression model.[15]

Primary cost and clinical outcome analyses were performed with the SAS procedure PROC GENMOD (version 9.3; SAS Institute, Inc., Cary, NC). Secondary clinical analyses were performed with Stata (version 12; StataCorp, College Station, TX).

Costs and clinical outcomes were descriptively compared with a cost-consequences economic analysis. Thus, the costs were reported separately from the clinical outcomes and were not combined into a single indicator. Implementation costs were tabulated (see Table E1, available at www.annemergmed.com) but not included in the comparative analysis because they were a one-time fixed cost that is not limited to the 18-month study period.

RESULTS

We used cost data from 2,151 children with acute ankle injuries, 1,055 at the intervention sites and 1,096 at the control sites (Table 1). Implementation costs averaged $3,941.83 per site (Table E1, available online at http://www.annemergmed.com) or $6.28 per patient (n=628). There was a significant decrease in health care costs of $36.93 per patient at the intervention sites from phase 1 to phases 2 and 3 compared with the between-phase difference in the control sites (primary outcome) (Table 1). The largest health care cost reductions arising from the implementation of the Low Risk Ankle Rule at intervention sites were from reduced radiography costs (–$18.58/patient), follow-up visits with the orthopedic surgeon (–$8.37/patient), follow-up ED visits (–$5.72), and health care–paid immobilization devices (–$3.33) (Table E2, available online at http://www.annemergmed.com). Patient-paid cost difference between control and intervention sites and phases was $2.09, which was not statistically significant. Overall, there was a significant decrease in mean total costs per patient of $34.69. Total heath care costs by study period are detailed

Table 1. Comparison of cost and clinical consequences by treatment group and study period.

Consequence	Intervention		Control		Between-Group and Phase Differences (95% CI)*
	Baseline, Phase 1, n=427	Intervention, Phases 2 and 3, n=628	Baseline, Phase 1, n=463	Standard Care, Phases 2 and 3, n=633	
Cost consequence					
Cost perspective (SE), Can $					
Mean health care provider costs per patient	466.59 (6.90)	428.68 (6.65)	481.71 (24.92)	480.74 (18.23)	−36.93 (−68.65 to −5.21)
Mean patient-paid costs per patient	33.78 (4.45)	36.15 (4.06)	26.90 (3.01)	27.19 (4.14)	2.09 (−1.80 to 5.97)
Mean total health care and patient costs	500.27 (3.85)	464.92 (10.47)	508.47 (29.47)	507.81 (24.49)	−34.69 (−64.62 to −4.77)
Clinical consequence†					
Clinical outcome					
Ankle radiographs imaged, %	96.5	72.1	90.2	88.5	−22.9 (−28.6 to −15.2)
Length of stay, median (IQR), h	2.0 (1.4, 2.9)	2.0 (1.4, 2.9)	2.9 (2.0, 4.3)	2.5 (1.8, 3.6)	0.4 (−0.2 to 0.9)
Significant fractures missed, %	1.7	1.8	0	0.9	0.3 (−0.04 to 0.5)

SE, Standard error; *IQR*, interquartile range.
*Between-group and phase differences include cost differences between intervention and control sites and between phases (ie, phase 1 versus phases 2 and 3).
†Adapted from Boutis et al.[1]

Table 2. Resource use by treatment group and study period.

	Intervention, N=1,055		Control, N=1,096	
Resource	**Baseline, Phase 1, n=427**	**Intervention, Phases 2 and 3, n=628**	**Baseline, Phase 1, n=463**	**Standard Care, Phases 2 and 3, n=633**
Health care resource use, No. (%)*				
Initial ED visit				
Visit				
ED	427 (100)	628 (100)	463 (100)	633 (100)
Imaging				
Radiographs	413 (96.5)	454 (72.1)	418 (90.2)	560 (88.5)
CT	2 (0.5)	1 (0.2)	1 (0.2)	1 (0.2)
Health care provider				
Emergency physician	427 (100)	628 (100)	463 (100)	633 (100)
Orthopedic surgeon	13 (3.1)	13 (2.1)	13 (2.8)	19 (3.8)
Interventions				
Ankle immobilization/support (posterior splint, below-knee cast, elastic bandage)	324 (75.7)	484 (77.1)	423 (91.3)	586 (92.6)
Closed reduction with anesthesia	2 (0.5)	0	0	4 (0.8)
Surgery	1 (0.3)	1 (0.2)	0	1 (0.2)
Health care visits 1–7 days after initial presentation to the ED				
ED				
Visit	13 (3.1)	6 (1.0)	7 (1.5)	13 (2.6)
Physician	13 (3.1)	6 (1.0)	7 (1.5)	13 (2.6)
Radiographs	4 (1.0)	3 (0.5)	2 (0.4)	5 (1.0)
Family practice/walk-in				
Physician	10 (3.0)	39 (6.2)	6 (1.2)	24 (3.8)
Radiographs	0	3 (0.5)	0	1 (0.2)
MRI	0	0	0	1 (0.2)
Fracture clinic				
Visit†	58 (13.6)	95 (15.1)	97 (21.0)	121 (19.1)
Radiographs	14 (3.3)	25 (4.0)	42 (9.1)	33 (5.2)
CT	2 (0.5)	2 (0.4)	0	1 (0.2)
MRI	0	0	1 (0.2)	0
Sports medicine				
Physician	1 (0.3)	4 (0.8)	3 (0.6)	3 (0.6)
Radiographs	3 (0.9)	1 (0.2)	1 (0.2)	3 (0.6)
CT	1 (0.3)	2 (0.4)	0	1 (0.2)
Physiotherapist visits (excludes first assessment visit)‡	4 (1.2)	9 (1.4)	7 (1.4)	10
Health care visits 8–28 days after initial presentation to the ED				
ED				
Visit	13 (3.0)	17 (2.7)	8 (1.7)	17 (2.7)
Physician	13 (3.0)	17 (2.7)	8 (1.7)	17 (2.7)
Radiographs	3 (0.9)	7 (1.1)	3 (0.6)	8 (1.3)
CT	0	2 (0.4)	0	0
Family medicine/walk-in				
Physician	15 (3.5)	27 (4.3)	7 (1.5)	7 (1.1)
Radiographs	1 (0.3)	2 (0.4)	0	0
CT	0	1 (0.2)	0	0
MRI	0	1 (0.2)	0	0
Fracture clinic				
Visit†	113 (26.4)	109 (17.3)	212 (45.8)	265 (41.9)
Radiographs	34 (7.9)	42 (6.7)	75 (16.2)	79 (12.5)
CT	1 (0.3)	0	1 (0.2)	0
MRI	0	0	0	1 (0.2)
Sports medicine				
Physician	1 (0.3)	3 (0.5)	5 (1.0)	3 (0.6)
Radiographs	0	0	1 (0.2)	0
Physiotherapist visits	14 (3.3)	48 (7.6)	27 (5.8)	56 (8.8)
Patient-paid resource use, No. (%)				
Initial ED visit				
Ankle support devices (ankle brace, air cast walker)	102 (23.8)	170 (27.1)	39 (8.4)	47 (7.4)
Crutches	392 (91.5)	497 (79.1)	377 (81.4)	527 (83.2)

Table 2. Continued.

Resource	Intervention, N=1,055		Control, N=1,096	
	Baseline, Phase 1, n=427	Intervention, Phases 2 and 3, n=628	Baseline, Phase 1, n=463	Standard Care, Phases 2 and 3, n=633
Health care visits 1–7 days after initial presentation to the ED				
Physiotherapist	6 (1.4)	18 (2.9)	7 (1.5)	10 (1.6)
Health care visits 8–28 days after initial presentation to the ED				
Physiotherapist	9 (2.1)	19 (3.0)	15 (3.2)	25 (3.9)

ED, Emergency department; *CT,* computed tomography; *MRI,* magnetic resonance imaging.
*If CT or MRI is not reported, it is because there was none for that health care visit.
†Includes orthopedic surgeon fee.
‡First physiotherapy visit paid by patient.

in Table 2. For all 6 sites, total health care costs by study period are demonstrated in Figure 2.

The clinical consequences of implementing the Low Risk Ankle Rule are detailed in the article that focuses on clinical outcomes[1] and are summarized in Table 1. In brief, there was a 22.9% reduction of ankle radiographs at the intervention sites from phase 1 to phases 2 and 3 compared with that at control sites. The sensitivity of the rule during active implementation was 100% (95% confidence interval [CI] 85.4% to 100%). At intervention versus control across phases, implementation of the Low Risk Ankle Rule did not change length of stay (0 versus 0.4 hours), nor were there any differences in the frequency of missed clinically important fractures (0.1% versus 0.9%).

Other than the change in radiograph rates noted above, there were no significant differences in use of health care–paid resources between sites and phases (Table 3). Specifically for physician visits at intervention sites, there was a 3.2% increase in visits to family physicians from baseline to phases 2 and 3, but this was not statistically significant compared with the 2.6% increase at the control sites (difference 0.6%; 95% CI –0.2% to 1.0%). The baseline proportion of children with fracture clinic follow-up within 7 days was higher at control (21.0%) than intervention sites (13.6%) (difference 7.4%; 95% CI 2.4% to 12.3%); this baseline difference was also observed at 28 days (19.4%) (95% CI 13.1% to 25.4%). However, there were no differences between intervention and control sites and phases for the percentage of cases requiring orthopedic fracture clinic follow-up (difference –1.2%; 95% CI –7.1% to 4.6%). There were also no significant differences in the percentage of cases that required unscheduled ED visits (difference –0.8%; 95% CI –4.2% to 2.6%) or follow-up radiographs (difference 0.4%; 95% CI –0.2% to 1.0%). Resources such as sports medicine and physiotherapy were used relatively sparingly by this population at all sites.

For immobilization devices and support (Table 3), intervention sites had a higher preference for patient-paid

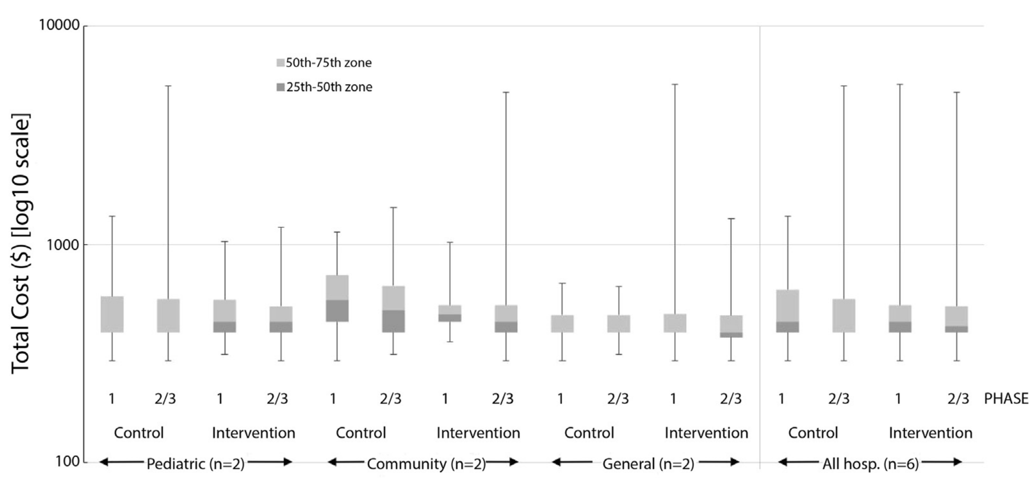

Figure 2. Effect of the Low Risk Ankle Rule on total costs at hospital-specific intervention versus control sites. All values are in Canadian dollars. Pediatric=pediatric ED located in tertiary care children's hospitals. General=general ED located in urban university-affiliated teaching hospitals. Community=community ED located in suburban hospitals with a limited teaching or academic mandate.

Table 3. Number or type of ankle immobilization devices applied by treatment group and study period.*

	Intervention		Control	
Ankle Support Devices	**Baseline, Phase 1, n=427**	**Intervention, Phases 2 and 3, n=628**	**Baseline, Phase 1, n=463**	**Standard Care, Phases 2 and 3, n=633**
Paid for by health care service provider, No. (%)				
Posterior splint	59 (13.8)	62 (9.9)	99 (21.4)	132 (20.9)
Below-knee cast	12 (2.8)	15 (2.4)	33 (7.1)	43 (6.8)
Elastic bandage	253 (59.1)	407 (64.8)	291 (62.9)	411 (64.9)
Total	324	484	423	586
Paid privately, No. (%)				
Crutches	392 (91.5)	497 (79.1)	377 (81.4)	527 (83.3)
Ankle brace	82 (19.2)	142 (22.6)	17 (3.7)	16 (2.5)
Air cast walker	20 (4.7)	28 (4.5)	22 (4.8)	31 (4.9)
Total	494	667	416	574
Total	818	1,151	839	1,160

*Not all patients received an ankle support device and some patients received more than 1 (eg, crutches, elastic bandage, and ankle brace).

immobilization devices than control sites (19.2% versus 3.7%; difference 15.5%; 95% CI 11.4% to 19.7%), which did not change significantly during implementation phases 2 and 3. Between phases, patients in the intervention sites had a significantly lower use of crutches (a patient-paid resource in Ontario) than those in the control sites (–11.8% versus 1.9%, respectively; difference –13.7%; 95% CI –20.1% to –7.1%).

LIMITATIONS

This study has some limitations. Because of site variation in specifics and the amortization of these costs over time, our cost analysis did not include costs of initial implementation and sustaining use of the Low Risk Ankle Rule beyond a 6-month interval. Resource use after the ED visit was based solely on parental report and therefore may be subject to error. The Low Risk Ankle Rule did not achieve the full potential radiograph use reduction reported in validation studies. However, our results are consistent with results from other ED clinical prediction rule implementation studies, which report imaging reductions of up to 28% but also increases of as much as 15%.[1] A convenience sample of participating sites was selected and allocation was not randomized. This may have introduced bias in favor of compliance with the Low Risk Ankle Rule at the intervention sites, resulting in a greater radiograph use reduction and respective cost savings. Furthermore, although the intervention and control sites were matched for key demographic variables, they were not identical pairs, and thus unknown confounders may have affected outcomes. A future study using a cluster randomized controlled trial design would provide the strongest validity with respect to effect of the Low Risk Ankle Rule on costs. The generalizability of our results requires detailed consideration and thus has been considered separately in the discussion.

DISCUSSION

We observed that implementing the Low Risk Ankle Rule in 3 different EDs resulted in a significant decrease in health care costs of approximately $37 per patient. The reduced costs were mainly due to a lower rate of radiograph use and follow-up visits to the orthopedic surgeon. Patient expenses were not significantly increased, and total combined health care and patient costs were significantly reduced by $35 per patient. The clinical consequences of applying the rule demonstrated a clinically and statistically important reduction in the proportion of radiographs ordered, with no significant differences in missed clinically important fractures or increased use of health care resources after discharge. The combined reduced costs and positive health care consequences suggest that implementation of the Low Risk Ankle Rule strategy in children with acute ankle injuries achieves economic dominance.[16]

The generalizability of our results needs to be considered. First, we demonstrated a significant decrease in health care costs, primarily because of reduced radiography, from the cost viewpoint of a publicly financed health care system. Although the directionality of cost savings is likely to be preserved across different health care systems, the beneficiaries will vary, depending on the health care system model. In a privately funded health care system, patients or insurance companies pay directly for specific services such as radiography and health care centers are compensated for performing them, so the cost beneficiary of reduced radiography would be the patient or insurer, and the heath care facility may experience lost revenue from reduced radiograph use. Therefore, we have explicitly reported the specific clinical benefits and cost differences that resulted from implementing the Low Risk Ankle Rule such that each health care system, facility, or physician can make a determination about the imperative for adopting this rule into practice. Second, our unit costs were obtained from provincial cost data of Ontario and regional hospital data, which might not be representative of costs at hospitals outside this province or country. Therefore, the magnitude of cost savings may not be generalizable to other sites. Finally, survey data suggest that clinical application of the Low Risk Ankle Rule remains low.[7] As a result, until there is more knowledge translation of the evidence supporting the rule and its related management strategy,[1,4,6,8,9,17,18] realization of the clinical benefits and potential cost savings will be limited.

This research did not demonstrate a significant change in per-patient paid costs. As demonstrated in related research,[6,19] implementing the Low Risk Ankle Rule and application of a patient-paid device (ankle brace) for low-risk ankle injuries may result in increased costs for the patient (or his or her insurer). At a minimum, therefore, we thought it was important that there not be an unintended increase in out-of-pocket costs to patients, and this study has shown this. A reduction in patient-paid costs may well occur in a health care system in which the patient pays for specific services such as a radiography. Finally, because this study did not examine other out-of-pocket expenses pre- and postimplementation (eg, child care, work loss), future study is required to definitively determine the financial effect on patients.

Our cost analysis did not include the costs of implementing the Low Risk Ankle Rule. We excluded these costs because Low Risk Ankle Rule implementation costs, once amortized over the numerous patients managed with the rule, would result in negligible per-case costs. Furthermore, implementation strategies and their respective costs change, have to be considered relative to the number of cases treated, and may vary with the needs of a given site. It is also likely that costs of implementing the Low Risk Ankle Rule would be location specific. One needs to consider costs of sustaining implementation of the rule. Our study demonstrated sustained beneficial effect during a 6-month period with a less intensive intervention that included the clinical decision support system alone. However, the effect of this single intervention or other site-specific interventions to sustain acceptability during a longer period needs to be considered in the cost evaluation at each site because these costs may limit sustained implementation.[19,20] As a result, individual sites considering adopting the Low Risk Ankle Rule into their ED practice should factor in the magnitude of its potential clinical benefits weighed against the local costs of implementing and sustaining its use in practice.

This research used a cost-consequences analysis to assess the economic effect of implementing the Low Risk Ankle Rule strategy. Cost-effectiveness analysis was not appropriate for this study because there was no appropriate single composite outcome measure that reflected the clinical consequences of applying the Low Risk Ankle Rule strategy. Cost utility analysis was problematic because quality-adjusted life-years would be difficult to measure for children with acute ankle injuries.[20] Cost-benefit analyses are controversial in health care systems in which patients are not accustomed to paying for treatment, and therefore assessing benefits of programs in terms of dollar values would be problematic and of questionable validity.[16] The cost-consequences approach appears well suited here because it allows decisionmakers to apply their own values to the resources used and consequences.[21] That is, decisionmakers can see clearly what is included and what is omitted, where information is quantitative and where qualitative. The method is also simple to understand and thus may be more likely to influence decisionmaking in practice.[22] Thus, decisionmakers can review this cost analysis of the Low Risk Ankle Rule implementation and select components most relevant to their context and generalize this analysis to their individual practice. Moreover, because there were both cost reductions and clinical benefits, a traditional economic evaluation that estimates the additional costs to obtain improved outcomes (eg, incremental cost per outcome gained) is not necessary. Rather, a decisionmaker can review the clinical benefit of significantly reducing radiograph use by approximately 23% in this population in the context of our cost savings estimate of approximately 7% of total costs.

In summary, widespread implementation of the Low Risk Ankle Rule could lead to a safe reduction of radiograph use for children with ankle injuries. Furthermore, applying this rule within a publicly funded health care system resulted in a per-patient reduction in cost of delivering effective care for these injuries, and this cost reduction was not at the expense of increasing patient costs.

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Table E1. Values and sources of unit costs of the resources measured in the study.

Resources	Unit	Unit Costs, Can $, 2012	Sources for Unit Costs
Health care provider-paid resources			
ED			
ED visit	ED visit (nursing, overhead, medication)	218.00	OCCI
Physician on duty in ED	Consultation in ED	74.25	OHIP schedule of benefits for physician services[1]
Orthopedic surgeon	Consultation	83.10	OHIP schedule of benefits for physician services[1]
Ankle support devices			
Posterior slab/splint	Device per person fitted	14.56	Obtained from St Joseph's Healthcare Hospital, Hamilton, 2013[2]
Below-knee cast	Device per person fitted	4.01	Obtained from St Joseph's Healthcare Hospital, Hamilton, 2013[3]
Elastic bandage (ACE bandage 3 inch with clips)	Device per person fitted	0.55	Obtained from St Joseph's Healthcare Hospital, Hamilton, 2013[4]
Physician billing for cast application	Application per person	24.10	OHIP schedule of benefits for physician services[1]
Closed reduction with anesthesia	Procedure per person	307.10	OHIP schedule of benefits for physician services[1]
Surgery (tibia/fibula fractures requiring surgery—Salter-Harris III, IV)	Surgery per person	4,604.00	OCCI
Follow-up physician costs			
Family physician	Consultation	77.20	OHIP schedule of benefits for physician services[1]
Pediatrician	Consultation	167.00	OHIP schedule of benefits for physician services[1]
Orthopedic surgeon	Consultation	83.10	OHIP schedule of benefits for physician services[1]
	Repeated consultation	51.70	OHIP schedule of benefits for physician services[1]
Sports medicine physician	Consultation	33.70	OHIP schedule of benefits for physician services[1]
Physiotherapist (subsequent visits)[5]	Per subsequent therapy visit	12.20	Ontario Physiotherapy Association Web site[6]
Imaging			
Ankle radiographs	Standard views per person	82.75	Obtained from hospital member of OCCI 2010; OHIP schedule of benefits for physician services[1]
CT scan	Standard images per person	119.60	Obtained from hospital member of OCCI 2010; OHIP schedule of benefits for physician services[1]
MRI	Standard images per person	139.15	Obtained from hospital member of OCCI 2010; OHIP schedule of benefits for physician services[1]
Strategy implementation costs (costs inclusive for all 3 intervention sites)			
Fixed costs, No.			
Posters	6	600.00	The Printing House, 2013
Pocket cards	120	300.00	The Printing House, 2013
Teaching session			
Webinar (online tutorial) or 15 min teaching	Average price of 15 min online Webinar or 3×15 min of ED physician salary for teaching	744.29	ICES[7]; 2009/10 salary inflated to 2011/12 salary using Consumer Price Index, health and personal care[8]
Computer decision support system	Development and ongoing costs (inclusive of hardware and software)	10,000.00	Contrail Consulting Services, 2013
Variable costs			
Paper chart reminders	Photocopying cost	300.00	The Printing House, 2013

Table E1. Continued.

Resources	Unit	Unit Costs, Can $, 2012	Sources for Unit Costs
Patient-paid costs			
Ankle support devices			
Crutches (wooden)	Devices per person fitted	30.00	Hospital for Sick Children, Toronto (January 2013)
Ankle brace	Devices per person fitted	47.35	Hospital for Sick Children, Toronto (January 2013); consistent with average retail price from Airbracestore Web site[9]
Air cast foam walker, no crutches	Devices per person fitted	104.95	Hospital for Sick Children, Toronto (January 2013); consistent with average retail price from Airbracestore Web site[10]
Physiotherapist (first assessment)[5]	First assessment visit	61.25	Mean fee of 4 designated OHIP physiotherapy clinics in Hamilton, Ontario, April 2013[11]

OCCI, Ontario Case Costing Initiative; *OHIP*, Ontario Health Insurance Plan; *ICES*, Institute for Clinical Evaluative Sciences.

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11. Mean fee of 4 designated OHIP physiotherapy clinics in Hamilton, Ontario. April 2013. ((45+80+70+50)/4)=61.25.

Table E2. Per-patient resource costs by study period and treatment group.

Resource	Intervention		Control	
	Baseline, Phase 1, n=427	Intervention, Phases 2 and 3, n=628	Baseline, Phase 1, n=463	Baseline, Phases 2 and 3, n=633
Health care cost, mean (SE) per patient, Can $				
Initial ED visit				
Visit				
ED	218.0 (0)	218.0 (0)	218.0 (0)	218.0 (0)
Imaging				
Radiographs	80.04 (0.71)	59.56 (1.48)	74.71 (1.14)	72.81 (1.07)
CT	0.56 (0.14)	0.19 (0.04)	0.26 (0.05)	0.19 (0.04)
Health care provider				
Emergency physician	71.98 (0.62)	72.71 (0.42)	72.17 (0.57)	72.37 (0.46)
Orthopaedic surgeon	2.53 (0.69)	1.72 (0.47)	2.33 (0.64)	2.49 (0.56)
Interventions				
Ankle immobilization/support (posterior splint, below-knee cast, elastic bandage)	12.95 (1.38)	9.62 (1.00)	22.02 (1.59)	21.28 (1.35)
Closed reduction with anesthesia	1.44 (1.02)	0	0	1.94 (0.97)
Surgery	10.79 (10.79)	7.34 (7.34)	0	7.28 (7.28)
Health care visits 1–7 days after initial presentation to the ED				
ED				
Visit	6.62 (1.53)	2.08 (0.35)	3.30 (0.71)	4.48 (1.22)
Physician	8.90 (2.43)	2.79 (1.14)	4.42 (1.66)	6.00 (1.89)
Radiographs	0.78 (0.39)	0.40 (0.23)	0.36 (0.25)	0.65 (0.29)
Family practice/walk-in				
Physician	1.81 (0.62)	4.91 (0.74)	1.00 (0.41)	2.32 (0.67)
Radiographs	0	0.39 (0.23)	0	0.13 (0.13)
CT	0	0	0	0.19 (0.19)
MRI	0	0	0	0.22 (0.22)
Fracture clinic				
Visit*	15.1 (1.43)	12.57 (1.22)	17.41 (1.96)	15.88 (1.73)
Plain radiographs	2.71 (0.71)	3.29 (0.65)	7.51 (1.11)	4.31 (0.73)
CT	0.56 (0.40)	0.38 (0.27)	0	0.19 (0.19)
MRI	0	0	0.30 (0.30)	0
Sports medicine				
Physician	0.08 (0.08)	0.21 (0.13)	0.22 (0.13)	0.16 (0.12)
Radiographs	0.58 (0.33)	0.13 (0.13)	0.18 (0.18)	0.39 (0.23)
CT	0.28 (0.28)	0.38 (0.27)	0	0.19 (0.19)
Physiotherapist visits (excludes first assessment visit)†	0.11 (0.09)	0.17 (0.07)	0.18 (0.12)	0.19 (0.09)
Health care visits 8–28 days after initial presentation to the ED				
ED				
Visit	6.62 (1.53)	5.90 (0.94)	3.77 (0.80)	5.85 (0.93)
Physician	8.90 (2.62)	7.91 (1.89)	5.05 (1.77)	7.85 (1.88)
Radiographs	0.58 (0.33)	0.92 (0.35)	0.54 (0.31)	1.05 (0.37)
CT	0	0.38 (0.27)	0	0
Family medicine/walk-in				
Physician	2.71 (0.69)	3.32 (0.67)	1.17 (0.50)	0.85 (0.32)
Radiographs	0.19 (0.19)	0.26 (0.19)	0	0
CT	0	0.19 (0.19)	0	0
MRI	0	0.22 (0.22)	0	0
Fracture clinic				
Visit*	21.99 (2.20)	14.42 (1.52)	31.05 (3.19)	30.85 (2.44)
Radiographs	6.59 (1.09)	5.53 (0.83)	13.40 (1.42)	10.33 (1.09)
CT	0.28 (0.28)	0	0.26 (0.26)	0
MRI	0	0	0	0.22 (0.22)
Sports medicine				
Physician	0.08 (0.08)	0.16 (0.09)	0.36 (0.16)	0.16 (0.09)
Radiographs	0	0	0.18 (0.18)	0
Physiotherapist visits (excludes first assessment visit)†	0.4 (0.18)	0.80 (0.24)	0.71 (0.26)	1.08 (0.29)
Patient-paid cost, mean (SE) per patient, Can $				
Initial ED visit				
Ankle support devices (crutches, ankle brace, air cast walker)	31.54 (1.40)	32.97 (1.15)	23.28 (1.21)	22.96 (1.01)

Table E2. Continued.

Resource	Intervention		Control	
	Baseline, Phase 1, n=427	Intervention, Phases 2 and 3, n=628	Baseline, Phase 1, n=463	Baseline, Phases 2 and 3, n=633
Health care visits 1–7 days after initial presentation to the ED				
Physiotherapist (first assessment visit)	0.86 (0.35)	1.76 (0.41)	0.93 (0.35)	0.97 (0.30)
Health care visits 8–28 days after initial presentation to the ED				
Physiotherapist (first assessment visit)	1.29 (0.43)	1.85 (0.42)	1.98 (0.50)	2.42 (0.47)

*Includes orthopedic surgeon fee.
†First physiotherapy visit paid by patient.