Is Hospital Type Associated with Application of Best-evidence Treatment Recommendations for Children's Low-risk Distal Radius Fractures Treated in Ontario Emergency Departments?

by

Tara Baxter, MD

A thesis submitted in conformity with the requirements
for the degree of Master of Science

Institute of Health Policy, Management and Evaluation
University of Toronto

© Copyright by Tara Baxter 2019

Is hospital type associated with application of best-evidence treatment recommendations for children's low-risk distal radius fractures treated in Ontario emergency departments?

Tara Baxter

Master of Science

Institute of Health Policy, Management and Evaluation
University of Toronto

2019

Abstract

Objectives:

Investigate the association of hospital and physician type with the application of best-evidence treatment for low-risk distal radius fractures in children aged 2-14 treated in Ontario emergency departments from 2003-2015.

Methods:

Retrospective population-based cohort study using administrative data. Multivariable log binomial regression was used to quantify associations between hospital and physician type and best-evidence treatment.

Results:

70,801 fractures were analyzed. Only 21% received best-evidence care. Significant associations were identified between best-evidence treatment and paediatric (RR 1.16, 95%CI 1.07-1.26), community (RR 1.13, 95%CI 1.06-1.20), or small (RR 1.86, 95%CI 1.72-2.01) hospitals, and treatment by FP/GP (RR 1.09, 95%CI 1.02-1.16), paediatrician (RR 1.22, 95%CI 1.11-1.34), or subspecialty paediatric emergency medicine training (RR 1.73, 95%CI 1.56-1.92).

Conclusion:

Hospital and physician types involved in generating best-evidence are most successfully implementing it.

Acknowledgments

I owe immense gratitude to my supervisor, the always kind and approachable Dr. Andrew Howard. Thank you for allowing me to let this project change and take shape as my knowledge and understanding of research and fractures evolved. Thank you especially for the independent thinking you fostered by allowing me time to think through tough spots on my own before volunteering solutions. Your support, wisdom, and coaching always came at the moment when they were needed most.

Thank you to my thesis committee, without whom this work would not have been possible. Thank you to Teresa To for demystifying ICES for an orthopaedic surgery resident. Your calm demeanor, incredible patience and knowledge of all things research chiefly contributed to keeping this project on track. Thank you to Maria Chiu who was always the first to locate difficult to find documents and answers to complex questions - her knowledge of research methodology and statistics still amazes me. To Dr. Mark Camp, thank you for keeping this project grounded and relevant to the orthopaedic realm - your keen eye for an opportunity to improve healthcare gave our results meaning in the real world.

Special thank you to Jing Zhu for her long hours spent cutting and re-arranging my data and answering my (sometimes incredibly specific) questions about ICES data holdings. Thank you to my friends and family for keeping life fun and guiding my learning and experiences beyond medicine and research. To JS, thank you for everything you have taught me about life, love, and adventure over the past few years; your daily support means the world to me.

Last, thank you to the Department of Surgery, Orthopaedic training program, and the CIP for affording me this amazing opportunity.

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

1.1 Background

Distal radius fractures, known colloquially as wrist fractures, are the most common paediatric orthopaedic injury, with an estimated 10,000 childhood fracture presentations yearly in Ontario[1]. There are many different type of children's wrist fractures that range in severity and incidence. This paper focuses on the discussion of low-risk children's wrist fractures - those fracture types with minimal initial displacement (defined as initial angulation <15 degrees in the sagittal plane or <5mm translation on the frontal plane) and amenable to conservative treatment.

In many of the low-risk fracture types, the periosteum, a tough connective tissue covering of bone that contributes to stability and bone healing, remains fully or partially intact[2]. Furthermore, the low energy mechanism of injury and minimal initial displacement of the bones associated with these injuries indicate a limited disruption of the surrounding soft tissues, which act as an internal splint for the fracture and counters later displacement beyond the magnitude of the initial injury. Therefore, these non-displaced or minimally displaced injuries are stable, low-risk fractures. While rare, any residual bony angulation reliably straightens within a few weeks to several months due to a process called remodelling. In fact, the distal radius growth plate contributes 80% of the forearm length, and thus has one of the most astounding remodelling potentials of any bone in the human body[3,4]. A deformity of up to 30 degrees can reliably be remodelled in a child under 10 years of age, although complete remodelling of more severe angulation has been observed. The degree of angulation deemed acceptable decreases beyond 10 years of age as remodelling potential gradually declines approaching skeletal maturity. An intact periosteum, stable fracture configuration, and the remarkable remodelling potential of a growing skeleton results in rapid healing and excellent clinical results for low-risk types of distal radius fractures[5-8].

The most common type of paediatric low-risk distal radius fracture, the buckle fracture, accounts for 40-60% of all wrist fracture presentations[9-12]. This fracture type is exclusive to the paediatric population, and is no longer seen once growth plates fuse.

The mechanism of injury for a wrist buckle fracture is a low-energy fall onto outstretched hands. The result is an incomplete fracture, meaning that the bone does not break into two distinct segments. Rather, the bone compresses (or “buckles”) under the axial load placed on the distal radius as a result of the fall. This compression results in telltale “bulges” seen on radiographs, and the absence of a defined fracture line. An area of bone in the flared, metaphyseal region of the lower radius is at particular risk as it transitions from spongy, cancellous bone to hard, cortical bone[13]. In fact, it is rare to find a buckle fracture elsewhere in the forearm. These injuries do not typically present with any significant fracture angulation, and in fact are sometimes missed.

Other paediatric wrist fracture types that may or may not be low-risk include those described below and illustrated in Figure 1:

1. Complete fractures: These fractures are transverse fractures of the distal radius that do not involve the joint or the growth plate. They account for 24% of children’s wrist fractures[12]. Involvement of the ulna is difficult to discern in administrative data and therefore this category of fractures may include distal both bone forearm fractures (involving both the radius and the ulna). These injuries are not exclusive to children, although children have more favourable outcomes for the reasons previously discussed. Many of these fractures are undisplaced or minimally displaced (defined as angulation <15 degrees or <5mm on the frontal plane)[9,39] at presentation and do not involve the joint or growth plate; these fractures are considered low-risk. Others have larger degrees of displacement and require fracture manipulation or operative intervention and would not be considered low-risk.

2. Greenstick fractures: This fracture type involves a complete fracture on one side of the distal radius, and an intact cortex on the opposite side. They are rare in the distal radius, accounting for

only ~8% of presentations[12]. As with transverse fractures, many are undisplaced or minimally displaced at presentation and therefore low-risk[9].

3. Salter- Harris II fractures: These fractures also account for ~8% of fracture presentations, although this number may be somewhat inflated as they are likely to be disproportionately represented at the paediatric institution where this prevalence data was obtained[12]. These are fractures that extend through the distal radius growth plate, and exit in the distal radius metaphysis. These injuries may present with a range of displacement and are more likely to require manipulation and/or operation.

4. Other fracture types: These include Salter-Harris I injuries (~1%), which are low-risk if non or minimally displaced, Salter Harris III-V injuries (<1%), which typically require manipulation and/or operative intervention and are higher risk, and fracture types not otherwise categorized (<1%)[12].

The majority of fractures present to the Emergency Department (ED) for initial management. Treatment for low-risk types of distal radius fractures is non-operative and the specific treatment algorithm has evolved over time. Historically, treatment consisted of a circumferential plaster cast for 3-6 weeks, multiple x-rays, and several follow-ups with an orthopaedic surgeon. Care for these fractures once entailed much parental and child frustration, time away from work and school, and significant cost to the healthcare system[14-16]. Non-operative intervention has other potential drawbacks: Cast removal causes anxiety in children and occasionally results in cast-saw related burns[17-20]. Thermal burns are a complication that has received media attention lately[21,22]. Children are exposed to radiation resulting from multiple rounds of x-rays, and follow-up appointments carry a risk of exposure to communicable diseases present in the hospital setting.

Figure 1: Types of children's distal radius fractures

Identifying the Problem

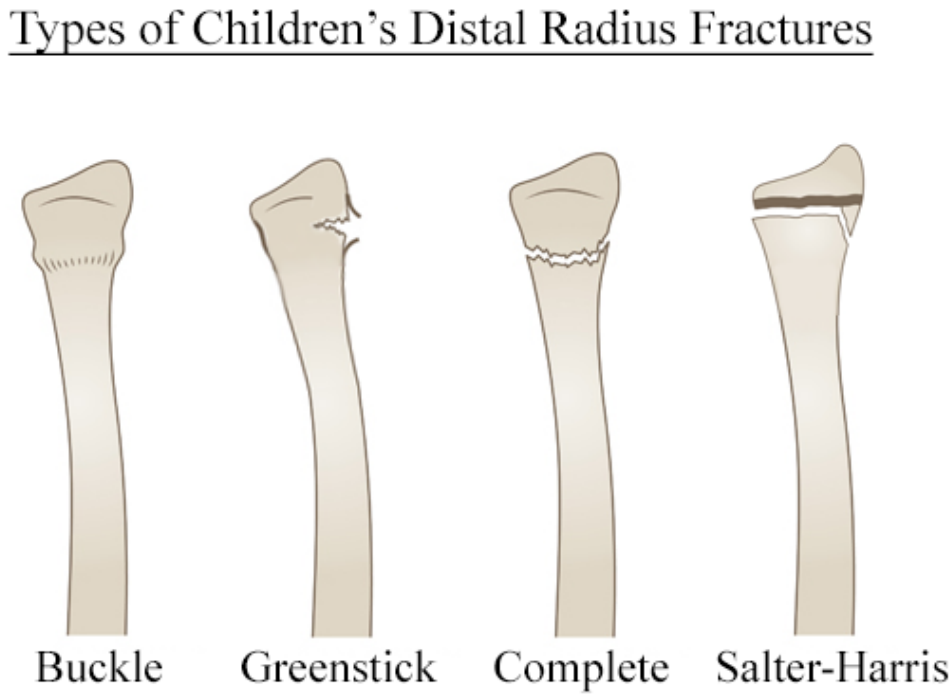
Since the early 2000's, a mounting body of evidence has demonstrated that the most common types of childhood low-risk distal radius fractures can be treated much more simply using removable splints instead of full casts and limiting visits and x-rays, with equivalent outcomes[6-9,15-16, 26-38]. However, recent publications demonstrate that these best-evidence treatment recommendations are not being uniformly applied, resulting in ongoing over-treatment of these injuries[38, 50-52].

1.2 Literature Review

1.2.1 The Knowledge-to-Action Cycle

The pathway from knowledge generation to knowledge application is complex and is best illustrated by the Knowledge-to-Action Cycle[23] (Figure 2). This framework has been adopted by major health organizations including the Canadian Institutes of Health Research and the World Health Organization in order to deepen understanding of, and improve knowledge translation. The framework is divided into two parts. The central triangle, or "Knowledge Funnel" part of the cycle represents the process through which knowledge is generated, refined, distilled, and tailored to the needs of knowledge end-users, while the outer "Action Cycle" highlights phases of activities that are needed for knowledge applications to achieve a deliberately engineered change amongst groups of practitioners that vary in size and setting[24]. This framework was used to review and detail the current state of knowledge generation and application as it applies to best evidence treatment of low-risk distal radius fractures.

Figure 2: The Knowledge-to-Action Cycle



1.2.2 The Knowledge Funnel: What is the Evidence?

Knowledge Inquiry

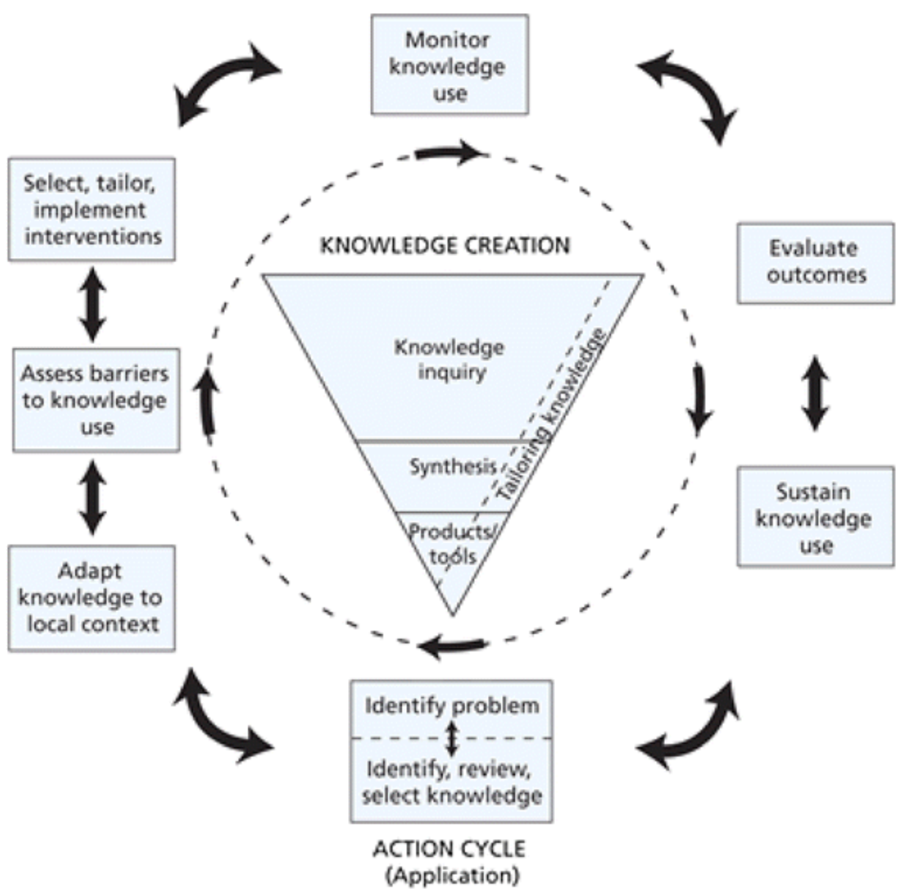
The first step in the Knowledge Funnel is Knowledge Inquiry. This step constitutes the pool of all primary literature addressing a given topic or question[24].

Undisplaced and minimally displaced Salter-Harris I injuries are difficult to discern clinically and radiographically from a wrist sprain. It has long been known that these fractures require no more than symptomatic management[25]. This approach was not applied to other low-risk wrist fracture types until the beginning of the 21st century when a large number of studies began reporting on simplified treatment algorithms for the most common type of wrist fracture, the buckle fracture.

The first randomized control trials investigating buckle fracture treatment approaches that deviated from historical norms were both published in 2001 in the British edition of The Journal of Bone & Joint Surgery. The study by Davidson et al.[15] concluded that velcro splinting is a safe and acceptable alternative to circumferential casting, and suggested that clinical and radiographic follow-up is unnecessary. Symons et al.[26] found that home removal of a plaster splint without follow-up was an effective alternative to circumferential casting with fracture clinic follow-up for this injury.

Since the publication of these inaugural studies, numerous subsequent randomized control trials (RCT) have confirmed the safety and effectiveness of buckle fracture treatment with removable forms of immobilization that are discontinued at home by the parent, and with no subsequent clinical follow-up[27-32]. A number of observational studies also support these conclusions[6-9,16, 33-38].

Boutis et al. applied simplified treatment algorithms to a wider variety of low-risk fracture types (but also including buckle fractures) that have traditionally been treated with circumferential cast immobilization and multiple orthopaedic follow-ups. This body of work demonstrated that many



distal radius fractures, including greenstick fractures and complete fractures +/- associated ulnar fractures angled less than 15 degrees or displaced less than 5mm at presentation do not require manipulation, and that outcomes are similar whether treated in a cast or removable splint[9, 39]. It is not new news that these fractures can be treated more simply. In 1998 Noonan et. al. reported that complete displacement, up to 1 cm of shortening and 15 degrees of angulation in the sagittal plane could be accepted in a variety of distal radius fracture types provided 2 years of growth remained[40].

There is no literature to date to support that Salter-Harris II fractures can be treated with removable splints without clinical follow-up.

Knowledge Synthesis

In the second step of the Knowledge Funnel, Synthesis, existing primary literature relevant to a specific research question is aggregated into comprehensive literature reviews, systematic reviews, and meta-analyses[24].

A 2008 Cochrane review[41] included four trials of children with buckle fractures and found that compared with plaster casting, removable splints did not adversely affect outcomes, were less costly, less restrictive, and home removal was strongly preferred by parents. The review concluded that buckle fractures can be treated with a splint that is removed at home.

Two systematic reviews published in 2016 further support these conclusions[42-43]. The reviews found splinting to be superior to plaster casting in terms of function, cost, and convenience, and with no significant difference in outcomes. The authors conclude that alternative splinting is preferable to plaster casting for buckle fractures of the distal radius.

Knowledge Products/Tools

The final step in the Knowledge Funnel is Products/Tools. In this step, available literature is distilled into recommendations that are presented in a clear, concise, and easily accessible manner for end-users[24].

Existing literature yields the following best-evidence recommendations for wrist buckle fractures fractures specifically, which comprise the overwhelming majority of low-risk distal radius fractures.

- They can be treated in a removable form of immobilization, removed as desired for activities or hygiene, and discontinued at home by parents once pain subsides, or after 3 weeks.
- No follow-up radiographs are required after diagnosis.
- Orthopaedic referral is not routinely necessary.
- No follow-up appointments are required if proper discharge instructions are provided, the child is functioning well, and pain is improving. Some authors noted that a single follow-up is justified to confirm diagnosis[6, 8, 15, 32]. However, emergency department physician diagnosis of buckle fractures has been shown to be reliable[44].

Furthermore, current research suggests that this treatment algorithm can also be applied to the remaining types of low-risk distal radius fractures, although further studies are needed to reinforce the safety an efficacy where other fracture types are concerned[9, 39].

The above recommendations have been the focus of two literature reviews targeting orthopaedic surgeons[5,45], and two case-based best-evidence treatment summaries targeting emergency department physicians[46-47]. Recent editions of popular paediatric orthopaedic textbooks have also included simplified treatment algorithms for low-risk distal radius fractures[48].

Based on the overwhelming evidence, the UK's Choosing Wisely Campaign, whose guidelines were launched in October 2016, included plaster casting and scheduled follow-up for distal radius buckle fractures in its list of treatments and procedures that are of little or no benefit to patients[49]. There are currently no North American-wide guidelines addressing wrist buckle fracture or low-risk distal radius fracture treatment, although some hospitals have created their own internal guidelines and clinical pathways as previously mentioned.

1.2.3 The Action Cycle: Translating Knowledge to Action

Once the problem has been identified and the literature appropriately distilled, the knowledge must be implemented. The Action Cycle addresses implementation. It is iterative, cyclical, and may proceed in an order different from that specified in Figure 2.

Adapt Knowledge to Local Context

This step involves customizing the recommendations for use within an organization or geographical region[24].

Minimal adaptation of the recommendations for low-risk distal radius fracture treatment should be required owing to their simplified nature which encourages health care providers treating these fractures to perform less tests and interventions. In our experience, adaptation, if needed, has proceeded at the individual institutional level.

In Ontario, plaster immobilization devices are covered by the Ontario Health Insurance Plan (OHIP), while velcro immobilization devices are not. Parents of patients with low-risk distal radius fractures are generally charged a nominal amount (20-40$) for a velcro splint, if desired, which is more easily removable and easier to clean than a plaster splint. In low income areas, it may be impractical for hospital EDs to stock velcro splints owing to patient/parent inability to pay for them. Hospitals in these areas may therefore not be able to apply best-evidence treatment and need to resort to only plaster.

Other adaptations to the recommendations may include automatic follow-up with an orthopaedic surgeon for low-risk distal radius fractures seen in EDs primarily staffed by physicians lacking specific musculoskeletal training and experience, and scheduled follow-up with a family practitioner for injuries seen in EDs serving low income or non-English speaking populations, where comprehension of follow-up instructions is a concern.

Assess Barriers to Knowledge Use

Three survey studies have qualitatively addressed practitioner reported barriers to knowledge use specifically for low risk treatment algorithms[50-52]. Identified barriers can be classified into four main areas:

1) Institutional infrastructure: Includes lack of availability of devices/materials for removable immobilization, device cost and reimbursement issues, lack of support from orthopaedic colleagues, and lack of access to an orthopaedic surgeon if problems arise.

2) Knowledge Deficits: Includes concern over complications, lack of knowledge regarding management, and potential medicolegal implications.

3) Patient characteristics: Includes parental preference for orthopaedic surgeon follow-up, parental preference for non-removable immobilization, and concerns regarding compliance.

4) Financial incentives: One barrier to knowledge use that is not mentioned in the referenced survey studies is the current fee and billing structure in the Ontario system. Physicians working in a fee-for-service practice receive payment for each individual service rendered. Many of the payments for check-ups and appointments use general fees and codes. For instance, a follow-up visit for a very complex wrist fracture that requires extensive counselling and a 20-minute visit pays the same amount as a 5-minute follow-up for a low-risk distal radius fracture. Fracture types that are associated with quick, simple visits (as is the case with low-risk distal radius fractures) are therefore financially incentivized.

The present study contributes to our knowledge of barriers by helping to identify factors that are positively and negatively associated with receiving best evidence care.

Select, Tailor, Implement Interventions

Interventions to promote implementation of best-evidence recommendations for low-risk distal radius fracture care have largely been conceived at the institutional level and aim to address the barriers listed above.

Some hospitals have developed their own internal best-evidence guidelines addressing management of this injury. While most of these guidelines are available exclusively through hospital intranets, a simple Google search identifies several publicly available ED guidelines. Similarly, some hospitals have developed patient pamphlets aimed at educating parents and patients and reinforcing discharge instructions.

The development of internal hospital guidelines and pamphlets requires clinicians with condition-specific knowledge who are comfortable reviewing, interpreting, and adapting research findings, and a sufficient volume of cases to make this pursuit worthwhile. Unsurprisingly, where a paediatric condition is the focus, paediatric hospitals, higher volume hospitals, and community hospitals with a paediatrician on staff are most likely to have such interventions in place[53-54].

Educational initiatives conducted by clinical leads and champions of best-evidence care have also been employed at the hospital level. Owing to an inherent academic culture and mandate to educate future caregivers regarding best practices, many of these initiatives such as teaching rounds, small group learning, and journal clubs occur at higher frequency at academic institutions. Furthermore, paediatric hospitals that have participated in generating best-evidence research, two of which are located in Ontario, have the additional benefit of staff physician involvement in research, presentation of results at research rounds, dissemination and discussion of findings amongst colleagues, and modelling best-evidence practice.

Interventions aimed at reaching individual clinicians have included conference presentations and journal publications. The effects of both of these methods of knowledge dissemination are likely to be siloed; the beneficial information is presented to a single specific audience(members of an association, specialty, subspecialty, or research group present at a conference or reading a specific journal). Canadian research contributions to evidence based care of low-risk distal radius fractures have largely been generated by physicians working specifically in paediatric emergency medicine or orthopaedic surgery and presented at their respective conferences. A presentation at the annual Paediatric Emergency Research Canada meeting, for instance, caters to an academic, research-oriented audience, thereby confining the transfer of knowledge to a network of emergency physicians working in paediatric teaching centers. Conference presentations may therefore completely neglect the educational needs of other relevant practitioners like family doctors working in the ED and other emergency medicine specialists who initially see and treat the largest proportion of these injuries.

The same is true of journal publications. Much of the Canadian generated research has been successfully published in paediatric and emergency medicine journals associated with the same physician groups where conference presentations are made. Research from other countries has been mostly confined to publication in orthopaedic journals. Potential knowledge transfer is again limited through selective knowledge dissemination using a single modality that catering to specific audiences.

Monitor Knowledge Use

Four recent North American survey studies have reported on the uptake of best-evidence recommendations for distal radius buckle fracture treatment specifically. In the most recent study, Ontario wrist buckle fracture patients were discharged home from the ED with the specific instruction to follow-up with their primary care practitioner after 2 weeks[38]. A follow-up telephone call 28 days later confirmed that 87% followed-up exclusively with primary care practitioners. The remaining patients either opted out of follow-up entirely, or were referred elsewhere. These findings indicate that most primary care physicians are comfortable with monitoring this injury and that few parents felt the need to independently seek orthopaedic consultation.

The second study asked Canadian emergency department physicians to self-report their institutional standard or personal practices for wrist buckle fracture treatment[50]. Sixty-three percent reported using a removable device to immobilize wrist buckle fractures. Only 16% percent prescribed no scheduled follow-up, and 53% referred to a primary care practitioner for scheduled follow-up. Thirty-one percent continued to refer to an orthopaedic surgeon for follow-up. Uptake is likely overestimated in this study given that a disproportionately large number of respondents to this survey had specific paediatric emergency research affiliation.

The third study asked North American paediatricians to self-report their treatment practices for distal radius buckle fractures[51]. Sixty-nine percent of respondents agreed that these fractures can be managed in a primary care physician's office. Canadian paediatricians were significantly more in favour of this management strategy compared with their American counterparts (OR 2.3). Despite high agreement with primary care management, 44% of respondents stated that they would refer a wrist buckle fracture diagnosed in their clinic to the ED or an orthopaedic surgeon for management. Half of Canadian respondents felt than more than one follow-up was necessary and 28-43% routinely re-imaged buckle fractures over the course of treatment.

The fourth study asked North American orthopaedic surgeons to self-report treatment practices for wrist buckle fractures[52]. Fifty-five percent of Canadian respondents recommended removable immobilization devices for treatment.

In contrast to the above studies, reports from the early 2000's revealed that most distal radius buckle fractures were treated in circumferential plaster casts, few were followed outside of orthopaedic fracture clinics, and most were seen at least twice for follow-up[15, 35, 55]. The body of evidence suggests a significant shift in management trends for these fractures, though there is still considerable room for improvement.

It is frequently quoted that it takes 17 years for research evidence to reach clinical practice[56-58]. This number properly refers to knowledge translation in biomedical research, which includes a number of time-consuming steps prior to reaching the clinical research phase. We expect knowledge translation to proceed more rapidly for healthcare practices that originated from the clinical research stage. However, in the case of low-risk distal radius fractures, it seems that we are still far from full application of best evidence practices fifteen years after the publication of the first clinical RCTs.

The present study provides an account of knowledge use in low-risk distal radius fracture care over the past 12 years on a much larger scale and with increased objectivity than previous research.

Evaluate Outcomes

Many of the previously mentioned studies that confirmed the safety and effectiveness of simplified treatment algorithms for low-risk distal radius fractures also investigated other patient and health systems outcomes.

Compared with plaster cast immobilization, removable immobilization has been found to have equivalent or decreased pain scores, range of motion, and strength, less complications arising from application and removal of immobilization devices, less revisits to the ED, earlier return to activities, and increased satisfaction and convenience[15, 26-32, 39]. In fact, only one study reported significant negative findings. Oakley et al.[59] identified higher pain levels during the first few days of treatment and delayed return to activities in their removable immobilization group. Pain levels were comparable however at 2 weeks, and all fractures healed uneventfully.

In the U.K., another country with universal health care, home removal of splints instead of plaster casting for wrist buckle fractures resulted in a cost savings of 51-100 pounds per patient[15,32]. The cost savings are more pronounced in U.S. studies where the cost of treating paediatric distal radius fractures has been quoted at upwards of 2 billion dollars annually[60]. The cost savings associated with foregoing a manipulation ranged from 266$ to over 3000$ per patient and two hours less spent in the ED[16, 61]. One author estimated a cost savings of 35 million dollars yearly in the U.S.

by simply eliminating unnecessary x-rays in wrist buckle fracture care[7]. Further significant cost savings would also result from eliminating unnecessary follow-up appointments and other healthcare costs associated with complications arising from cast removal.

Sustain Knowledge Use

We identified only one study, conducted in the U.S., aimed at encouraging use of simplified treatment algorithms for low-risk distal radius fractures. The authors were successful in greatly increasing use of removable immobilization by using quality improvement methodology and the results were sustained one year following the intervention[62]. We did not identify any published Canadian work pertaining to interventions or efforts to sustain knowledge use in the case of low-risk distal radius fracture care.

Integral to sustaining knowledge use however, is an understanding of who, where, how, and whether the knowledge is being applied. This study improves our understanding of the factors contributing to knowledge use so that future efforts to sustain it can be informed and targeted.

1.3 Summary of Level 1 Evidence

Table 1: Summary of level 1 evidence (See Appendix H for definition)

Author and Country	Journal and Year	Study Design	Intervention	Summary of Findings
Davidson et al. UK[15]	*JBJS British* 2001	RCT n = 201	Cast vs. velcro splint	No clinical or radiological differences between groups. Suggests that clinical and radiologic follow-up is not necessary.
Symons et. al. UK[26]	*JBJS British* 2000	RCT n = 87	Home removal of splint vs. fracture clinic follow-up	No differences in terms of deformity, tenderness, ROM, and satisfaction. Home removal was preferred. No complications were encountered.
West et. al. Australia[27]	*J Pediatr Orthop* 2005	RCT n = 39	Cast vs. soft bandage	Soft bandage was superior in terms of ROM after removal. Positive trends towards increased comfort and convenience. No difference in pain.
Plint et. al. Canada[28]	*Pediatrics* 2006	RCT n = 87	Cast vs. plaster splint	Splinted children had better physical functioning and less difficulty with activities at 2 weeks, but by 4 weeks there was no difference. No differences in pain. No complications were encountered.
Williams et. al. USA[29]	*Paediatric Emergency Care 2013*	RCT n = 94	Cast vs. velcro splint	Splint superior in terms of patient and parental satisfaction, convenience, and satisfaction. No difference in pain. Cast group required greater use of additional assistance, took longer to immobilize, and had longer delays from radiograph to immobilization.
Kropman et al. Netherlands[30]	*Trauma* 2010	RCT n = 92	Cast vs. soft bandage	ROM significantly better in bandage group at 4 weeks, but comparable by 6 weeks. Pain significantly higher in the bandage group at week 1, no difference thereafter. Overall discomfort was significantly higher in the cast group.

Author and Country	**Journal and Year**	**Study Design**	**Intervention**	**Summary of Findings**
Khan et al. Ireland[31]	*Acta Orthop. Belg.* 2007	RCT n = 117	Cast vs. soft cast removed at home	No difference in terms of ROM, satisfaction, or clinical appearance. Significantly less complications with immobilization method in soft cast group. Significant preference for soft cast treatment.
Witney-Lagen et. al. UK[32]	*Injury* 2012	Quasi RCT n = 232	Cast vs. soft cast with home removal	No significant difference in terms of satisfaction, comfort, or complications. Treatment with soft cast was preferred by both groups.
Boutis et al. Canada[39]	*CMAJ* 2010	RCT n = 92	Cast vs. prefabricated splint	Minimally displaced distal radius fractures: No difference in terms of physical function, ROM, and grip strength at 6 weeks, no difference in pain scores throughout the treatment, and no difference in fracture angulation at 1 and 4 weeks.
Oakley et al. Australia[59]	Pediatr Emerg Care 2008	RCT n = 84	Cast vs. fiberglass splint	Splint group experienced pain of longer duration (3 vs. 6 days), and had a lower rate of return to normal activity at 2 weeks. Significantly more complications in the cast group. All patients had good outcomes.
Abraham et al. UK[41]	*Evid.-Based Child Health* 2009	Cochrane review n = 827	Cast vs. removable immobilization	Removable and soft splints are less restrictive and uncomfortable than cast immobilization, enable more activities and are more desirable
Jiang et al. China[42]	*Pediatr Emerg Care* 2016	Systematic review n = 781	Cast vs. nonrigid immobilization	Nonrigid immobilization was superior in terms of preference, cost, functional recovery, and complication rate.
Hill et. al. UK[43]	*J Pediatr Orthop* 2016	Systematic review n = 825	Cast vs. alternative splinting	Alternative splinting superior in terms of function, cost, and convenience. No difference in pain levels or fracture complications.

1.4 Rationale

Low-risk distal radius fractures are the most prevalent type of childhood fracture. Compelling evidence supporting minimal treatment algorithms has existed for almost two decades yet current research demonstrates that these fractures continue to be over treated, resulting in unnecessary health care expenditure, waste of parent and patient time, and harm to patients as a result of complications arising from this unnecessary care.

The factors that contribute to the provision of best-evidence care for these injuries remain unclear. The available information regarding factors affecting low-risk distal radius fracture care is based on physician self-report and anecdotal evidence, and does not investigate beyond individual physician factors[38,50-52]. There has been no centralized or coordinated dissemination effort and no national guideline development. Educational presentations and publications have largely been restricted to the institution, physician specialty, or physician group that generated the evidence. Therefore, we hypothesize that institutional and physician factors are currently playing the largest role in evidence dissemination and application.

Physician type and institution type are intimately related. Certain subtypes of institutions attract a specific subtype of physician. For example, a larger proportion of physicians working in rural hospital emergency departments are FP/GP or FP/ER trained. Likewise, it is unusual to find a paediatrician or PEM trained physician working outside of a paediatric hospital. We have observed that efforts to disseminate findings are mainly occurring at the institutional level and/or within physician specialty groups with the creation of internal guidelines and teaching sessions conducted by clinical leads and champions of best-evidence care. Many of the reported barriers to evidence utilization are also directly related to institutional resources and practices (lack of materials, lack of support, cost/reimbursement issues, lack of knowledge), or physician training (knowledge deficits) further indicating a potential role for physician type and institution type in evidence uptake.

Institutional culture, available support, and leadership are known to play an important role in evidence uptake within medicine[63-70] and the effect of institution type on the application of best evidence in emergency department care has previously been investigated for non-musculoskeletal paediatric conditions[53]; paediatric hospitals were found to have higher application of evidence than both non-paediatric academic hospitals and community hospitals. Physician training has also been shown to play a role in medical decision making[71].

This study investigates whether hospital and physician type are associated with application of best-evidence for children's low-risk distal radius fractures treated in the emergency department (ED) setting, and provide a descriptive overview of trends in low-risk distal radius fracture management in Ontario since the early 2000's. A better understanding of trends and the role of hospital and physician type is essential in order to identify, engage, and educate the highest yield target populations for further knowledge translation endeavours, with the ultimate goal eliminating unnecessary complications, decreasing associated costs, improving patient satisfaction, and optimizing the delivery of low-risk distal radius fracture care across the province.

2. Objectives and hypotheses

2.1 Primary research question

Is hospital type associated with application of best-evidence recommendations for children's low-risk distal radius fractures treated in Ontario Emergency Departments?

2.2 Objectives

1. Test the association of hospital type with the occurrence of best-evidence treatment for children's low-risk distal radius fractures seen in Ontario Emergency Departments.
2. Test the association of ED provider specialty with the occurrence of best-evidence treatment for children's low-risk distal radius fractures seen in Ontario Emergency Departments.
3. Describe care trends over the length of the study period for children's low-risk distal radius fractures.

2.3 Hypotheses

We hypothesized:

1. There will be a stronger association between best-evidence treatment and paediatric hospitals compared with other hospital types.
2. There will be a stronger association between best-evidence treatment and patients seen by an emergency medicine specialist with paediatric training compared with patients seen by other ED provider types.

3. There will be an overall increase over time in best-evidence treatment across all hospital types and physician specialties.

3. Methodology

3.1 Literature search

A literature search was conducted by accessing the PubMed database. Search terms consisting of key words, concepts, and their synonyms were identified (See Appendix I for keywords used in the search strategy). Search terms were then executed alone and in combination using Boolean operators. The titles and abstracts of resulting articles were manually scanned to determine the relevance of the search results. Further key words were brainstormed based on language from the resulting articles and the search was repeated. The reference lists of all relevant articles were then manually searched to identify further pertinent literature.

3.2 Research design and participants

The study design is a retrospective population-based cohort study of children with low-risk distal radius fractures, using multiple linked administrative databases housed at the Institute for Clinical Evaluative Sciences (ICES) in Toronto, Ontario.

The population of interest is all children aged 2-12 years for girls, and 2-14 years for boys with a diagnosis of a low-risk distal radius fracture made in an Ontario Emergency Department between October 1st, 2003 and February 17, 2015, and living in Ontario at the time of diagnosis and follow-up. The lower age limit corresponds to the age where children are reliably walking (a requisite to have a fall onto outstretched hands with enough force to cause a fracture) and are beginning to run and play. It is exceedingly rare to see a wrist fracture in a child who is not yet walking. Furthermore, a wrist fracture in a child who is not ambulatory is suspicious for child abuse, which has a remarkably different course of follow-up than that of a low-risk distal radius fracture. The upper age limit corresponds to the approximate age of skeletal maturity for each sex, after which low-risk type fractures are no longer seen. Figure 3 presents a graphical depiction of the study timeline. See Appendix A for the list of codes used to identify low-risk distal radius fractures in ICES data.

Figure 3: Study cohort timeline

3.3 Data sources

Data were obtained by linking multiple administrative databases housed at ICES. ICES is an independent not-for-profit corporation that receives funding from the Ministry of Health and Long Term Care and serves as a repository for Ontario's health-related data. Data holdings include population-based health surveys and clinical and administrative databases. Data elements can be linked across multiple databases using the ICES Key Number (IKN), an anonymized code that identifies individual patient records.

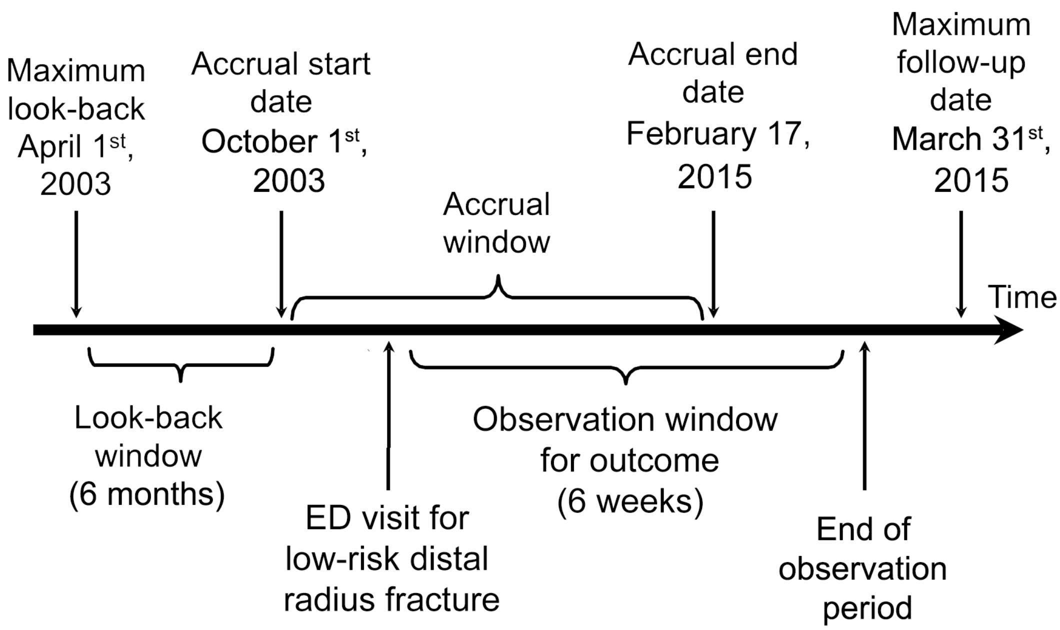
The following databases were accessed in order to obtain data for this study:

1. The National Ambulatory Care Reporting Service (NACRS) database:

The NACRS database contains information regarding visits made for ambulatory care across Ontario facilities[72]. Ambulatory care comprises visits not requiring an admission or prolonged stay at the facility such as outpatient and day surgery, emergency department visits, and outpatient clinic visits in both hospital and community settings. Only data relating to emergency department visits were used for this study. Emergency Department data collection and reporting to NACRS began April 1, 2000. Specific data elements accessed were the date of service, main diagnostic code, main intervention codes, and visit disposition. Reporting of these data elements to NACRS is mandatory for all ED's in Ontario.

There is no previously validated algorithm for identifying low-risk distal radius fractures in ICES data. NACRS main diagnosis codes and disposition were used to identify ED visits for closed distal radius fractures that were discharged home after being seen. Main diagnosis codes in NACRS are coded according to the ICD-10CA, which came into use in the 2002/2003 fiscal year. The ICD-9 was used prior to this. Classification changes typically affect quality of data in the first year following the change[72] and therefore the 2003/2004 fiscal year was chosen at the start date for this study. The ICD-10CA presents thousands of diagnoses coded alphanumerically, up to

6 digits in length. Each subsequent digit adds a layer of specificity to the diagnosis. For instance,



"fracture of the femur" is coded as a 2-digit code, but "fracture of shaft of femur, closed" is a 5-digit code. Interventions are coded according to the Canadian Classification of Health Interventions (CCI), using 9 digit codes. Intervention codes were used to exclude closed distal radius fractures that had undergone manipulation during the ED visit.

A re-abstraction study that investigated data quality for coding of main diagnosis and interventions in the emergency department was released by the Canadian Institute for Health Information (CIHI) in 2007 and reported on 2004/2005 fiscal year data[73].

There was a 90.4% exact code match between coders and re-abstractors for specific intervention codes. A further 3.1% of codes matched on the rubric (the first 5 digits of the 9 digit code), which is adequate for all but two interventions pertaining to this study. The two interventions in question are not commonly used in the emergency department, and were also captured using the CIHI-DAD and SDS. Therefore we expect approximately 93.5% accuracy in coding for interventions in the ED.

The same re-abstraction study found 78.5% agreement in the exact diagnostic coding for the main problem. A further 10.3% were found to agree on the first 3 digits of the 6 digit ICD-10CA code, which is sufficient for the purpose of this study. CIHI's reabstraction study also notes that agreement was even higher for common diagnoses. Therefore, we expect 88.8% accuracy for main problem coding as it pertains to this study. Further clarifications and updates to the NACRS abstracting manual may have resulted in further improved accuracy since the 2004/2005 fiscal year.

2. The Ontario Health Insurance Plan (OHIP) database:

The OHIP database contains the records of all claims for insured services made to Ontario's universal health insurance plan. Information in this database relies on submission of billing information by physicians as part of a fee-for-service practice or alternately funded model with required submission of shadow billing information. Over 90% of Ontario's physicians are either compensated predominantly using a fee-for-service model or are required to submit shadow billing[74-75]. Non-insured visits and services provided by physicians working under alternate funding models that do not require shadow billing are not reflected in the OHIP database. Underreporting is a known issue in compensation models requiring physicians to shadow bill. For example, in the 2008/2009 fiscal year, 13.9% of ED visits that appeared in NACRS did not have a corresponding ED coded submission in the OHIP database. Upon further investigation it was found that 28.0% of these unmatched visits were because the patient left without being seen, and a further 41.6% had a non-ED OHIP claim submitted instead. This leaves 30.3% (4.2% of all ED visits) without any submission in OHIP. Of these visits with no submission to OHIP, over three quarters were from facilities utilizing alternate funding models[76].

Specific elements accessed from the OHIP database were billed fee codes, diagnostic codes, and date of service. This study used OHIP fee codes in combination with diagnostic codes and date of service to identify subsequent physician visits for low-risk distal radius fracture care following the initial ED presentation. OHIP fee codes are outlined in the "Schedule of Benefits"[77]. There are no validation studies that report on accuracy of OHIP fee codes for fractures.

3. The Registered Persons Database (RPDB):

The RPDB contains the registration information of all persons who have received an OHIP number since July 1, 1991, and their ongoing eligibility to receive coverage. This database provides demographic data such as patient gender, age, location of residence, and OHIP eligibility.

4. The ICES Physician Database (IPDB):

The IPDB contains information on physician demographics, training, practice location, and specialty. The IPDB was created by ICES using a combination of provider information from the Ontario Physician Human Resource Data Centre (OPHRDC), the Corporate Provider Database, and the OHIP database. Physician specialty and year of medical school graduation were obtained from the IPDB for this study.

5. Census data:

This database contains data from the Canadian Census survey that is conducted by Statistics Canada every 5 years. The Census survey collects information regarding demographics, ethnicity, income, housing conditions, family structure, and spoken languages from households across Canada. Information from the 2006 Census was used in this study to derive the Ontario Marginalization Index (ON-Marg) to adjust for patient socioeconomic status. The ON-Marg is a composite index representing four different dimensions: Residential Instability, Material Deprivation, Dependency, and Ethnic Concentration. The index is derived at the level of the dissemination area, a small geographic unit with a population of 400-700 people, and therefore represents the marginalization of a particular area, rather than that of a singular person. In population-dense urban areas, the ON-Marg may be derived from a geographical unit representing up to 8000 individuals, called the census tract. The index is presented in quintiles with 1 being the least marginalized and 5 being the most marginalized[78].

6. CIHI-DAD and SDS

The CIHI-DAD contains information from individual hospital admissions in Ontario including diagnoses and procedures performed. The data is obtained by abstraction from patient discharge summaries and hospital records.

The SDS contains information regarding same day surgical procedures performed across Ontario and has been derived from NACRS since April 2003. Prior to this, the SDS was maintained in conjunction with the CIHI-DAD.

Both the CIHI-DAD and SDS are coded according to the ICD-10CA and CCI beginning with the 2002/2003 fiscal year. The ICD-9 and Canadian Classification of Diagnostic, Therapeutic, and Surgical Procedures (CCP) were used prior to this.

Intervention codes were accessed from both databases for the purpose of excluding patients having undergone any type of operative intervention for their closed distal radius fracture in the 6 weeks following the initial ED visit.

In addition, diagnostic codes were used from both databases to exclude children with hospital admissions during the observation window and to exclude children with comorbidities that increase the likelihood of fracture, delayed fracture healing, or otherwise necessitate increased surveillance.

7. Ontario Cancer Registry (OCR):

The OCR contains information regarding cancer diagnoses in Ontario residents. This database was accessed in order to exclude individuals with a cancer diagnosis.

3.4 Exclusion Criteria

See Appendix B for the full list of codes used for the exclusion criteria

1. Individuals with no valid Ontario Health Insurance Plan (OHIP) number during the study period. These individuals do not appear in the administrative databases and thus we are unable to assess their exposure or outcome status.
2. Individuals that left the ED without being seen. These individuals did not have the chance to have best-evidence treatment applied.

3. Individuals who were admitted to hospital (inpatient or day surgery). These individuals have comorbidities which make accurate determination of the outcome of interest difficult when using administrative data.
4. Individuals that received an operation. Low-risk distal radius fractures do not require operation.
5. Individuals that received fracture manipulation. Low-risk distal radius fractures do not require manipulation.
6. Individuals that died in the ED. We are unable to observe the outcome of interest in such individuals.
7. Individuals having another fracture in any location in the 6 months prior to or after the diagnosis of a low-risk distal radius fracture. These individuals have comorbidities which make accurate determination of the outcomes of interest difficult when using administrative data.
8. Individuals with a pathologic diagnosis that makes fractures either more common or more difficult to treat: adrenal disease, cancer, cerebral palsy, cognitive impairment, cystic fibrosis, diabetes, kidney disease, malnutrition and malabsorption syndromes, metabolic disorders, osteogenesis imperfecta, osteoporosis, and thyroid disease.

3.5 Exposure

3.5.1 Main Exposure

The main exposure of interest was hospital type. Hospital type is an existing data element and was extracted from the NACRS database by linking to the INST database. It is a categorical variable with 4 levels:

-Paediatric hospital
-Academic hospital, non-paediatric
-Community hospital
-Small hospital

The original definition of academic, community, and small hospital types was established by the Joint Policy and Planning Committee (JPPC), however the hospital type designation is now maintained by the MOHLTC. A fourth hospital type, pediatric hospital, was created by ICES by subdividing the academic hospital designation into paediatric and non-paediatric hospitals. This subdivision has previously been used for research purposes[53]. Hospitals included in this category are: The Children's Hospital of Eastern Ontario, The Hospital for Sick Children, and McMaster Children's Hospital (as of 2011).

Academic hospitals were defined as all member hospitals of the Council of Academic Hospitals of Ontario (CAHO), except those included in the paediatric category (Appendix C).
A small hospital was defined as a single community provider, with an annual weighted case load under 2700[79]. A community hospital was defined as any hospital not considered academic, paediatric, or small.

3.5.2 Secondary exposure

The secondary exposure of interest was the type of physician providing treatment in the ED. This data element was extracted from the IPDB and is a categorical variable with 6 levels:

-Emergency medicine (ER)
-General practitioner or family practitioner with emergency medicine certification (FP/ER)
-Family practitioner or general practitioner (FP/GP)
-Paediatrician
-Subspecialty paediatric emergency medicine (PEM)
-Orthopaedic surgery

Specialty designations in the IPDB are sourced from specialty designations as reported by the College of Physicians and Surgeons of Ontario (CPSO) and the College of Family Physicians Canada (CFPC). Additions of new specialty designations depend on when the Royal College of Physicians and Surgeons began certifying physicians in those specialties and when certification information became available from the CPSO or CFPC. The first certification exams for PEM were offered in 2008. Therefore, this specialty designation does not appear in the IPDB's list of specialties until the 2008/2009 fiscal year. See Appendix H for physician type definitions.

3.6 Primary Outcome

See Appendix D for the full list of codes used.

The primary outcome of interest was whether or not best-evidence treatment occurred. This outcome was derived from the OHIP database and operationalized as a binary, yes/no, variable. For the purpose of the primary analysis, best-evidence treatment was defined as having no follow-up visit with a clinician for the low-risk distal radius fracture coded in the administrative data for a period of 6 weeks following the initial visit to the emergency department.

3.7 Covariates

The following additional covariates were collected, listed by database:

1. NACRS:

-Year of service

2. The Registered Persons Database (RPDB):

-Patient age

-Patient gender

-Rural location of residence

3. The ICES Physician Database (IPDB):

-Year of MD graduation

4. Census:

-Deprivation quintile

5. Institutional Database (INST):

-Hospital rurality

3.8 Sample Size

Assuming a rate of best-evidence treatment of 50% from the ED, 1264 fractures are needed to detect a 1.2 fold relative risk (1.5 fold odds ratio) difference between the two groups, with 80% power and an alpha of 0.05.

There are 10,000 wrist fractures billed through OHIP yearly. We estimated that 70% of those are low-risk distal radius fractures. This estimate is based on published data and our own internal data[1,12]. We should therefore have 7000 low-risk distal radius fractures per year available, which equates to ~77,000 fractures over the 12 year study period.

3.9 Statistical analysis

All statistical analysis was conducted using SAS version 9.4.

Baseline descriptive characteristics, consisting of mean and standard deviation for continuous variables and frequencies and percentages for categorical variables were calculated and reported for all variables of interest, stratified by the outcome of interest, best-evidence treatment, and year of fracture.

3.9.1 Objectives 1 and 2

Univariate log binomial regressions were used to identify significant associations between covariates of interest, hospital and physician type, and best-evidence treatment.

A multivariable log binomial regression model was chosen to assess the association between the main covariates of interest, hospital and physician type, and the outcome of interest, best-evidence treatment, while adjusting for other relevant variables. This type of regression model was chosen for its advantage of reporting risk ratios as a measure of association. Risk ratios are intuitive and easy to understand for clinicians and laypeople alike compared with the alternative odds ratio that results from logistic regression. The odds ratio may approximate the risk ratio when the outcome in question is rare (<10%), however this is not likely to be the case in this study.

An *a priori* model was determined to be the best choice for model building and selection. The *a priori* model was determined based on physician judgment of the potential clinical relevance of available covariates and the relationship of these variables with one another (Appendix E). The *a priori* model consisted of the outcome variable, best-evidence treatment, variables of interest hospital and physician type, and covariates age, sex, deprivation quintile, rural residence, and fiscal year.
Model selection methods relying on statistical significance are less useful with administrative data because almost any variable is statistically significant due to large sample sizes. Methods that examine change in parameter estimates may not be sufficiently comprehensive for a model seeking to quantify and explain a relationship as completely and precisely as possible. Other model selection strategies that were considered were backward selection, optimization of AIC/BIC, and change in estimate strategy for comparison to the *a priori* model.

Collinearity was assessed using the variance inflation factor (VIF) generated from a multiple linear regression model consisting of the primary outcome of interest and all potential covariates. The threshold for collinearity was set at VIF > 2.5. In the case of collinear variables, only the most clinically relevant variable was included in the final model. In the case of equal clinical relevance, the variable with with the higher VIF was removed.

Formal model assumptions have not been developed and studied for log binomial regression models. Convergence was verified for all models. In the case of failed convergence of the model, logistic regression was considered.

In the final adjusted model, the association between the main predictors of interest, hospital and physician type, and the outcome of interest, best-evidence treatment, was expressed as adjusted risk ratios (RR) with 95% confidence intervals and their corresponding p-values.

3.9.2 Objective 3

Graphs were generated from the descriptive statistics to visually depict yearly variation in care parameters. Resulting graphs were visually inspected for trends.

3.10 Sensitivity analyses

Refer to *Appendix D for codes used.*

A number of sensitivity analyses were performed in which the diagnostic algorithm used in the administrative data to isolate low-risk distal radius fractures or the definition of outcomes or predictors were varied.

Variations in diagnostic algorithm used:

1. Further excluded diagnostic and billing codes that might commonly be used to code for low-risk distal radius fractures, but technically should not be used for this purpose.

Variations in definition of predictors or outcome of interest:

1. Defined outcome of interest as either no follow-up OR follow-up with a primary care physician only for the wrist fracture.
2. Combined paediatric specialty and paediatric with emergency medicine subspecialty training into a single category and combined FP/GP and FP/ER into one category.
3. Defined outcome of interest as no follow-up AND no x-ray coded in the administrative data for 6 weeks following the wrist fracture

3.11 Ethics Approval

This study was approved by the Research Ethics Board at the Hospital for Sick Children and the University of Toronto. In addition, a Privacy Impact Assessment was conducted by ICES and approved.

4. Results

We identified 118,779 eligible ED visits in NACRS for a closed distal radius fracture in children aged 2-12 for girls, and 2-14 for boys between October 1st, 2003 and February 17, 2015. After excluding fractures that had undergone manipulation or operation, there were 90,173 fractures that were deemed to be low-risk distal radius fractures. A further 11,921 fractures were excluded after comorbidities, duplicate visits, and multiple fractures in a single individual were considered, leaving 78,252 unique low-risk distal radius fractures in our cohort.

During analysis, 508 fractures were identified to have an incompatible practitioner type providing care in the ED (ie.: psychiatry, pathology, etc.), and 6,943 were missing data on relevant predictors. Where values were missing for one predictor, typically all predictor values were missing. After excluding these, 70,801 fractures remained in the analytic cohort (Figure 4).

4.1 Description of cohort

Table 2 shows the results of the descriptive analysis. The mean age of the cohort was 9.24 years, with a higher percent of boys than girls (61% vs. 29%). A higher proportion of the least marginalized patients experienced low-risk distal radius fractures. Eight percent of the EDs in this study were considered rural and 11% of patients in the cohort lived in a rural area at the time of their visit to an ED with a low-risk distal radius fracture.

Seventy-six percent of these fractures were initially seen in community EDs. The most common physician types to provide initial care in the ED were FP/ER trained (44 %) followed by FP/GP training (38 %). Less than one percent of low-risk distal radius fractures were initially seen by an orthopaedic surgeon in the ED. Twenty-one percent of patients with low-risk distal radius fractures received no follow-up after their initial ED visit (ie.: best-evidence care). The remaining 79% received follow-up with a primary care practitioner (10%) or had orthopaedic surgery follow-up (69%).

Figure 4: Exclusion flow diagram

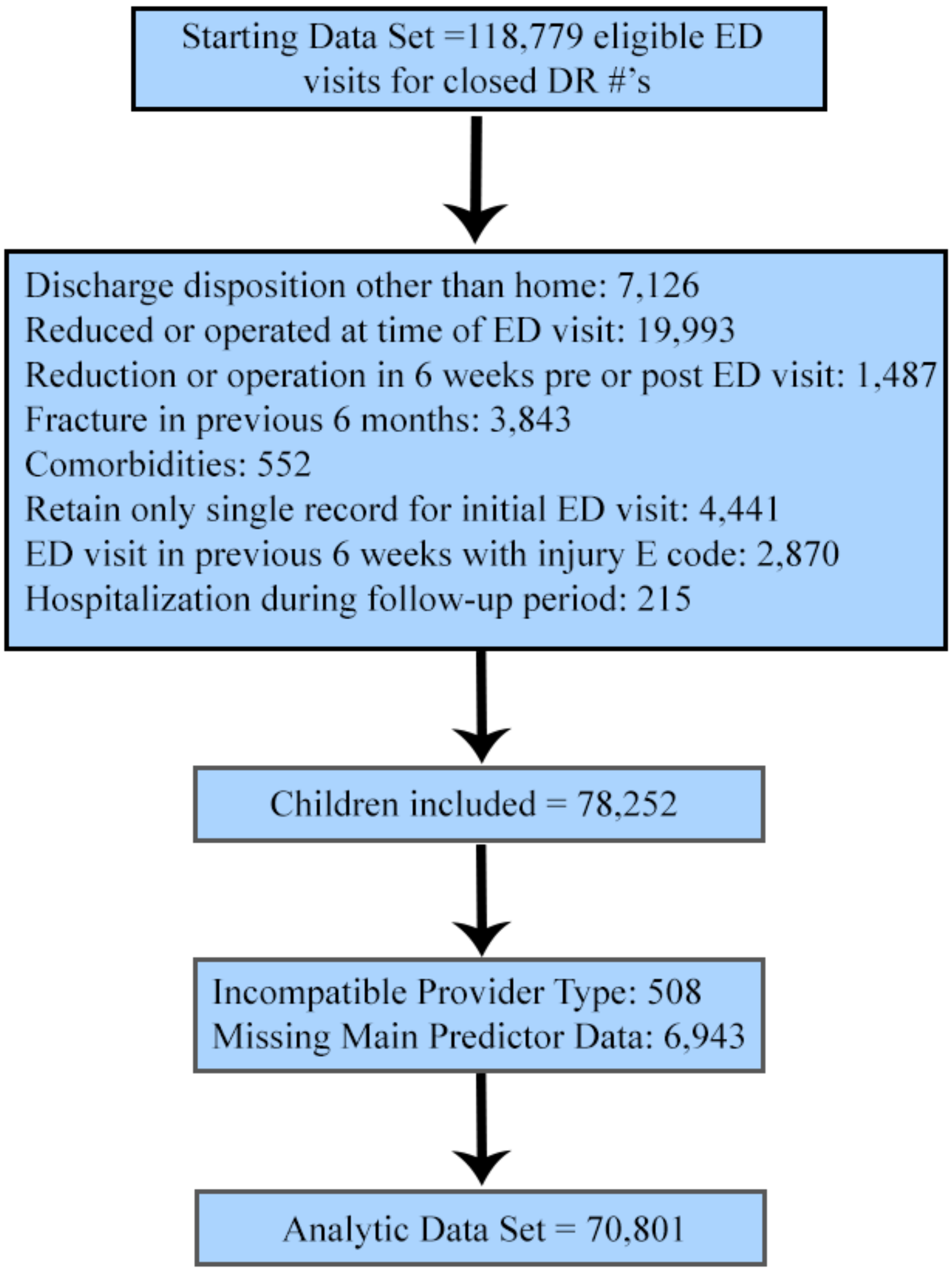


Table 2: Description of low-risk distal radius fracture cohort, stratified by outcome of interest, best-evidence treatment. Mean (SD) for continuous, N(%) for categorical variables

Predictor of interest	Best-evidence treatment	Other treatment	Total
Sample size, N(%)	14,742 (20.82)	56,059 (79.18)	70,801 (100.0)
Patient sex, N(%)			
Male	8775 (59.52)	34,713 (61.92)	43,488 (61.42)
Female	5967 (40.48)	21,346 (38.08)	27,313 (38.58)
Patient age at diagnosis, Mean(SD)	9.22 (3.21)	9.25 (3.20)	9.24 (3.20)
Patient deprivation quintile, N(%)			
(Least Marginalized) 1	3733 (25.32)	15,408 (27.49)	19,141 (27.03)
2	3162 (21.45)	12,228 (21.81)	15,390 (21.74)
3	2856 (19.37)	10,258 (18.30)	13,114 (18.52)
4	2578 (17.49)	8974 (16.01)	11,552 (16.32)
(Most marginalized) 5	2413 (16.37)	9191 (16.40)	11,604 (16.39)
Rural patient residence, N(%)			
Yes	2689 (18.24)	5135 (9.16)	7824 (11.05)
No	12,053 (81.76)	50,924 (90.84)	62,977 (88.95)
Rural ER, N(%)			
Yes	2135 (14.48)	3458 (6.17)	5593 (7.90)
No	12,607 (85.52)	52,601 (93.83)	65,208 (92.10)
Hospital Type, N(%)			
Paediatric	1362 (9.24)	4298 (7.67)	5,660 (7.99)
Teaching	1274 (8.64)	5880 (10.49)	7154 (10.10)
Community	10,394 (70.51)	43,495 (77.59)	53,889 (76.11)
Small	1712 (11.61)	2386 (4.26)	4,098 (5.79)
Year of MD graduation, N(%)			
Before 2002	12,012 (81.48)	44,637 (79.63)	56,649 (80.01)
After 2002	2730 (18.52)	11,422 (20.37)	14,152 (19.99)
Physician specialty in ED, N(%)			
ER	1103 (7.48)	5022 (8.96)	6125 (8.65)
FP/ER	5894 (39.98)	25,276 (45.09)	31,170 (44.02)
FP/GP	6130 (41.58)	20,450 (36.48)	26,580 (37.54)
Peds	984 (6.67)	3559 (6.35)	4,543 (6.42)
PEM	522 (3.54)	1090 (1.94)	1612 (2.28)
Ortho	109 (0.74)	662 (1.18)	771 (1.09)
Fiscal Year			
2003	429 (2.91)	1939 (3.46)	2368 (3.34)
2004	1187 (8.05)	5089 (9.08)	6276 (8.86)
2005	1174 (7.96)	4854 (8.66)	6028 (8.51)
2006	1222 (8.29)	4552 (8.12)	5774 (8.16)
2007	1167 (7.92)	4561 (8.14)	5728 (8.09)
2008	1136 (7.71)	4439 (7.92)	5575 (7.87)
2009	1160 (7.87)	4464 (7.96)	5624 (7.94)
2010	1208 (8.19)	4352 (7.76)	5560 (7.85)
2011	1263 (8.57)	4414 (7.87)	5677 (8.02)
2012	1238 (8.40)	4152 (7.41)	5390 (7.61)
2013	1262 (8.56)	4412 (7.87)	5674 (8.01)
2014	1261 (8.55)	4522 (8.07)	5783 (8.17)
2015	1035 (7.02)	4309 (7.69)	5344 (7.55)

Table 3: Unadjusted analysis of factors predictive of receiving best-evidence treatment for low-risk distal radius fractures

Predictor of interest	RR for best-evidence treatment (95% CI)	p-value
Patient sex		
Male	1.00 (ref)	<0.0001 *
Female	1.08 (1.05-1.11)	
Patient age at diagnosis	1.00 (0.99-1.00)	0.2869
Patient deprivation quintile		
(Least Marginalized) 1	1.00 (ref)	-
2	1.05 (1.01-1.10)	0.0159 *
3	1.12 (1.07-1.17)	<0.0001 *
4	1.14 (1.09-1.20)	<0.0001 *
(Most marginalized) 5	1.07 (1.02-1.12)	0.0060 *
Rural patient residence		
Yes	1.80 (1.73-1.86)	<0.0001 *
No	1.00 (ref)	
Rural ER		
Yes	1.97 (1.90-2.05)	<0.0001 *
No	1.00 (ref)	
Hospital Type		
Paediatric	1.35 (1.26-1.45)	<0.0001 *
Teaching	1.00 (ref)	-
Community	1.08 (1.03-1.14)	0.0030 *
Small	2.35 (2.21-2.49)	< 0.0001 *
Year of MD graduation		
Before 2002	1.00 (ref)	<0.0001*
After 2002	0.91 (0.88-0.94)	
Physician specialty in ED		
ER	1.00 (ref)	-
FP/ER	1.05 (0.99-1.11)	<0.1000
FP/GP	1.28 (1.21-1.36)	<0.0001 *
Peds	1.20 (1.11-1.30)	<0.0001 *
PEM	1.80 (1.65-1.96)	<0.0001 *
Ortho	0.79 (0.65-0.94)	0.0092 *
Fiscal Year		
2003	1.00 (ref)	-
2004	1.04 (0.94-1.15)	0.3979
2005	1.08 (0.97-1.19)	0.1555
2006	1.17 (1.06-1.29)	0.0021 *
2007	1.12 (1.02-1.24)	0.0211 *
2008	1.12 (1.02-1.24)	0.0214 *
2009	1.14 (1.03-1.26)	0.0109 *
2010	1.20 (1.09-1.32)	0.0003 *
2011	1.23 (1.11-1.36)	<0.0001 *
2012	1.27 (1.15-1.40)	<0.0001 *
2013	1.23 (1.11-1.35)	<0.0001 *
2014	1.20 (1.09-1.33)	0.0002 *
2015	1.07 (0.97-1.18)	0.1978

* p significant at < 0.05

4.2 Univariate Analysis

After stratification by the outcome of interest, the provision of best-evidence care, unadjusted point-estimates of the risk ratio were calculated for the main predictor of interest and all covariates. Results are shown in Table 3.

4.2.1 Hospital Type

The likelihood of receiving best-evidence care was highest in small hospitals (RR 2.35, 95% CI 2.21-2.49, p <.0001) and paediatric hospitals (RR 1.35, 95% CI 1.26-1.45, p <.0001). Visiting a community hospital ED also conferred a statistically significant higher likelihood of receiving best-evidence care, although with a comparatively lower RR of 1.08 (95% CI 1.03-1.14, p .0030).

4.2.1 Physician Type

ED physicians who were PEM trained had the highest likelihood of providing best-evidence care (RR 1.80, 95% CI 1.65-1.96, p<.0001). Treatment provided by a FP/GP or paediatrician also conferred an increased likelihood of receiving best-evidence treatment (RR 1.28, 95% CI 1.21-1.36, p<.0001) and (RR 1.20, 95% CI 1.11-1.30, p<.0001), respectively. Orthopaedic surgery trained physicians had the lowest likelihood of providing best-evidence care (RR 0.79, 95% CI 0.65-0.94, p .0092).

4.2.3 Other Covariates

Females had a small but statistically significant higher risk of receiving no follow-up after being seen in the ED for a low-risk distal radius fracture (RR 1.08, 95% CI 1.05-1.11, p<.0001) compared to males. Age was not significantly associated with receiving best-evidence care. All deprivation quintiles demonstrated small but statistically significant associations with best-evidence care, although no overarching trend emerged. Rural patient residence was positively associated with receiving best-evidence care (RR 1.80, 95% CI 1.73-1.86, p<.0001) as was rural location of the ED (RR 1.97, 95% CI 1.90-2.05, p<.0001). Physicians having graduated medical school after 2002 were less likely to provide best-evidence care for low-risk distal radius fractures (RR 0.91, 95% CI 0.88-0.94, p<.0001).

4.3 Multivariable Analysis

No variables reached the VIF threshold of >2.5 for collinearity and therefore all variables in the *a priori* model were included in the final model (Table 4). The final model included the outcome variable, best-evidence treatment, variables of interest hospital and physician type, and covariates age, sex, deprivation quintile, rural residence, and fiscal year. Variables not included in the model were year of medical school graduation and rural location of ED. Results of the multivariable analysis are shown in Table 5 and are graphically depicted in Figure 5.

Table 4: Comparison of variance inflation estimates associated with outcomes and predictors of interest

Variable	VIF
Sex	1.08
Age	1.08
Deprivation quintile	1.01
Rural patient residence	1.08
Hospital Type	1.08
Physician specialty	1.02
Fiscal year	1.01

Table 5: Multivariable log binomial regression analysis of factors predictive of receiving best-evidence treatment for a low-risk distal radius fracture (n = 70,801)

Predictor of interest	Adjusted RR for best-evidence treatment (95% CI)	p-value
Sex		
Male	1.00 (ref)	<0.0001 *
Female	1.08 (1.05-1.11)	
Age	1.00 (0.99-1.01)	0.1572
Patient deprivation quintile, N(%)		
(Least Marginalized) 1	1.00 (ref)	-
2	1.01 (0.97-1.05)	0.6043
3	1.04 (0.99-1.09)	0.0542
4	1.06 (1.01-1.10)	0.0171 *
(Most marginalized) 5	1.03 (0.99-1.08)	0.1847
Rural Residence		
Yes	1.44 (1.38-1.50)	<0.0001 *
No	1.00 (ref)	-
Hospital Type		
Paediatric	1.16 (1.07-1.26)	0.0002 *
Teaching	1.00 (ref)	-
Community	1.13 (1.06-1.20)	<0.0001 *
Small	1.86 (1.72-2.01)	<0.0001 *
Physician specialty in ED		
ER	1.00 (ref)	-
FP/ER	1.00 (0.94-1.06)	0.9474
FP/GP	1.09 (1.02-1.16)	0.0077 *
Pediatrics	1.22 (1.11-1.34)	<0.0001 *
PEM	1.73 (1.56-1.92)	<0.0001 *
Orthopaedics	0.76 (0.63-0.91)	0.0027 *
Fiscal Year		
2003	1.00 (ref)	-
2004	1.05 (0.95-1.16)	0.3119
2005	1.09 (0.99-1.21)	0.0782
2006	1.18 (1.07-1.31)	0.0007 *
2007	1.13 (1.03-1.25)	0.0138 *
2008	1.16 (1.05-1.28)	0.0034 *
2009	1.14 (1.04 -1.26)	0.0074 *
2010	1.19 (1.08-1.32)	0.0004 *
2011	1.20 (1.09-1.33)	0.0002 *
2012	1.24 (1.12-1.37)	<0.0001 *
2013	1.21 (1.09-1.33)	0.0002 *
2014	1.19 (1.08-1.31)	0.0005 *
2015	1.06 (0.95-1.17)	0.2896

*** p significant at < 0.05**

Log binomial regression of predictors of best-evidence treatment

Both hospital type and physician type were significantly associated with receiving best-evidence treatment after adjustment.

4.3.1 Hospital Type

Small hospital type had the largest positive association with best-evidence care (RR 1.86, 95% CI 1.72-2.01, p<0.0001) when compared with teaching hospitals as a reference category. Paediatric hospital (RR 1.16, 95% CI 1.07-1.26, p .0002) and community hospital (RR 1.13, 95% CI 1.06-1.20, p<.0001) types were also statistically significant predictors of receiving best-evidence care in the ED.

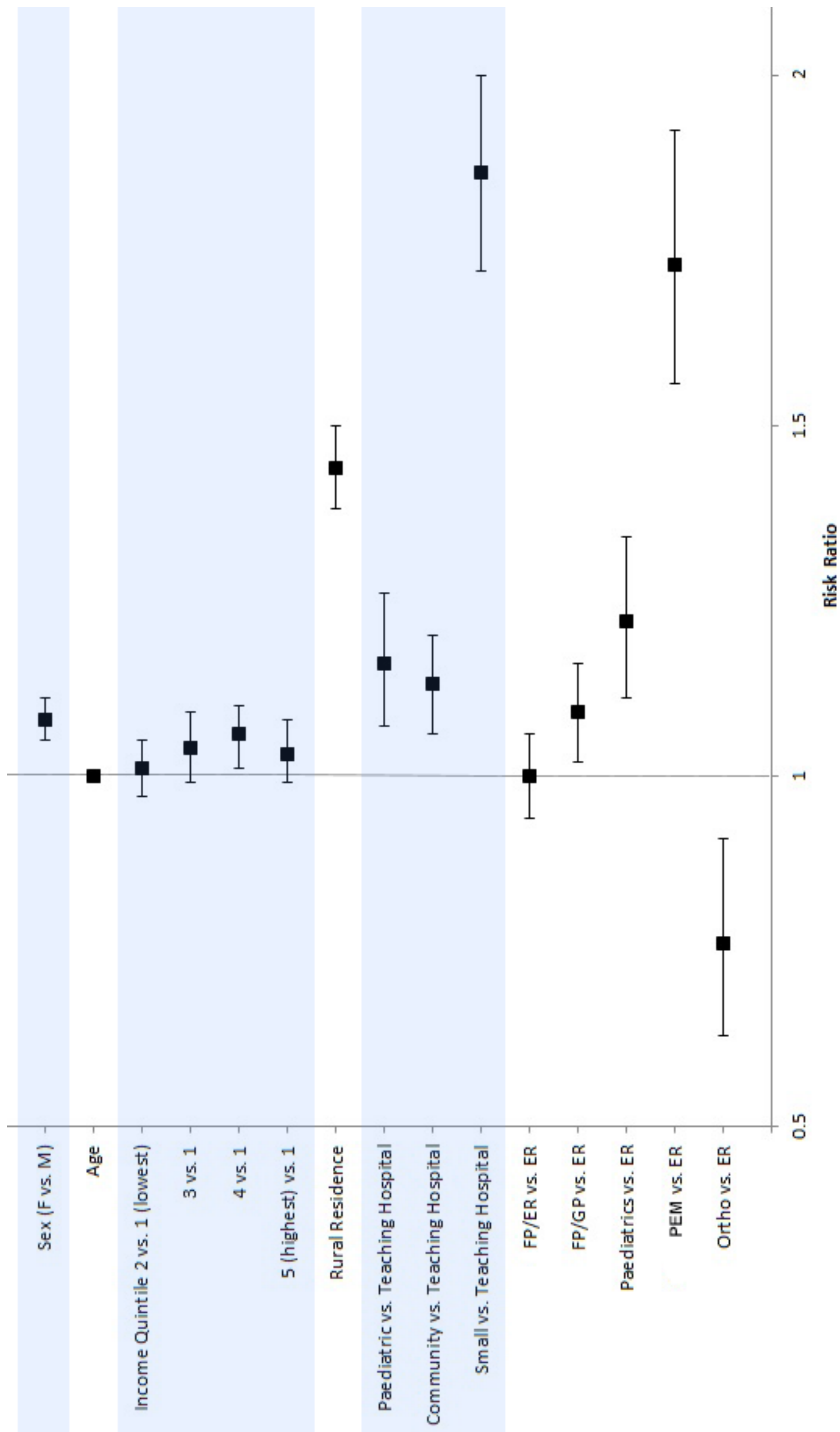
4.3.2 Physician Type

The risk ratios for PEM training (RR 1.73, 95% CI 1.56-1.92, p<.0001), paediatricians (RR 1.22, 95% CI 1.11-1.34, p<.0001), FP/GP (RR 1.09, 95% CI 1.02-1.16, p .0077), and orthopaedic surgeons (RR 0.77, 95% CI 0.64-0.92, p .0027) were statistically significant. FP/ER training was not a statistically significant predictor (RR 1.00, 95% CI 0.94-1.06, p .9474).

4.3.3 Other Covariates

Rural patient residence showed a large statistically significant association with best-evidence treatment after adjustment (RR 1.44 95% CI 1.38-1.50, p<.0001). Female sex had a small but statistically significant association (RR 1.08, 95% CI 1.05-1.11, p<. 0001). One patient deprivation quintile reached statistical significance (fourth quintile, RR 1.06, 95% CI 1.01-1.10, p .0171), with no trend demonstrated amongst the quintiles. Age was not a significant predictor (RR 1.00, 95% CI 0.99-1.01, p .1572).

Figure 5: Forest plot illustrating results of multivariable analysis of factors predictive of receiving best-evidence treatment


Sex (F vs. M)
Age
Income Quintile 2 vs. 1 (lowest)
3 vs. 1
4 vs. 1
5 (highest) vs. 1
Rural Residence
Paediatric vs. Teaching Hospital
Community vs. Teaching Hospital
Small vs. Teaching Hospital
FP/ER vs. ER
FP/GP vs. ER
Paediatrics vs. ER
PEM vs. ER
Ortho vs. ER
0.5
1
1.5
2
Risk Ratio

4.4 Trends Over Time

Results are shown in Tables 6-8 and important findings are graphically depicted in Figures 6-13. The overall percentage of patients receiving orthopaedic follow-up remained stable at 67-68% from 2003-2013, with a small increase to 73.4% over the last 2 years of the study. The percentage receiving no follow-up also saw little variation over the study period, increasing from 18.1 % in 2003 to a high of 23.0 % in 2012, and falling again to 19.4% by 2015. The percentage receiving primary care follow-up slowly decreased over the course of the study period from 13.5% in 2003 to 7.2% by 2015.

4.4.1 Hospital Type

The proportion of low-risk distal radius fractures seen in paediatric hospitals experienced a decrease from 8.2% in 2003 to a low of 4.9% in 2009, rose again to 11.1% in 2013, and finished at 10.0% in 2015. The proportion of these injuries seen in teaching, community and small hospitals experienced very little fluctuation throughout the study.

The proportion of patients seen in the EDs of paediatric hospitals and receiving no follow-up for low-risk distal radius fractures increased from 8.2% in 2003 to a high of 30.7% in 2012, then decreased slightly to 26.0% in 2015. A similar trend was seen in teaching hospitals, increasing the proportion of patients receiving no follow-up from 5.6% to a high of 26.0% in 2012, and decreasing slightly to 18.0% in 2015. Small hospitals saw fluctuation between 39% and 49% during the study period, but without any overarching trend. Community hospitals remained consistent between 17-20% in their proportion of best-evidence care over the study period. Where orthopaedic follow-up was concerned, paediatric hospitals decreased from 88.7% in 2003 to a low of 55.3% in 2013, and ending at 60.5% in 2015. Teaching hospitals decreased their orthopaedic follow-up from 90.9% to a low of 71.5% in 2012, finishing with 76.0% in 2015. Community and small hospitals both increased their proportion of orthopaedic follow-up over the entire length of the study period, from 66.9% to 77.0% and from 26.7% to 48.1%, respectively.

4.4.2 Physician Type

Emergency medicine trained physicians treating children with low-risk distal radius fractures rose from 6.6% in 2003 to 9.6% in 2007 with little fluctuation thereafter.

FP/ER experienced a dramatic increase as a physician group treating these injuries over the study period, increasing from 32.8% in 2003 to a high of 56.6% in 2010, and finishing at 48.2% in 2015. FP/GP experienced a dramatic decrease from 49.7% in 2003 to a low of 25.5% in 2010, finishing at 32.6% in 2015. Paediatricians seeing these injuries in the ED decreased from 9.3% in 2003 to 5.9% in 2015. PEM training did not appear in the data until 2009. Orthopaedic surgeons consistently treated less than two percent of these injuries in the ED.

Emergency medicine trained physicians decreased their orthopaedic follow-up from 85.3% in 2003 to a low of 69.3% in 2014 while increasing their proportion of no follow-up from 10.9% to 24.6% during the same time period. Paediatricians working in the ED also decreased their orthopaedic follow-up, from 91.8% in 2003 to 55.1% in 2015, and increased their proportion of no follow-up from 4.5% to 28.5% during the same time period. PEM training also saw decreasing orthopaedic follow-up rates, and increased no follow-up rates, however data for this specialty is only available as of 2009.

FP/GP and FP/ER experienced small variations in no follow-up with no overarching trend but experienced noticeable increases in orthopaedic follow-up over the course of the study.

4.4.3 Other Covariates

There was a trend towards decreased age at diagnosis, beginning at 9.9 years in 2003 and declining to 8.9 years by 2015. There was also a trend of increasing proportion of fractures over time in the least deprived quintile, with no trend observed in the other quintiles.

No trends were observed in terms of fracture rate, sex, patients residing in rural locations, and visits to rural EDs.

Table 7: Yearly variation in the incidence of best-evidence treatment for low-risk distal radius fractures from 2003-2015, stratified by exposures of interest

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Hospital Type (%)													
Paediatric	8.3	7.7	11.5	20.6	23.8	30.1	18.1	27.4	29.8	30.7	30.5	28.8	26.0
Teaching	5.6	13.5	18.3	16.2	15.3	16.1	15.9	19.5	20.0	26.0	20.3	22.8	18.0
Community	18.9	18.8	18.9	20.1	19.4	18.4	19.9	19.6	19.9	20.3	19.9	19.2	17.3
Small	39.3	43.6	42.7	49.2	41.2	48.3	41.1	44.9	40.6	38.2	39.2	40.6	34.8
Physician Type (%)													
ER	10.9	12.5	12.9	16.7	17.2	17.9	19.6	21.1	19.0	19.2	20.4	24.6	15.6
FP/ER	18.4	18.3	18.9	19.6	17.2	17.7	19.7	19.0	19.8	20.4	19.5	19.0	17.4
FP/GP	22.0	21.6	22.1	23.5	23.4	23.3	22.6	26.9	25.6	24.9	23.9	22.3	20.3
Paediatric	4.6	11.5	12.6	20.0	21.0	26.1	18.1	22.1	29.4	32.6	30.6	29.0	28.5
PEM	-	-	-	-	-	-	18.2	29.4	30.6	34.8	33.7	36.0	31.1
Ortho	0	16.5	14.9	14.3	15.0	10.8	8.1	18.7	12.5	10.3	22.2	20.6	17.7

Table 8: Yearly variation in the incidence of orthopaedic follow-up for low-risk distal radius fractures from 2003-2015, stratified by exposures of interest

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Hospital Type (%)													
Paediatric	88.7	89.6	85.4	73.8	68.8	63.5	72.8	65.4	62.2	58.7	55.3	61.0	60.5
Teaching	90.9	82.3	78.8	79.3	82.0	80.4	80.4	75.0	75.1	71.5	75.5	72.4	76.0
Community	66.9	68.5	67.0	67.2	68.4	69.6	69.2	70.4	70.3	70.8	72.0	73.5	77.0
Small	26.7	22.8	24.2	24.2	30.8	31.7	39.9	37.7	44.1	47.0	45.7	46.5	48.1
Physician Type(%)													
ER	85.3	82.6	82.1	75.2	76.3	76.8	74.6	72.8	73.6	72.0	72.9	69.3	79.4
FP/ER	72.3	71.1	70.2	70.1	73.6	72.7	72.0	72.6	72.0	71.8	72.6	74.7	77.7
FP/GP	58.5	61.7	60.4	61.3	61.1	61.0	63.2	57.7	60.7	64.2	66.5	68.4	70.9
Paediatric	91.8	84.7	83.9	73.7	72.0	68.5	73.9	70.9	62.5	57.1	54.8	58.6	55.1
PEM	-	-	-	-	-	-	81.8	63.1	61.4	55.7	54.7	54.1	55.2
Ortho	89.7	83.5	83.9	80.5	82.5	87.7	87.1	80.0	85.7	89.7	75.0	76.5	76.5

Table 6: Yearly variation in general fracture characteristics (n = 70,801)

Variable	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Fracture rate (/100,000 eligible population)	126.2	338.3	329.2	318.6	318.5	312.0	316.8	313.9	321.0	305.3	322.3	328.4*	303.5*
Male sex, (%)	63.67	61.49	61.78	61.47	61.49	61.04	62.46	62.18	61.05	60.11	61.42	61.77	59.71
Patient age at diagnosis (mean)	9.90	9.27	9.33	9.38	9.35	9.31	9.39	9.31	9.14	9.08	9.07	9.05	8.90
Patient deprivation quintile, (%)													
(Least) 1	24.84	23.80	24.35	25.29	25.65	27.09	27.38	27.36	27.64	28.55	29.26	29.76	29.98
2	23.32	22.61	22.30	21.74	21.98	21.18	20.84	22.09	21.02	21.74	21.34	22.29	20.86
3	18.93	19.18	18.63	18.24	19.64	18.94	17.78	18.33	19.02	18.83	17.54	17.59	18.32
4	17.07	17.70	16.34	17.73	16.45	16.14	16.79	16.10	16.03	15.58	16.00	14.75	15.63
(Most) 5	15.84	16.70	18.38	17.01	16.29	16.65	17.21	16.13	16.29	15.29	15.86	15.61	15.21
Rural Residence (%)	12.08	11.41	10.82	10.93	11.75	10.12	11.81	11.82	11.24	11.30	10.59	10.05	10.31
Rural ER (%)	7.10	7.54	6.90	7.72	8.85	7.12	8.34	8.35	8.54	8.13	8.42	7.26	8.08
Hospital Type (%)													
Paediatric	8.20	7.07	6.49	6.81	5.94	6.13	4.91	6.76	10.16	10.69	11.05	10.20	9.99
Teaching	8.32	9.08	12.26	11.62	12.24	11.61	11.61	10.14	8.91	8.85	8.41	8.40	8.72
Community	77.78	78.25	76.39	76.43	76.10	77.06	77.56	76.80	74.46	74.58	74.60	75.26	74.83
Small	5.70	5.59	4.86	5.14	5.73	5.20	5.92	6.29	6.46	5.88	5.94	6.14	6.46
Physician specialty in ED (%)													
ER	6.59	6.50	7.98	8.50	9.64	9.60	9.82	8.85	8.35	9.07	9.18	8.85	8.65
FP/ER	32.78	36.06	34.22	35.31	34.46	44.00	41.71	56.64	53.85	51.91	50.16	48.92	48.22
GP/FP	49.68	47.47	49.12	46.95	47.77	38.17	41.18	25.05	26.18	26.92	29.20	31.85	32.62
Paediatric	9.29	8.43	7.23	7.90	6.74	7.07	5.80	3.58	5.16	6.49	5.53	5.60	5.91
Pediatric/ER	0	0	0	0	0	0	0.39	4.53	5.48	5.06	5.29	4.18	3.97
Ortho	1.65	1.55	1.44	1.33	1.40	1.17	1.10	1.35	0.99	0.54	0.63	0.59	0.64
Type of follow-up (%)													
Orthopaedic	68.44	68.69	67.55	66.82	67.91	68.47	68.94	68.47	68.24	68.13	68.88	70.47	73.39
PCP	13.48	12.40	12.97	12.02	11.71	11.16	10.44	9.80	9.51	8.91	8.88	7.73	7.24
None	18.08	18.91	19.48	21.16	20.37	20.37	20.63	21.73	22.25	22.97	22.24	21.81	19.37
Year of MD graduation (%)													
Before 2002	100.0	99.75	97.89	94.865.14	89.54	84.47	81.33	75.34	70.92	69.44	62.94	62.01	58.31
After 2002	0.00	0.25	2.11		10.46	15.53	18.67	24.66	29.08	30.56	37.06	37.99	41.69

* computed from 2013 population values

Figure 6: Yearly Variation in proportion of visits for low-risk distal radius fractures, by hospital type

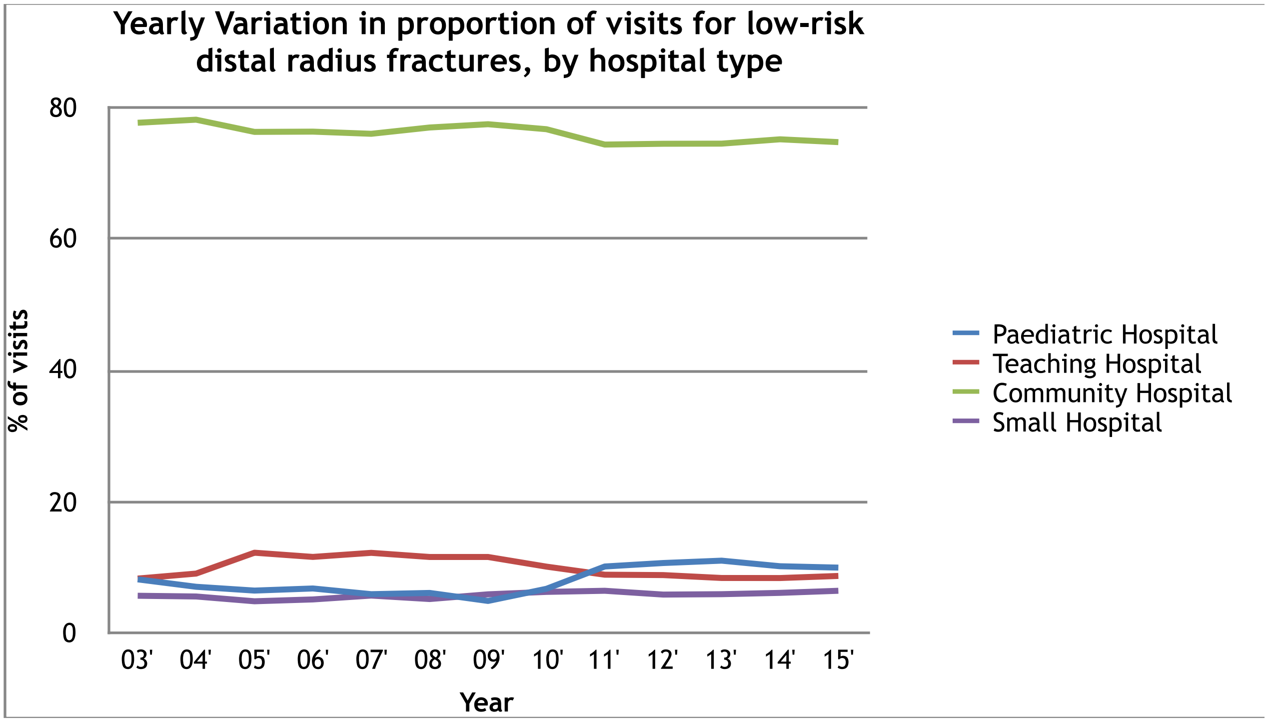


Figure 7: Yearly variation in proportion of visits for low-risk distal radius fractures, by physician type

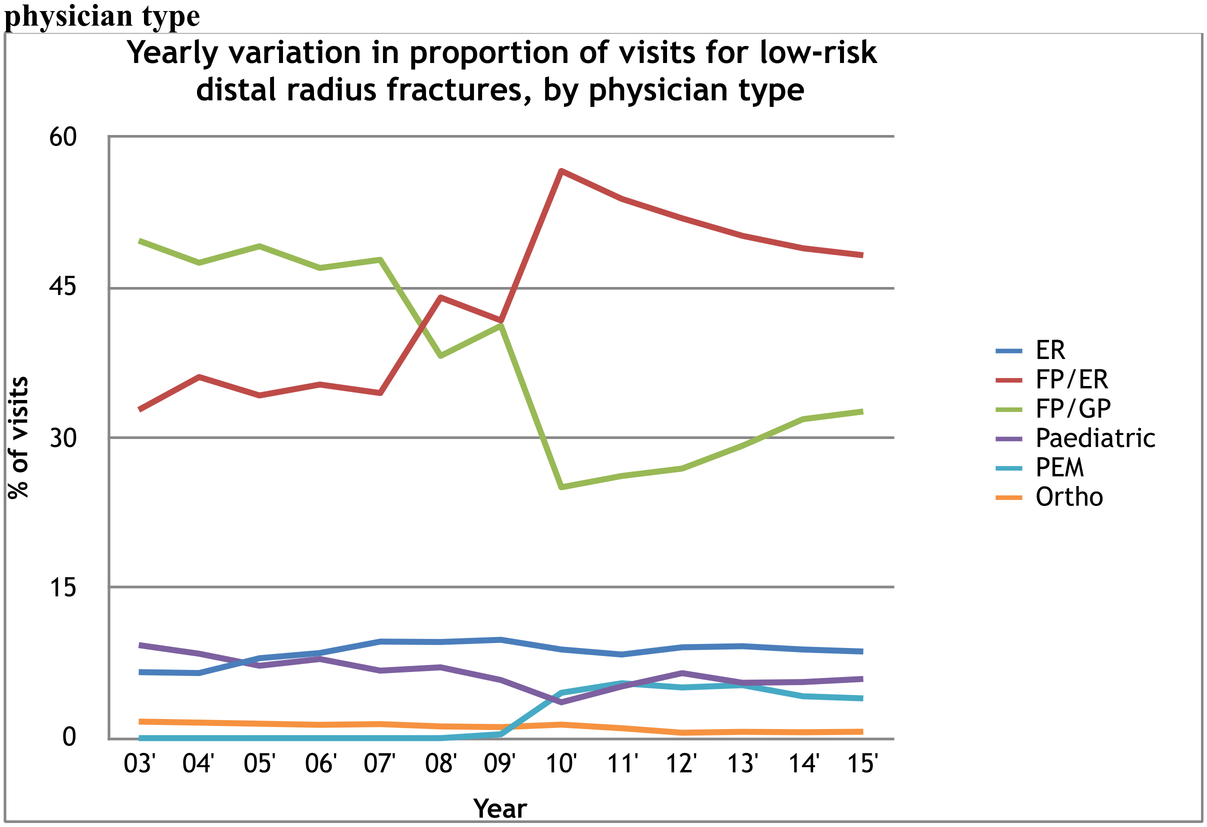


Figure 8: Yearly variation in proportion of visits for low-risk distal radius fractures, by deprivation quintile

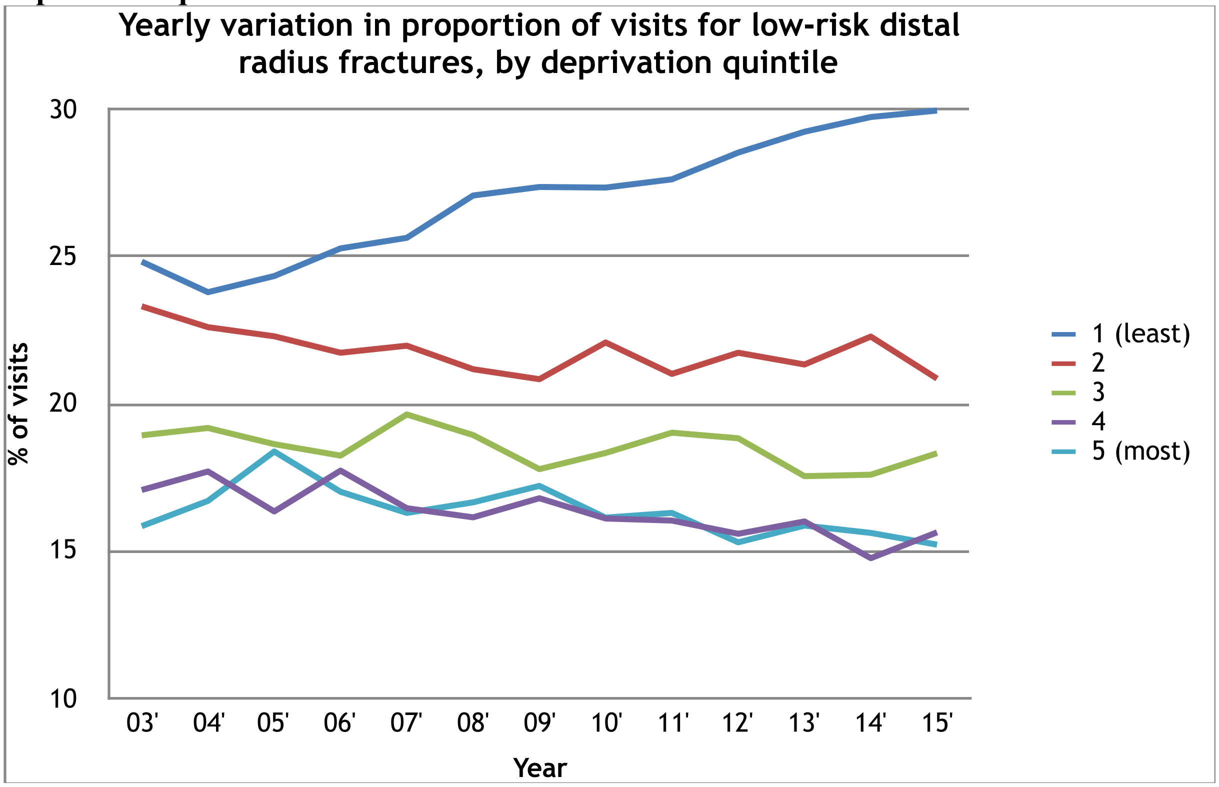


Figure 9: Yearly variation in type of follow-up visit for low-risk distal radius fractures

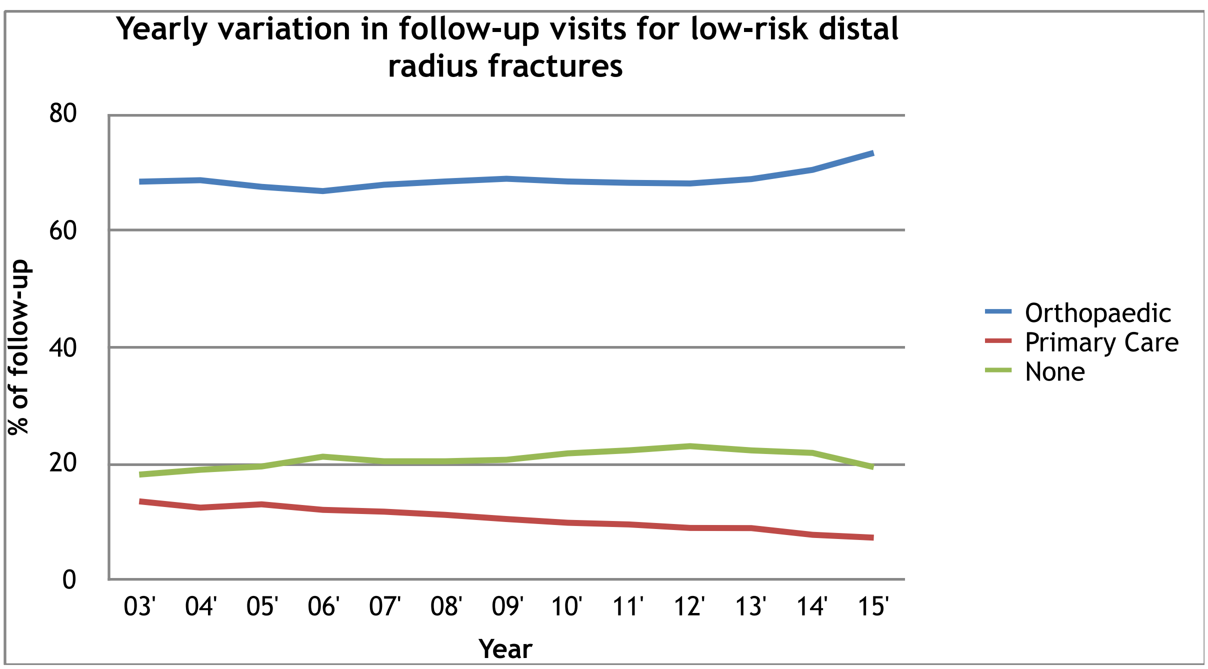


Figure 10: Yearly variation in best-evidence treatment, by hospital type of ED where patient initially presented

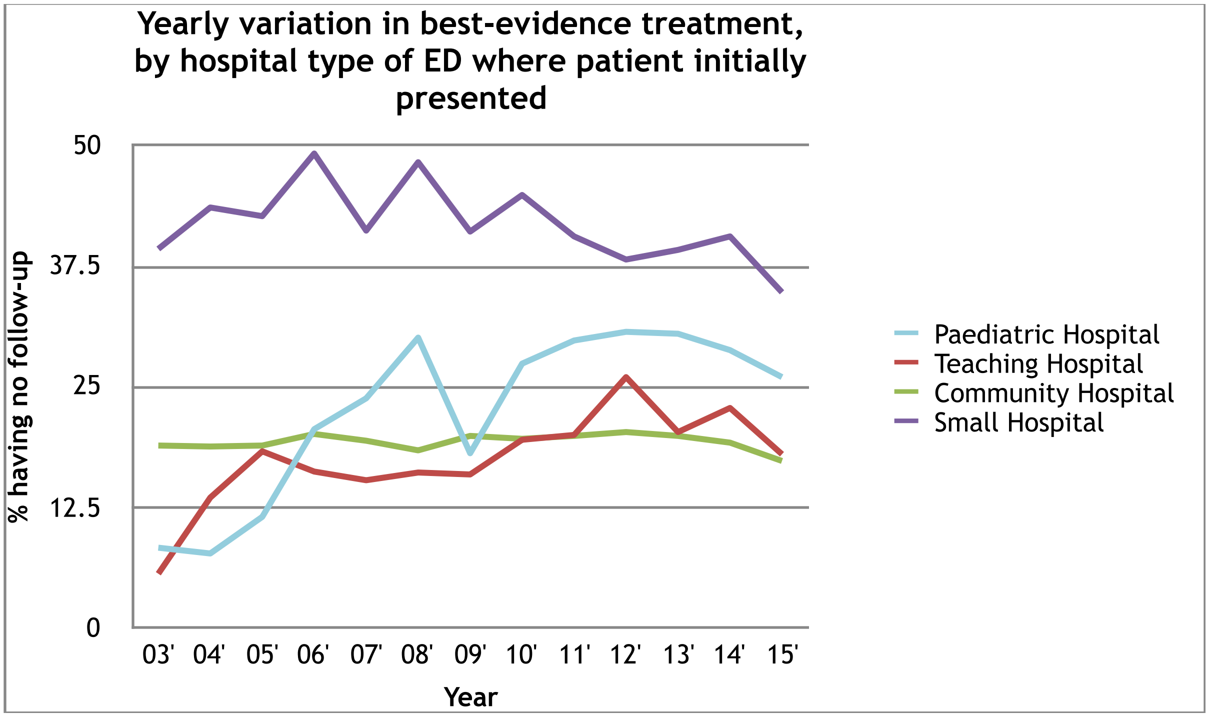


Figure 11: Yearly variation in best-evidence treatment, by physician type

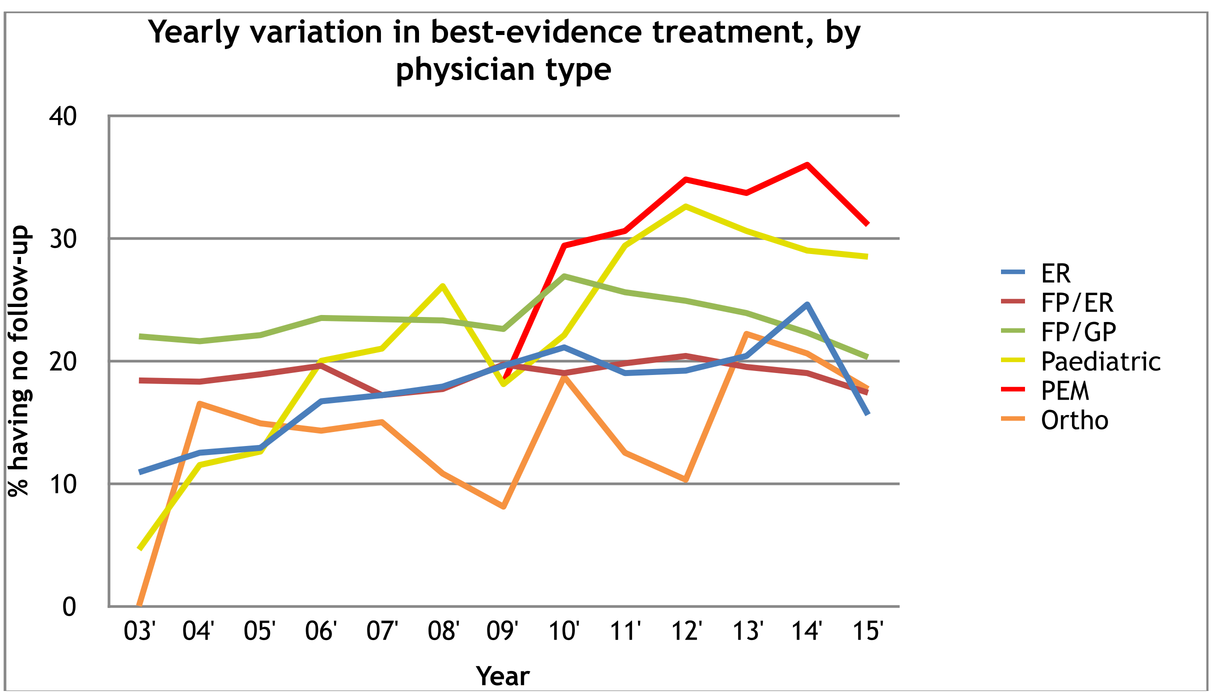


Figure 12: Yearly variation in orthopaedic follow-up, by hospital type of ED where patient initially presented

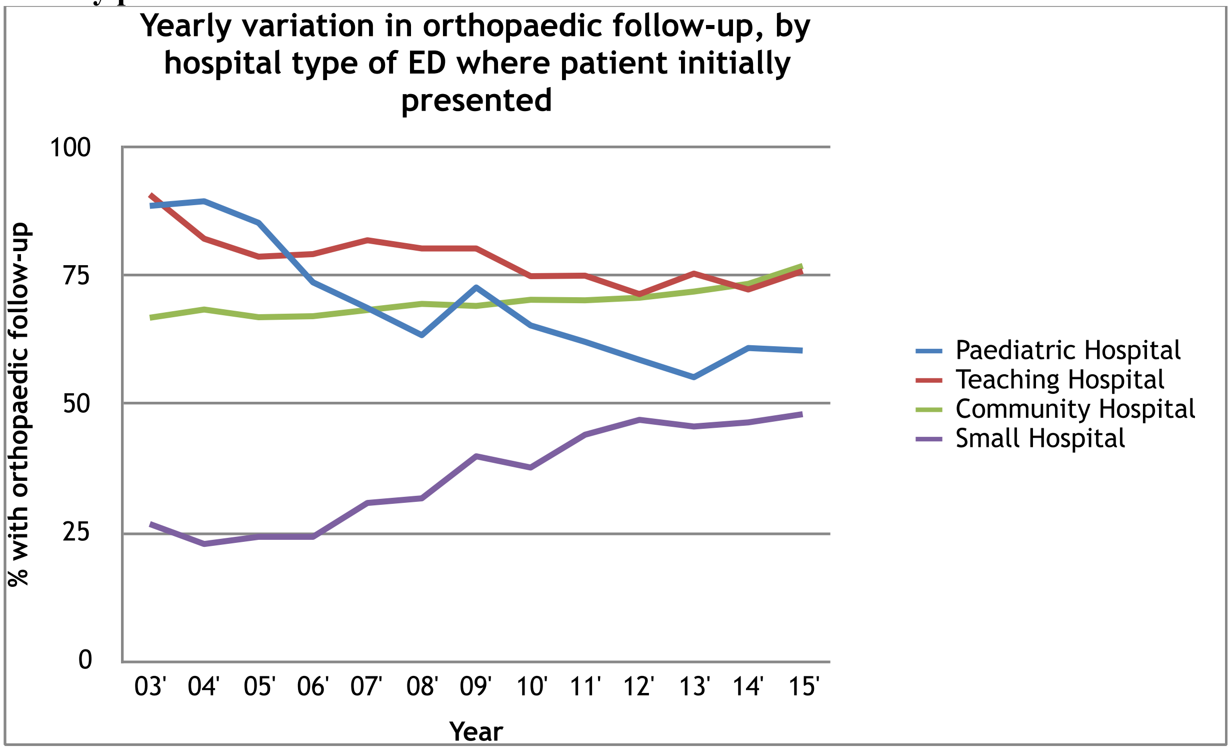
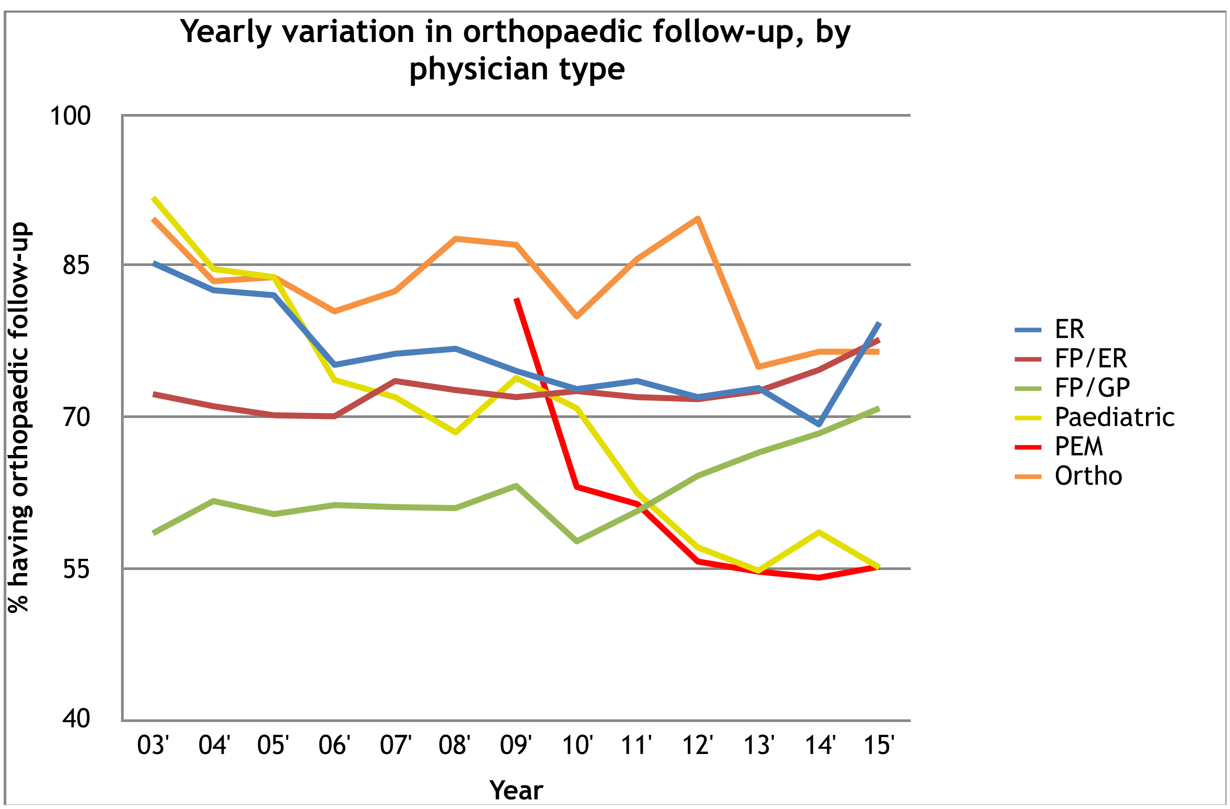


Figure 13: Yearly variation in orthopaedic follow-up, by physician type



4.5 Sensitivity Analyses

Complete results of the sensitivity analyses are presented in Appendix F.

1. When we increased the specificity of the diagnostic algorithm for low-risk distal radius fractures, the magnitude and significance of important results were similar to those obtained in the primary model.

2. When we varied the outcome definition to allow for primary-care follow-up in addition to no follow-up as the definition of "best-evidence", the magnitude and significance of important results were similar to those obtained in the primary model.

3. When we combined paediatricians and PEM into a single category and combined FP/GP and FP/ER into one category, the magnitude and significance of important results were similar to those obtained in the primary model.

4. When we defined the outcome of interest as no follow-up AND no x-ray coded in the administrative data for 6 weeks following the fracture, significance of all variables was maintained compared with the primary model. The risk ratios for small and community hospitals were lower than in the primary model however, and the direction of association was reversed for community hospitals. One possible explanation for this deviation is that radiographic review and billing submissions for radiographic interpretation may not coincide with the date the x-ray was taken and this discrepancy may differ across Ontario in a manner that we do not understand.

5. Discussion

Over the last fifteen years, a substantial body of evidence has accumulated to support simplified treatment for low-risk paediatric distal radius fractures. Until now, little was known about the dissemination and application of this evidence and the factors that contribute to it. Our results indicate that, despite ample best-evidence in the past 17 years to support the safety and efficacy of simplified treatment for low-risk paediatric distal radius fractures, the proportion of patients receiving best-evidence care has not substantially changed since 2003 and only 21% of patients in Ontario receive care in line with these recommendations. Perhaps more surprising, 69% of patients are unnecessarily seen for follow-up in an orthopaedic surgeon's office for a benign, non-surgical injury and this proportion has also been stable since 2003.

The distal radius is the most commonly fractured bone in childhood and represents twenty-five percent of all paediatric fractures; the social and economic impact of this unnecessary care is therefore tremendous[1]. Paediatric hospitals and PEM trained physicians are leading the way in terms of application of best-evidence; children are 89% more likely to receive best-evidence treatment when they are initially managed in a paediatric hospital by a PEM physician, and this percentage has been increasing with time. Small hospitals conferred an overall 86% increased likelihood of receiving best-evidence treatment, but have been deteriorating over time.

To our knowledge, this study presents the first population-based investigation of factors affecting the application of best-evidence in children's low-risk distal radius fracture care. Other strengths of this study are the use of prospectively collected administrative data from individuals and hospitals across Ontario, a large sample size, and robust sensitivity analyses. Furthermore, our results are likely generalizable to other Canadian province and territories, whose health care systems are similarly structured and experience similar constraints.

5.1 Key Findings

5.1.1 The role of hospital type

Hospital type plays a role in best-evidence treatment: Paediatric and small hospitals are more likely to provide patients with best-evidence care

An unexpected finding in this study, small hospitals and rural patient location emerged as significant and independent predictors of receiving best-evidence care for a low-risk paediatric distal radius fracture.

Contrary to our initial belief, limited resources in the small hospital and rural residence setting may actually be an asset in the provision of best-evidence treatment for these fractures. The option of orthopaedic follow-up may seem less alluring when the fracture follow-up clinic servicing a small hospital or rural patient population is only offered once per week, and might be several hours commute from the patient's home. Patients may therefore prefer to follow-up with their family physician and may be more amenable to foregoing follow-up altogether. Emergency physicians in these settings have likely adapted to the lack of specialist services in their area by necessarily becoming excellent resource stewards and have thus made a habit of managing common and amenable ED presentations without specialist referrals. Furthermore, small EDs are commonly staffed by local family/general physicians who also have family/general clinical practices nearby where convenient follow-up with continuity of care can easily be provided for their own patients seen in the ED, thereby decreasing the allure of orthopaedic referral. It is also possible that patients who are seeing their own family or general practitioner in the ED feel more comfortable with discharge instructions because they are provided by a physician that they already know and trust.

Consistent with our hypothesis, the current study demonstrated that paediatric hospitals were 16% more likely to provide best-evidence care for paediatric patients who presented to the ED with a low-risk distal radius fracture between 2003 and 2015. While this was an expected finding, the magnitude of the effect of paediatric hospital type was lower than anticipated. Canadian research on best practices for low-risk paediatric distal radius fractures was largely conducted in paediatric hospitals with the education, assistance, and cooperation of ED physicians working in those facilities. Combined with the high volume of these injuries seen in paediatric ED's, potential presence of standardized treatment protocols, and availability of removable immobilization devices, we had believed that paediatric hospital type would emerge as the predominant determinant of best-evidence care.

The risk ratios from the adjusted analysis only provide an overall picture of best-evidence treatment for low-risk distal radius fractures in Ontario averaged over the entire study period. We must also consider trends in the application of evidence over time; we have demonstrated that some hospital types have improved, while others have deteriorated. Therefore, while the risk ratios from the adjusted analysis reveal that small hospitals have overall been most successful in terms of their provision of best-evidence care, they are also experiencing an alarmingly rapid increase in the provision of unnecessary follow-up care for low-risk paediatric distal radius fractures that is not seen with other hospital types.

Paediatric and teaching hospitals demonstrated trends suggestive of active assimilation and application of best-evidence

Paediatric and teaching hospitals, which both had orthopaedic follow-up rates around 90% at the beginning of the study period, decreased their proportion of orthopaedic follow-up by 28% and 15% respectively by the last year of the study while increasing their proportion of patients not receiving any follow-up. This findings was consistent with our hypothesis and lends support to the notion that dissemination and translation of best evidence practices for this injury type are occurring through channels directly related to academia and paediatric emergency medicine groups.

Small and community hospitals experienced a decrease in application of best-evidence

Most notably, small hospitals nearly doubled their proportion of orthopaedic follow-up during the study period. Despite this trend, small hospitals were still ***overall*** the most "best-evidenced" in their follow-up of low-risk paediatric distal radius fractures, having the lowest proportion of orthopaedic follow-up and highest proportion of no follow-up in every single individual year of the study. By the end of the study however, the margin of superiority for small hospitals was substantially narrowed due to other hospital comparator types either improving or remaining stagnant in their practices while small hospitals deteriorated. Community hospitals also demonstrated a trend of increasing orthopaedic follow-up, though not nearly as dramatic as the trend seen with small hospitals.

Increased orthopaedic follow-up in these hospital types might be explained by the saturation of the orthopaedic surgery profession which reached a peak between 2008 and 2015. Jobs in bigger cities became more scarce during this time; new graduates therefore accepted more positions and locums in traditionally underserved areas of the province, thereby increasing availability of orthopaedic surgeons in areas where small and community hospitals are found in abundance. This increased access to specialists may have resulted in increased referrals due to convenience or due to surgeons seeking new patients to fill their clinical booking time.

5.1.2 The role of physician type

Physician type plays a role in best-evidence treatment: PEM specialists are most likely to provide patients with best-evidence care

In this study, physician type emerged as one of the primary drivers of best-evidence care, largely within paediatric hospitals. PEM physicians independently contributed a 73% increased likelihood of receiving best-evidence care. These physicians work almost exclusively in paediatric hospitals, which confer a 16% increased likelihood, potentially resulting in a combined 89% increased likelihood of best-evidence treatment when managed by a PEM physician.

Paediatricians working in the ED, a staffing arrangement that is also almost exclusive to paediatric hospitals, provided a 22% increase likelihood of receiving best-evidence care.

These results suggest that within paediatric hospitals, physician type working in the ED is the predominant determinant of whether best-evidence care is provided and corroborates a portion of our initial hypothesis regarding how best-evidence for this fracture has been disseminated in the Ontario landscape thus far - conference presentations, research participation, and journal articles catered to a specific physician type audience.

FP/GP, FP/ER, and emergency medicine physician types were either associated with a very modest or no significant increase in the likelihood of providing best-evidence care.
These physician types work across all four hospital types and in both rural and urban settings and therefore their application of best-evidence appears to be more related to the type of hospital they are working in or perhaps their individual experience and familiarity with these injuries.

Orthopaedic surgery practitioner type was found to be associated with a significantly increased likelihood of subsequent orthopaedic follow-up. It is possible that this finding represents a tendency for orthopaedic surgeons to want to follow patients they have initially seen in the ED, despite best evidence. More likely however is that the few hundred fractures that were initially seen in the ED by an orthopaedic surgeon represent more severe fracture types at baseline that may have been miscoded in the administrative data.

Paediatric training, emergency medicine training, and the combination of the two demonstrated trends that are reflective of best-evidence being assimilated and applied

These three physician types were successful in decreasing their proportion of orthopaedic follow-up over the course of the study, while also increasing their proportion of patients receiving no follow-up. This findings is consistent with our hypothesis and, similar to hospital type, lends support to the notion that dissemination and translation of best evidence practices for this injury type are occurring through channels directly related to academia and paediatric emergency medicine groups.

Primary care practitioners working in the ED were largely unchanged in their application of best-evidence

FP/ER training had stable proportions of both orthopaedic and no follow-up during the study period. FP/ER training also demonstrated stables proportions over time in terms of no follow-up, but experienced a small increase in orthopaedic follow-up. The lack of evidence uptake seen with primary care practitioners may be related to a lack of training, experience and comfort in dealing with these injuries. This may be the result of a weak educational curriculum in fracture care during medical school and residency training programs potentially owing to the view that fractures are not primary care issues. More likely however is that changes over time were not observed in these practitioner types because other influences, such as hospital type, predominated where evidence uptake is concerned or that paediatric or orthopaedic literature is not being adequately disseminated in the primary care setting.

5.1.3 Other findings

A large proportion of low-risk distal radius fractures are being seen for follow-up by an orthopaedic surgeon

More than two thirds of patients in this study were seen in follow-up by an orthopaedic surgeon. These unnecessary specialist follow-ups are costly for the healthcare system and needlessly inconvenience patients and parents. While no follow-up is the ideal treatment option, we acknowledge that some patients may have questions or require reassurance while the fracture is healing and thus may require a follow-up appointment. A follow-up visit with a primary care practitioner can appropriately address these concerns and is the preferred alternative to orthopaedic follow-up. The primary care practitioner can subsequently refer the patient to an orthopaedic surgeon if concerns arise during fracture healing that they are unable or not equipped to address. We investigated this alternative scenario for best-evidence care (ie.: defining best-evidence follow-up as *either* PCP follow-up or no follow-up) in a sensitivity analysis and found the conclusions to be comparable to those reached when best-evidence follow-up was defined exclusively as no follow-up.

Optimizing resource utilization and decreasing health care costs in the context of a health care system with finite resources has become a focus in Ontario and other universal health care systems. An orthopaedic follow-up visit can be billed to OHIP at a cost of up to 151$, while a follow-up with a family doctor costs 20-33$[77] (*orthopaedic follow-up calculated as A065 + F027; family doctor follow-up quoted for minor or intermediate assessment)*. A change in practice from routine orthopaedic referral for low-risk paediatric distal radius fractures to no follow-up would obviously produce a 100% costs saving, but a less drastic change to an as needed primary care follow-up instead of orthopaedic follow-up could also result in an impressive 80%+ cost savings. The cost savings would likely be even greater when other unnecessary costs that often arise in conjunction with follow-up visits, such as follow-up x-rays to assess healing and cast changes/removal, are considered.

There are a number of possible reasons why a high rate of orthopaedic follow-up persists for these injuries. There is a general perception by emergency physicians, patients, and parents alike that fractures or “broken bones” necessitate specialized follow-up. Accordingly, some emergency physicians or departments may reflexively refer all fractures, regardless of severity, to fracture clinic. Concerns regarding misdiagnosis and medicolegal implications may also lead emergency department physicians to favour orthopaedic referral. Enhanced education in emergency medicine training programs and CME regarding common fracture management may help address these concerns and knowledge gaps. Challenges in communication, managing parental expectations, and parental discomfort with a lack of follow-up may also potentiate orthopaedic referral. Parental and patient expectations can be addressed with adequate patient education prior to discharge from the ED, but this can be time consuming and may keep the emergency physician from treating and billing for other sick patients that need medical attention.

Some orthopaedic surgeons may have arrangements with their respective hospitals to have every fracture seen in the ED, regardless of severity, follow-up in fracture clinic. This type of arrangement may be beneficial for the orthopedist because the ratio of compensation to time spent on follow-up visits for minor fractures in a fee-for-service model is favourable. Finally, availability of splinting materials for removable immobilization may also dictate follow-up; any child treated with a circumferential cast must return to fracture clinic to have it removed because neither parents nor primary care physicians will have the necessary tools for removal.

The least marginalized patients have the highest proportion of low-risk distal radius fractures, and this proportion has increased over the last 12 years

Research shows that individuals of lower socioeconomic status are more likely to have medical comorbidities, disability, injury, and higher healthcare utilization and associated costs. This has been attributed to lower socioeconomic status being associated with more hazardous occupations, neighbourhoods, and lower levels of education[80]. Therefore, this finding presents an interesting reversal of the expected social gradient.

Higher injury rates and more sport related injuries have previously been shown in children from non-poor families. Low-risk distal radius fractures are most often sustained while engaging in sporting activity or free play[81]. Due to higher associated costs, individuals of higher socioeconomic status are more likely to engage in organized or competitive sporting activities which are more likely to be of higher intensity, higher energy, practiced multiple times per week, and involve contact with other participants. It is therefore likely that organized and competitive sporting activities may carry a higher risk of sustaining a low-risk distal radius fracture than free play or informal sport participation, which could explain the observed association.

The application of best-evidence in paediatric low-risk distal radius fracture care has changed over time

The overall proportion of low-risk paediatric distal radius fractures receiving no follow-up has remained relatively stable over the time period of this study. Likewise, the overall proportion of orthopaedic follow-ups for these fractures has also remained largely stable, save a five percent increase over the last 2 years of the study. These findings were the opposite of what we hypothesized. It is often quoted that it takes 17 years for evidence to be put into practice; this study spanned a twelve year period with no appreciable trend to suggest that a shift in province-wide care patterns is on the horizon. Clearly, some significant barriers to parsimonious care for this fracture type remain in Ontario.

Without examining the trends over time, one could incorrectly conclude that the accumulation of evidence since the early 2000's has failed to have any beneficial effect whatsoever on the way these fractures are treated. It is true that the overall resource utilization associated with the care of low-risk distal radius fractures has remained relatively stable in Ontario during the 12 year study period, but stratification and examination of the data by year revealed important shifts in practice at each of these levels as discussed in the previous paragraphs. We must examine in depth the knowledge translation activities taking place in settings that are improving over time and use them to model further endeavours in settings that have been less successful in the uptake of best-evidence practices for this injury.

5.2 Limitations

This study has a number of limitations, many of which relate to the use of administrative data.

Administrative data is collected and submitted to ICES largely for the purpose of health systems oversight and physician compensation. Data elements used in this study rely on accurate submission of physician billing codes and diagnostic codes for determination of follow-up care and diagnostic precision and discrimination. Coding biases associated with specific reimbursement strategies, absent submissions from AFP physicians, documentation errors, and non medical personnel determining and submitting codes all have the potential to affect the accuracy of the information on which this study relies. Given that administrative data is not collected for the primary purpose of clinical research, we were unable to obtain and include potentially relevant risk factors, like physician funding models, and other aspects of best evidence care, such as method of immobilization and x-ray examinations, in our analysis. We were therefore limited to analyzing follow-up care practices and our attempt to provide a picture of parsimonious care in Ontario is incomplete. Due to limitations with data linkage, we were also unable to capture initial presentations of low-risk distal radius fracture in urgent care, walk-in, or family/general practice clinics, although we believe this represents a small minority of initial visits and that many of these are immediately sent to the ED anyway. Furthermore, the algorithm used to isolate our cohort of interest has never been validated in terms of its ability to correctly identify patients with low-risk distal radius fractures.

While our study results are likely to be generalizable to other Canadian provinces and territories, it is unclear whether they would apply in other countries and healthcare systems owing to differing systemic pressures, physician distribution and training, compensation models, quality of medical education, and dissemination of best-evidence. The UK in particular would make a worthy comparator, having heavily contributed to the current best-evidence and functioning within a similar universal healthcare system as Ontario.

Finally, we experienced questionable convergence in one adjusted model in the sensitivity analysis. Despite this, we maintain confidence in the results from this particular model given that the confidence intervals were narrow and the risk ratios were consistent with the remainder of analyses.

5.3 Future Directions and Implications

This study highlights a large gap between what best-evidence recommends, and what is practically done in low-risk paediatric distal radius fracture care. We have demonstrated that there are multiple contributors underlying this gap and therefore a multimodal approach aimed at improving the dissemination and application of best-evidence is necessary. Strategies that address hospital-level needs and physician education and concerns are key and we may be able to learn from knowledge translation endeavours already underway in the most successful hospital and physician types identified in this study.

At the hospital level, all EDs should have access and funding for materials needed to provide patients with a form of removable immobilization. The potential small increase in cost is justified by the large predicted decrease in cost associated with foregoing orthopaedic follow-up and cast removal. The widespread implementation of clinical care guidelines and pathways, with enthusiastic support from champions of evidence based care and subject matter experts at each institution can also help guide decision making within hospital EDs. Fostering a cooperative atmosphere between specialties is imperative for timely and accurate diagnosis and to provide ED physicians with the necessary support to confidently apply clinical care guidelines.

For physicians, availability of information in widely read journals and interdisciplinary conferences would yield a larger audience. Interactive CME modules covering musculoskeletal topics are currently being explored as an innovative and formative option at our institution. Access to training material should also be provided to residents and medical trainees who may become primary care practitioners working in an emergency department, but having never had the benefit of training in a paediatric center. A “virtual fracture clinic” is another potential approach; fracture diagnosis is confirmed virtually by an orthopaedic surgeon thereby providing decision support for physicians working in the ED who might be concerned about misdiagnosis and medicolegal implications. The development and publication of national guidelines by influential groups such as the American Academy of Orthopaedic Surgeons, or Choosing Wisely Canada could ultimately be of most benefit. Physician concerns regarding lost income resulting from removing the need for follow-up or the added workload from additional radiograph interpretations could be alleviated with the institution of universal fees and salaried work.

For patients, additional information and support would be beneficial in the form of patient pamphlets, printed instructions, and phone applications offering the possibility of virtual follow-up or communication with a physician.

Future research should aim to address the limitations encountered in the present study. A multicenter prospective cohort study could provide a more comprehensive picture of best-evidence care while conferring increased diagnostic accuracy, allowing definite discrimination between subtypes of low-risk paediatric distal radius fractures, and including more detailed hospital, physician, and patient factors than were available through ICES. Where trends over time are concerned, a multicenter retrospective chart review would be informative. Additionally, costing analyses could help inform the MOHLTC of potential cost savings associated with widespread application of best-evidence for this injury and might inform a revision of funding models and/or the Schedule of Benefits to better reflect and support the provision of best-evidence care.

5.4 Conclusion

Despite a preponderance of level one evidence suggesting simplified treatment using a removable splint with primary care or no follow-up, the majority of low-risk distal radius fracture follow-up care for Ontario's children continues to be provided by orthopaedic surgeons in hospital fracture clinics. At best, this over-treatment is inefficient and expensive and at worst, it exposes children to the risk of iatrogenic injury including burns and scars from cast removal.

The hospital type is the most important determinant of treatment received, with paediatric, small, and community hospitals being more likely to provide best-evidence care than teaching hospitals. The specialty of the physician was also a significant determinant, with the highest likelihood of appropriate care being provided by PEM physicians -- the specialist group that developed the bulk of the evidence.

Paediatric and academic hospitals were observed to improve over time in terms of their provision of best-evidence care while small and community hospitals deteriorated. Likewise, subpecialist physicians working in the ED improved over time, while their primary care colleagues stagnated or deteriorated. Much to our disappointment however, these trends negated each other and therefore we did not observe an overall increase in adoption of evidence or improved resource utilization over time for the whole of Ontario. Taken together, these results call strongly for a system based approach to explicitly apply clinical evidence in clinical practice in the care of common children's fractures.

References

1. Escott B. Childhood Fracture Begets Childhood Fracture: A Population-based Study of Longitudinal Fracture Patterns in Ontario Children [master's thesis]. [Toronto(ON)]: University of Toronto; 2012. 71p.

2. Jacobsen FS. Periosteum: its relation to pediatric fractures. J Pediatr Orthop B. 1997 Apr;6(2): 84-90. Review.

3. Ogden JA, Beall JK, Conlogue GJ, Light TR. Radiology of postnatal skeletal development. IV. Distal radius and ulna. Skeletal Radiol. 1981;6(4):255-66.

4. Wilkins KE. Principles of fracture remodeling in children. Injury. 2005 Feb;36 Suppl 1:A3-11. Review.

5. Bae DS, Howard AW. Distal radius fractures: what is the evidence? J Pediatr Orthop. 2012 Sep; 32 Suppl 2:S128-30.

6. Bennett DL, Mencio GA, Hernanz-Schulman M, Nealy BJ, Damon B, Kan JH. Buckle fractures in children: Is urgent treatment necessary? J Fam Pract. 2009 Oct;58(10):E1-6. Erratum in: J Fam Pract. 2010 Jan;59(1):13.

7. Farbman KS, Vinci RJ, Cranley WR, Creevy WR, Bauchner H. The role of serial radiographs in the management of pediatric torus fractures. Arch Pediatr Adolesc Med. 1999 Sep;153(9): 923-5.

8. van Bosse HJ, Patel RJ, Thacker M, Sala DA. Minimalistic approach to treating wrist torus fractures. J Pediatr Orthop. 2005 Jul-Aug;25(4):495-500.

9. Al-Ansari K, Howard A, Seeto B, Yoo S, Zaki S, Boutis K. Minimally angulated pediatric wrist fractures: is immobilization without manipulation enough? CJEM. 2007 Jan;9(1):9-15.

10. Randsborg PH, Sivertsen EA. Distal radius fractures in children: substantial difference in stability between buckle and greenstick fractures. Acta Orthop. 2009 Oct;80(5):585-9.

11. Schranz PJ, Fagg PS. Undisplaced fractures of the distal third of the radius in children: an innocent fracture? Injury. 1992;23(3):165-7.

12. Unpublished data. Hospital for Sick Children, Toronto, ON.

13. Light TR, Ogden DA, Ogden JA. The anatomy of metaphyseal torus fractures. Clin Orthop Relat Res. 1984 Sep;(188):103-11.

14. Nellans KW, Kowalski E, Chung KC. The epidemiology of distal radius fractures. Hand Clin. 2012 May;28(2):113-25. doi: 10.1016/j.hcl.2012.02.001. Epub 2012 Apr 14. Review.

15. Davidson JS, Brown DJ, Barnes SN, Bruce CE. Simple treatment for torus fractures of the distal radius. J Bone Joint Surg Br. 2001 Nov;83(8):1173-5.

16. Do TT, Strub WM, Foad SL, Mehlman CT, Crawford AH. Reduction versus remodeling in pediatric distal forearm fractures: a preliminary cost analysis. J Pediatr Orthop B. 2003 Mar;12(2): 109-15.

17. Monroe KC, Sund SA, Nemeth BA, Noonan KJ, Halanski MA. Cast-saw injuries: assessing blade-to-skin contact during cast removal. Does experience or education matter? Phys Sportsmed. 2014 Feb;42(1):36-44.

18. Ansari MZ, Swarup S, Ghani R, Tovey P. Oscillating saw injuries during removal of plaster. Eur J Emerg Med. 1998 Mar;5(1):37-9

19. Katz K, Fogelman R, Attias J, Baron E, Soudry M. Anxiety reaction in children during removal of their plaster cast with a saw. J Bone Joint Surg Br. 2001 Apr;83(3):388-90.

20. Shore BJ, Hutchinson S, Harris M, Bae DS, Kalish LA, Maxwell W 3rd, Waters P. Epidemiology and prevention of cast saw injuries: results of a quality improvement program at a single institution. J Bone Joint Surg Am. 2014 Feb 19;96(4):e31.

21. Halanski M, Noonan KJ. Cast and splint immobilization: complications. J Am Acad Orthop Surg. 2008 Jan;16(1):30-40. Review.

22. Bridges, A. (2017, July 19) 'Inadequate and insulting': Sask. family unhappy doctor not disciplined after boy burned during cast removal. *CBC News.* Retrieved from http://www.cbc.ca/news/canada/saskatoon/burns-cast-removal-saskatoon-saw-1.4211672

23. Graham ID, Logan J, Harrison MB, Straus SE, Tetroe J, Caswell W, Robinson N. Lost in knowledge translation: time for a map? J Contin Educ Health Prof. 2006 Winter;26(1):13-24.

24. The Knowledge-To-Action Cycle. Retrieved 21 April 2016 from http://ktclearinghouse.ca/knowledgebase/knowledgetoaction.

25. Rang, M. (1974). Children's fractures. Philadelphia: Lippincott Williams & Wilkins.

26. Symons S, Rowsell M, Bhowal B, Dias JJ. Hospital versus home management of children with buckle fractures of the distal radius. A prospective, randomised trial. J Bone Joint Surg Br. 2001 May;83(4):556-60.

27. West S, Andrews J, Bebbington A, Ennis O, Alderman P. Buckle fractures of the distal radius are safely treated in a soft bandage: a randomized prospective trial of bandage versus plaster cast. J Pediatr Orthop. 2005 May-Jun;25(3):322-5.

28. Plint AC, Perry JJ, Correll R, Gaboury I, Lawton L. A randomized, controlled trial of removable splinting versus casting for wrist buckle fractures in children. Pediatrics. 2006 Mar; 117(3):691-7.

29. Williams KG, Smith G, Luhmann SJ, Mao J, Gunn JD 3rd, Luhmann JD. A randomized controlled trial of cast versus splint for distal radial buckle fracture: an evaluation of satisfaction, convenience, and preference. Pediatr Emerg Care. 2013 May;29(5):555-9.

30. Kropman RH, Bemelman M, Segers MJ, Hammacher ER. Treatment of impacted greenstick forearm fractures in children using bandage or cast therapy: a prospective randomized trial. J Trauma. 2010 Feb;68(2):425-8.

31. Khan KS, Grufferty A, Gallagher O, Moore DP, Fogarty E, Dowling F. A randomized trial of 'soft cast' for distal radius buckle fractures in children. Acta Orthop Belg. 2007 Oct;73(5):594-7.

32. Witney-Lagen C, Smith C, Walsh G. Soft cast versus rigid cast for treatment of distal radius buckle fractures in children. Injury. 2013 Apr;44(4):508-13.

33. Vernooij CM, Vreeburg ME, Segers MJ, Hammacher ER. Treatment of torus fractures in the forearm in children using bandage therapy. J Trauma Acute Care Surg. 2012 Apr;72(4):1093-7.

34. Mbubaegbu CE, Munshi NI, Currie L. Audit of patient satisfaction with selfremovable soft cast for greenstick fractures of the distal radius. J. Clin. Effect. 1997 Mar; 2(1):14-15.

35. Solan MC, Rees R, Daly K. Current management of torus fractures of the distal radius. Injury. 2002 Jul;33(6):503-5.

36. Bochang C, Katz K, Weigl D, Jie Y, Zhigang W, Bar-On E. Are frequent radiographs necessary in the management of closed forearm fractures in children? J Child Orthop. 2008 Jun; 2(3):217-20. doi: 10.1007/s11832-008-0101-5. Epub 2008 Apr 26.

37. Plint AC, Perry JJ, Tsang JL. Pediatric wrist buckle fractures. Should we just splint and go? CJEM. 2004 Nov;6(6):397-401.

38. Koelink E, Schuh S, Howard A, Stimec J, Barra L, Boutis K. Primary Care Physician Follow-up of Distal Radius Buckle Fractures. Pediatrics. 2016 Jan;137(1).

39. Boutis K, Willan A, Babyn P, Goeree R, Howard A. Cast versus splint in children with minimally angulated fractures of the distal radius: a randomized controlled trial. CMAJ. 2010 Oct 5;182(14):1507-12.

40. Noonan KJ, Price CT. Forearm and distal radius fractures in children. J Am Acad Orth Surg. 1998 6:146-156

41. Abraham A, Handoll HH, Khan T. Interventions for treating wrist fractures in children. Cochrane Database Syst Rev. 2008 Apr 16;(2):CD004576.

42. Jiang N, Cao ZH, Ma YF, Lin Z, Yu B. Management of Pediatric Forearm Torus Fractures: A Systematic Review and Meta-Analysis. Pediatr Emerg Care. 2016 Nov;32(11):773-778. Review.

43. Hill CE, Masters JP, Perry DC. A systematic review of alternative splinting versus complete plaster casts for the management of childhood buckle fractures of the wrist. J Pediatr Orthop B. 2016 Mar;25(2):183-90.

44. Mardani-Kivi M, Zohrevandi B, Saheb-Ekhtiari K, Hashemi-Motlagh K. How Much are Emergency Medicine Specialists' Decisions Reliable in the Diagnosis and Treatment of Pediatric Fractures? Arch Bone Jt Surg. 2016 Jan;4(1):60-4.

45. Firmin F, Crouch R. Splinting versus casting of "torus" fractures to the distal radius in the paediatric patient presenting at the emergency department (ED): a literature review. Int Emerg Nurs. 2009 Jul;17(3):173-8.

46. Howes MC, Cutting P, Thomas M. Best Evidence Topic report. Bet2. Splinting of buckle fractures of the distal radius in children. Emerg Med J. 2008 Apr;25(4):222-3.

47. May G, Grayson A. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. Bet 3: do buckle fractures of the paediatric wrist require follow up? Emerg Med J. 2009 Nov;26(11):819-22.

48. Raymond T. Morrissy, Stuart L. Weinstein. (2006). Lovell and Winter's pediatric orthopaedics. Philadelphia :Lippincott Williams & Wilkins.

49. Choosing Wisely UK. [2016]. Recommendations, Royal College of Emergency Medicine. Retrieved from http://www.choosingwisely.co.uk/i-am-a-clinician/recommendations/#1476654326462-140275b8-1d63

50. Boutis K, Howard A, Constantine E, Cuomo A, Narayanan U. Evidence into practice: Emergency physician management of common pediatric fractures. Pediatr Emerg Care. 2014 Jul; 30(7):462-8.

51. Koelink E, Boutis K. Paediatrician office follow-up of common minor fractures. Paediatr Child Health. 2014 Oct;19(8):407-12.

52. Boutis K, Howard A, Constantine E, Cuomo A, Somji Z, Narayanan UG. Evidence into practice: Pediatric orthopaedic surgeon use of removable splints for common pediatric fractures. J Pediatr Orthop. 2015 Jan;35(1):18-23.

53. Li, P. A population-based study on the association of standardized protocols in the emergency department for childhood asthma with outcomes in Ontario, CA [master's thesis]. [Toronto(ON)]: University of Toronto; 2010. 77p.

54. Kinlin LM, Bahm A, Guttmann A, Freedman SB. A survey of emergency department resources and strategies employed in the treatment of pediatric gastroenteritis. Acad Emerg Med. 2013 Apr;20(4):361-6.

55. Plint A, Clifford T, Perry J, Bulloch B, Pusic M, Lalani A, Ali S, Nguyen BH, Joubert G, Millar K. Wrist buckle fractures: a survey of current practice patterns and attitudes toward immobilization. CJEM. 2003 Mar;5(2):95-100.

56. Morris ZS, Wooding S, Grant J. The answer is 17 years, what is the question: understanding time lags in translational research. J R Soc Med. 2011 Dec;104(12):510-20.

57. Green LW, Ottoson JM, García C, Hiatt RA, Roditis ML. Diffusion theory and knowledge dissemination, utilization and integration. Front Public Health Serv Syst Res. 2014;3(1):3.

58. Westfall JM, Mold J, Fagnan L. Practice-based research-"Blue Highways" on the NIH roadmap. JAMA. 2007 Jan 24;297(4):403-6.

59. Oakley EA, Ooi KS, Barnett PL. A randomized controlled trial of 2 methods of immobilizing torus fractures of the distal forearm. Pediatr Emerg Care. 2008 Feb;24(2):65-70.

60. Ryan LM, Teach SJ, Searcy K, Singer SA, Wood R, Wright JL, Chamberlain JM. Epidemiology of pediatric forearm fractures in Washington, DC. J Trauma. 2010 Oct;69(4 Suppl):S200-5.

61. Crawford SN, Lee LS, Izuka BH. Closed treatment of overriding distal radial fractures without reduction in children. J Bone Joint Surg Am. 2012 Feb 1;94(3):246-52.

62. Godfrey J, Little KJ, Roger C, Carr P, Samora J. Increasing Brace Treatment for Distal Radius Buckle Fractures: Using Quality Improvement Methodology to Implement Evidence-Based Medicine. 2017 Sept:49(9):S25.

63. Swennen MH, van der Heijden GJ, Boeije HR, van Rheenen N, Verheul FJ, van der Graaf Y, Kalkman CJ. Doctors' perceptions and use of best-evidence medicine: a systematic review and thematic synthesis of qualitative studies. Acad Med. 2013 Sep;88(9):1384-96.

64. Swennen MH, van der Heijden GJ, Blijham GH, Kalkman CJ. Career stage and work setting create different barriers for best-evidence medicine. J Eval Clin Pract. 2011 Aug;17(4):775-85.

65. Cummings GG, Estabrooks CA, Midodzi WK, Wallin L, Hayduk L. Influence of organizational characteristics and context on research utilization. Nurs Res. 2007 Jul-Aug;56(4 Suppl):S24-39.

66. Stetler CB, Ritchie JA, Rycroft-Malone J, Schultz AA, Charns MP. Institutionalizing best-evidence practice: an organizational case study using a model of strategic change. Implement Sci. 2009 Nov 30;4:78.

67. Marchionni C, Ritchie J. Organizational factors that support the implementation of a nursing best practice guideline. J Nurs Manag. 2008 Apr;16(3):266-74.

68. Hisham R, Liew SM, Ng CJ, Mohd Nor K, Osman IF, Ho GJ, Hamzah N, Glasziou P. Rural Doctors' Views on and Experiences with Best-evidence Medicine: The FrEEDoM Qualitative Study. PLoS One. 2016 Mar 31;11(3):e0152649.

69. Hisham R, Ng CJ, Liew SM, Hamzah N, Ho GJ. Why is there variation in the practice of best-evidence medicine in primary care? A qualitative study. BMJ Open. 2016 Mar 9;6(3):e010565.

70. Wallin L, Ewald U, Wikblad K, Scott-Findlay S, Arnetz BB. Understanding work contextual factors: a short-cut to best-evidence practice? Worldviews Evid Based Nurs. 2006;3(4):153-64.

71. Bernthal NM, Mitchell S, Bales JG, Benhaim P, Silva M. Variation in practice habits in the treatment of pediatric distal radius fractures. J Pediatr Orthop B. 2015 Sep;24(5):400-7.

72. The health analyst's toolkit. Toronto, Ont: Ontario Ministry of Health and Long-Term Care, Health System Information Management and Investment Division, Health Analytics Branch, 2012.

73. Canadian Institute for Health Information, CIHI Data Quality Study of Ontario Emergency Department Visits for Fiscal Year 2004–2005—Executive Summary (Ottawa: CIHI, 2008).

74. ICES. Ontario Health Insurance Plan (Overview). March 2017. Retrieved from: https://ssl.ices.on.ca/dataprog/Data%20Holdings/Health%20Services ohip/,DanaInfo=.aioulhjFpkn2K00Nrq,SSL+index.htm

75. Chan B. Supply of physicians' services in Ontario. Hosp Q. 1999-2000 Winter;3(2):17.

76. ICES. Matching NACRS ED visits with ICES-derived OHIP ER claims. November 2014. Retrieved from: https://ssl.ices.on.ca/dataprog/Data%20Holdings/Health%20Services/nacrs-sds/,DanaInfo=.aioulhjFpkn2K00Nrq,SSL+matching_nacrsedvisits_with_ohip.htm

77. Ontario Ministry of Health and Long-Term Care. Schedule of benefits for physician services under the Health Insurance Act (October 30, 2015 (effective December 21, 2015)). Toronto: The Ministry; 2015. Retrieved from: http://www.health.gov.on.ca/english/providers/program/ohip/sob/physserv/physserv_mn.html

78. Matheson FI. Ontario Agency for Health Protection and Promotion (Public Health Ontario). 2011 Ontario marginalization index: user guide. Toronto, ON: St. Michael’s Hospital; 2017. Joint publication with Public Health Ontario.

79. Hospital report 2007 : emergency department care. Ottawa, Ont: Canadian Institute for Health Information. 2007.

80. Berkman LF, Kawachi I. Social epidemiology. New York: Oxford Press, 2000.

81. Ni H, Barnes P, Hardy AM. Recreational injury and its relation to socioeconomic status among school aged children in the US. Inj Prev. 2002 Mar;8(1):60-5.

Appendix A

List of ICD-10CA codes used for baseline low-risk distal radius fracture cohort identification in NACRS:

ICD-10A Code	**Description**
S52500	Colle’s fracture, closed
S52580	Other fracture of lower end of radius, closed
S52590	Unspecified fracture lower end of radius, closed
S52600	Fracture of lower end of ulna and radius, closed

Appendix B

Tables 2B-5B: List of codes used to identify exclusion criteria

Table 1B: CCI codes used to exclude fractures requiring manipulation, reduction, or operation in NACRS

CCI Code	Description
1UB73JA	Reduction, wrist joint using closed (external) approach
1UB73LA	Reduction, wrist joint using open approach
1TV73JA	Reduction, radius and ulna using closed (external) approach
1TV73JA	Reduction, radius and ulna using open approach
1UB03HAKC	Immobilization, wrist joint using percutaneous external fixator
1TV03HAKC	Immobilization, radius and ulna using percutaneous external fixator

Table 2B: CIHI-SDS/CIHI-DAD intervention codes used to exclude fractures requiring operation

CIHI-SDS/CIHI-DAD Code	**Description**
1TV74HAKD	Fixation, radius and ulna
1TV74HALQ	Fixation, radius and ulna
1TV74HANV	Fixation, radius and ulna
1TV74HANW	Fixation, radius and ulna
1TV74LA	Fixation, radius and ulna
1TV74LAKD	Fixation, radius and ulna
1TV74LAKDA	Fixation, radius and ulna
1TV74LAKDK	Fixation, radius and ulna
1TV74LAKDN	Fixation, radius and ulna
1TV74LAKDQ	Fixation, radius and ulna
1TV74LALQ	Fixation, radius and ulna
1TV74LALQA	Fixation, radius and ulna
1TV74LALQK	Fixation, radius and ulna
1TV74LALQN	Fixation, radius and ulna
1TV74LALQQ	Fixation, radius and ulna
1TV74LANV	Fixation, radius and ulna
1TV74LANVQ	Fixation, radius and ulna
1TV74LANVN	Fixation, radius and ulna
1TV74LANVQ	Fixation, radius and ulna
1TV74LANW	Fixation, radius and ulna
1TV74LANWA	Fixation, radius and ulna
1TV74LANWK	Fixation, radius and ulna
1TV74LANWN	Fixation, radius and ulna
1TV74LANWQ	Fixation, radius and ulna
1TV03HAKC	Fixation, radius and ulna
1UB74DAKD	Fixation, wrist joint
1UB74DAKDA	Fixation, wrist joint

CIHI-SDS/CIHI-DAD Code	**Description**
1UB74DAKDK	Fixation, wrist joint
1UB74DAKDN	Fixation, wrist joint
1UB74DAKDQ	Fixation, wrist joint
1UB74DADANV	Fixation, wrist joint
1UB74DANVA	Fixation, wrist joint
1UB74DANVK	Fixation, wrist joint
1UB74DANVN	Fixation, wrist joint
1UB74DANVQ	Fixation, wrist joint
1UB74DANW	Fixation, wrist joint
1UB74DANWA	Fixation, wrist joint
1UB74DANWK	Fixation, wrist joint
1UB74DANWN	Fixation, wrist joint
1UB74DANWQ	Fixation, wrist joint
1UB74HAKD	Fixation, wrist joint
1UB74HAKDN	Fixation, wrist joint
1UB74HALQ	Fixation, wrist joint
1UB74HANV	Fixation, wrist joint
1UB74HANW	Fixation, wrist joint
1UB74LAKD	Fixation, wrist joint
1UB74LAKDA	Fixation, wrist joint
1UB74LAKDK	Fixation, wrist joint
1UB74LAKDN	Fixation, wrist joint
1UB74LAKDQ	Fixation, wrist joint
1UB74LALQ	Fixation, wrist joint
1UB74LALQA	Fixation, wrist joint
1UB74LALQK	Fixation, wrist joint
1UB74LALQN	Fixation, wrist joint
1UB74LALQQ	Fixation, wrist joint
1UB74LANV	Fixation, wrist joint

CIHI-SDS/CIHI-DAD Code	Description
1UB74LANVA	Fixation, wrist joint
1UB74LANVK	Fixation, wrist joint
1UB74LANVN	Fixation, wrist joint
1UB74LANVQ	Fixation, wrist joint
1UB74LANW	Fixation, wrist joint
1UB74LANWA	Fixation, wrist joint
1UB74LANWK	Fixation, wrist joint
1UB74LANWN	Fixation, wrist joint
1UB74LANWQ	Fixation, wrist joint
1UB03HAKC	Fixation, wrist joint

Table 3B: OHIP fee codes used to identify individuals with previous fractures

OHIP FEECODE	**Description**
E532	Fracture tibial plateau
F004	Fracture phalanx
F005	Fracture phalanx
F006	Fracture IP joint
F007	Fracture phalanx
F008	Fracture metacarpal
F009	Fracture metacarpal
F010	Fracture IP joint
F011	Fracture metacarpal
F012	Fracture wrist
F013	Fracture wrist
F014	Fracture monteggia
F015	Fracture Bennett's
F016	Fracture carpus
F017	Fracture carpus
F018	Fracture scaphoid
F019	Fracture scaphoid
F020	Fracture scaphoid
F021	Fracture osteochondral
F022	Fracture monteggia
F023	Fracture monteggia
F024	Fracture forearm
F025	Fracture forearm
F026	Fracture forearm
F027	Fracture wrist
F028	Fracture wrist
F029	Fracture elbow

OHIP FEECODE	Description
F030	Fracture wrist
F031	Fracture wrist
F032	Fracture wrist
F033	Fracture wrist
F034	Fracture olecranon
F035	Fracture olecranon
F036	Fracture olecranon
F037	Fracture distal humerus
F038	Fracture distal humerus
F039	Fracture distal humerus
F040	Fracture distal humerus
F041	Fracture distal humerus
F042	Fracture shoulder, arm, chest
F043	Fracture shoulder, arm, chest
F044	Fracture shoulder, arm, chest
F045	Fracture distal humerus
F046	Fracture wrist
F047	Fracture proximal humerus
F048	Fracture proximal humerus
F049	Fracture proximal humerus
F050	Fracture proximal humerus
F051	Fracture proximal humerus
F052	Fracture proximal humerus
F053	Fracture proximal humerus
F054	Fracture proximal humerus
F055	Fracture proximal humerus
F056	Fracture phalanx
F057	Fracture IP joint
F058	Fractur phalanx

OHIP FEECODE	Description
F059	Fracture IP joint
F060	Fracture phalanx
F061	Fracture metatarsal
F062	Fracture metatarsal
F063	Fracture metatarsal
F064	Fracture metatarsal
F065	Fracture metatarsal
F066	Fracture tarsal
F067	Fracture tarsal
F068	Fracture tarsal
F070	Fracture os calcis
F071	Fracture os calcis
F072	Fracture os calcis
F074	Fracture ankle
F075	Fracture ankle
F076	Fracture ankle
F077	Fracture ankle
F078	Fracture tibia
F079	Fracture tibia
F080	Fracture tibia
F081	Fracture tibia
F082	Fracture fibula
F083	Fracture fibula
F084	Fracture fibula
F085	Fracture patella
F087	Fracture patella
F094	Fracture femur
F095	Fracture femur
F096	Fracture femur

OHIP FEECODE	**Description**
F097	Fracture femur
F098	Fracture hip
F099	Fracture hip
F100	Fracture hip
F101	Fracture hip
F102	Fracture carpus
F103	Fracture spine
F104	Fracture tibial plafond
F105	Fracture spine
F107	Fracture spine
F108	Fracture tibial plafond
F110	Fracture clavicle
F115	Fracture coccyx
F118	Fracture clavicle
F119	Fracture scapula
F120	Fracture scapula
F121	Fracture scapula
F122	Fracture sternum
F123	Fracture sternum
F124	Fracture sternum
F125	Fracture sternum
F130	Fracture ribs
F131	Fracture ribs
F134	Fracture pelvis
F135	Fracture pelvis
F136	Fracture nasal bones
F137	Fracture nasal bones
F138	Fracture mandible
F139	Fracture mandible

OHIP FEECODE	Description
F140	Fracture mandible
F142	Fracture maxilla
F143	Fracture maxilla
F144	Fracture maxilla
F146	Fracture mandible
F150	Fracture maxilla
F200	Fracture spine
F201	Fracture spine

Table 4B: CIHI-SDS/CIHI-DAD diagnosis codes used to identify co-morbid conditions

CIHI-SDS/CIHI-DAD ICD-10CA code ***(ICD-9 code in italics)***	**Description**
G80x *343.x*	Cerebral palsy
F06x *317, 318.x, 319*	Cognitive impairment/organic brain disorders
E84x *277.x*	Cystic fibrosis
E10x, E11x, E13x, E14x *250.x*	Diabetes
N250, N18x *255.x, 585, 588.x*	Kidney disease
E58, E835, K50x, K51x *275.4x, 269.3, 555.x, 556.x, 579.0*	Malnutrition and malabsorption syndromes
E22x, E23x, E24x, E26x, E27x, E55x *253.x, 259.3, 268.x, 275.3*	Metabolic disorders
Q780 *756.5x*	Osteogenesis imperfecta
M80xx, M81x, M82x *733.0x, 733.1x,*	Osteoporosis
E20x, E21x, D56x *252.0x, 252.1, 282.4x*	Thyroid disorders

x = denotes the inclusion of all subsequent codes under a main ICD code

Appendix C

List of Council of Academic Hospitals of Ontario (CAHO) member hospitals:

Baycrest Health Sciences

Bruyère Continuing Care

Centre for Addictions and Mental Health

Children's Hospital of Eastern Ontario

Hamilton Health Sciences

Health Sciences North

Holland Bloorview Kids Rehabilitation Hospital

The Hospital for Sick Children

Hotel Dieu Hospital

Kingston General Hospital

London Health Sciences Centre

Hôpital Monfort

Sinai Health System

North York General Hospital

The Ottawa Hospital

Providence Care

The Royal Ottawa Health Group

St-Joseph's Health Care, London

St-Joseph's Healthcare, Hamilton

St-Micheal's Hospital

SunnyBrook Health Sciences Centre

Thunder Bay Regional Health Sciences Centre

University Health Network

Women's College Hospital

Appendix D

List of OHIP codes used to determines the primary outcome of interest, best-evidence treatment

** denotes codes excluded to increase specificity in sensitivity analysis

Table 1D: OHIP diagnostic codes for distal radius fracture
Best-evidence care: The individual does not appear in the OHIP FEECODEs with any of the 3 DXCODEs for 6 weeks (42 days) after initial diagnosis.

OHIP diagnosis code (DXCODE)	Description
813	Radius and/or ulna
842 **	Wrist, hand, fingers
829 **	Other fractures

Table 2D: Orthopaedic follow-up
First follow-up after initial diagnosis is one of the following:

OHIP FEECODE	Description	Conditions
A063	Specific assessment	
A064	Partial assessment	
A065	Consultation	
A066	Repeat consultation	
A935 **	Special surgical consultation	if specialty = orthopaedic surgery
F024	Radius and ulna shaft, no reduction, rigid immobilization	if specialty = orthopaedic surgery
F027	Distal radius, no reduction, rigid immobilization	if specialty = orthopaedic surgery
F031	Radius or ulna, no reduction, rigid immobilization	if specialty = orthopaedic surgery
F028 **	Distal radius, no reduction, rigid immobilization closed reduction	if specialty = orthopaedic surgery
F032 **	Radius or ulna, no reduction, rigid immobilization, closed reduction	if specialty = orthopaedic surgery
F046 **	Distal radius, no reduction, rigid immobilization closed reduction	if specialty = orthopaedic surgery

Table 3D: Primary care follow-up
FEECODE must be accompanied by one of the 3 diagnostic codes in table 1D

OHIP FEECODE	Description	Conditions
A001	Minor assessment	
A003	General assessment	
A004	General reassessment	
A005	Consultation, family practice	
A006	Repeat consultation	
A007	Intermediate assessment	
A008	Mini assessment	
A260	Special paediatric consultation	
A261	Level 1 - paediatric assessment	
A262	Level 2 - paediatric assessment	
A263	Medical specific assessment	
A264	Medical specific re-assessment	
A265	Consultation, paediatric	
A266	Repeat consultation	
A565	Limited consultation	
A888	Emergency department equivalent - partial assessment	
A901	House call assessment	
A903 **	Pre-operative general assessment	
A905	Limited consultation	
A917	Sport medicine focused practice assessment	
K013	Individual counselling	
K017	Periodic health visit, child	
K130 **	Periodic health visit, adolescent	
K267	Periodic health visit, age 2-11, paediatric	
K269	Periodic health visit, age 11-17, paediatric	
Q601	Minor assessment, nurse practitioner	
Q603	Intermediate assessment, nurse practitioner	

OHIP FEECODE	Description	Conditions
F024	Radius and ulna shaft, no reduction, rigid immobilization	if specialty = orthopaedic surgery
F027	Distal radius, no reduction, rigid immobilization	if specialty ≠ orthopaedic surgery
F031	Radius or ulna, no reduction, rigid immobilization	if specialty ≠ orthopaedic surgery
F028 **	Distal radius, no reduction, rigid immobilization closed reduction	if specialty ≠ orthopaedic surgery
F032 **	Radius or ulna, no reduction, rigid immobilization, closed reduction	if specialty ≠ orthopaedic surgery
F046 **	Distal radius, no reduction, rigid immobilization closed reduction	if specialty ≠ orthopaedic surgery

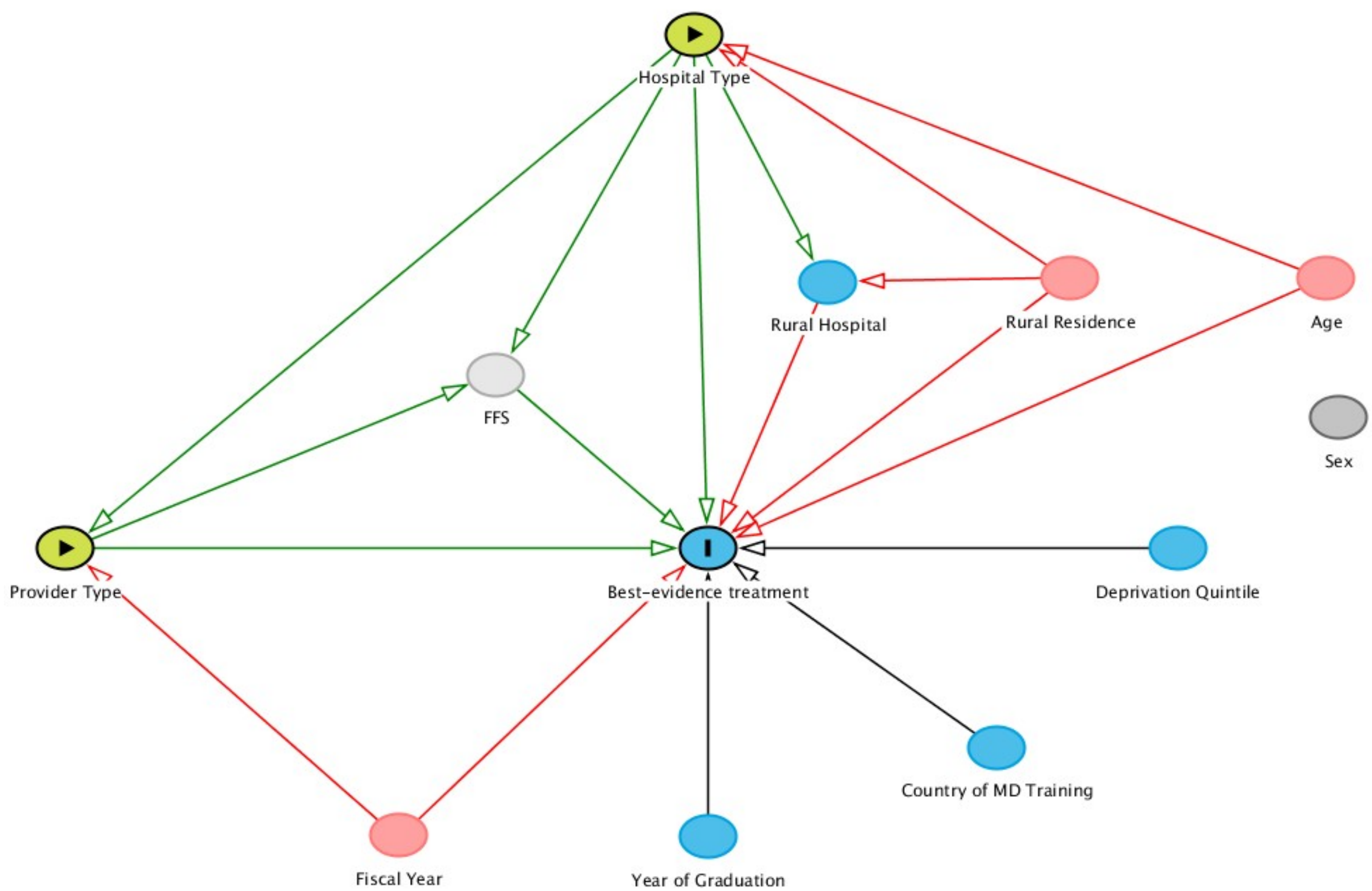
Table 4D: OHIP coding of x-rays for sensitivity analysis

Any of the following >2days and up to 6 weeks following diagnosis.

OHIP fee code	Description
X052	Diagnostic radiology forearm and 1 joint)
X053	Diagnostic radiology wrist, 2/3 views
X055	Diagnostic radiology wrist and hand, 2/3 views
X217	Diagnostic radiology forearm and 1 joint, 3 or more views
X218	Diagnostic radiology wrist, 4 or more views
X220	Diagnostic radiology wrist and hand, 4 or more views

Appendix E

Figure 1E: Directed Acyclic Graph depicting relationships of potentially relevant predictors of best-evidence treatment



Appendix F

Table 1G:
Sensitivity analysis - Increased specificity of diagnostic algorithm by excluding diagnostic and billing codes that might commonly be used to code for low-risk distal radius fractures, but technically should not be used for this purpose.

n=64,521		Adjusted RR for best-evidence treatment (95% CI)	p-value
Sex			
	Male	1.00 (ref)	<0.0001 *
	Female	1.06 (1.03-1.08)	
Age		1.00 (0.99-1.00)	0.1639
Patient deprivation quintile			
	(Least Marginalized) 1	1.00 (ref)	-
	2	1.01 (0.98-1.04)	0.5625
	3	1.03 (0.99-1.06)	0.0973
	4	1.05 (1.02-1.09)	0.0018*
	(Most marginalized) 5	0.99 (0.95-1.02)	0.5079
Rural residence			
	Yes	1.57 (1.52-1.62)	<0.0001 *
	No	1.00 (ref)	-
Hospital Type			
	Teaching	1.00 (ref)	-
	Paediatric	1.26 (1.18-1.35)	<0.0001 *
	Community	1.52 (1.44-1.61)	<0.0001 *
	Small	2.18 (2.04-2.32)	< 0.0001 *
Physician type			
	ER	1.00 (ref)	-
	FP/ER	1.00 (0.95-1.05)	0.9882
	FP/GP	1.16 (1.10-1.22)	<0.0001 *
	Pediatrics	1.26 (1.16-1.36)	<0.0001 *
	PEM	1.89 (1.73-2.07)	<0.0001 *
	Orthopaedics	0.64 (0.54-0.75)	<0.0001 *
Fiscal Year			
	2003	1.00 (ref)	-
	2004	1.02 (0.95-1.10)	0.5369
	2005	1.06 (0.99-1.14)	0.0772
	2006	1.08 (1.01-1.16)	0.0250*
	2007	1.05 (0.98-1.12)	0.1969
	2008	1.04 (0.97-1.12)	0.2865
	2009	0.99 (0.92-1.07)	0.8401
	2010	1.01 (0.94-1.09)	0.7449
	2011	1.00 (0.93-1.07)	0.9380
	2012	1.01 (0.94-1.09)	0.7377
	2013	0.98 (0.91-1.04)	0.5086
	2014	0.95 (0.89-1.02)	0.1897
	2015	0.86 (0.80-0.93)	0.0001*

Table 2G:
Sensitivity analysis - Defined outcome of interest as either no follow-up OR follow-up with a primary care physician only for the wrist fracture.

n=70,801		Adjusted RR for best-evidence treatment (95% CI)	p-value
Sex			
	Male	1.00 (ref)	<0.0001 *
	Female	1.05 (1.03-1.07)	
Age		1.00 (0.99-1.00)	0.0124*
Patient deprivation quintile			
	(Least Marginalized) 1	1.00 (ref)	-
	2	1.01 (0.98-1.04)	0.4669
	3	1.02 (0.99-1.06)	0.1594
	4	1.05 (1.01-1.08)	0.0055*
	(Most marginalized) 5	0.99 (0.95-1.02)	0.3865
Rural residence			
	Yes	1.61 (1.56-1.66)	<0.0001 *
	No	1.00 (ref)	-
Hospital Type			
	Teaching	1.00 (ref)	-
	Paediatric	1.25 (1.18-1.34)	<0.0001 *
	Community	1.43 (1.36-1.51)	<0.0001 *
	Small	2.03 (1.91-2.16)	<0.0001 *
Physician specialty in ED			
	ER	1.00 (ref)	-
	FP/ER	1.02 (0.97-1.07)	0.5193
	FP/GP	1.21 (1.15-1.27)	<0.0001 *
	Pediatrics	1.32 (1.22-1.43)	<0.0001 *
	PEM	1.95 (1.79-2.13)	<0.0001 *
	Orthopaedics	0.61 (0.52-0.71)	<0.0001 *
Fiscal Year			
	2003	1.00 (ref)	-
	2004	0.99 (0.93-1.06)	0.8731
	2005	1.04 (0.98-1.11)	0.2156
	2006	1.04 (0.98-1.11)	0.1985
	2007	1.01 (0.94-1.08)	0.8029
	2008	1.01 (0.94-1.08)	0.7968
	2009	0.98 (0.91-1.03)	0.3277
	2010	0.98 (0.92-1.05)	0.6497
	2011	0.97 (0.90-1.03)	0.3174
	2012	0.96 (0.90-1.03)	0.2642
	2013	0.95 (0.89-1.01)	0.1148
	2014	0.90 (0.84-0.96)	0.0024*
	2015	0.82 (0.77-0.88)	<0.0001*

Table 3G:
Sensitivity analysis - Combined paediatrician and PEM into a single category and combined FP/GP and FP/ER into one category.

n=70,801	Adjusted RR for best-evidence treatment (95% CI)	p-value
Sex		
Male	1.00 (ref)	<0.0001 *
Female	1.08 (1.05-1.11)	
Age	1.00 (0.99-1.01)	0.1406
Patient deprivation quintile		
(Least Marginalized) 1	1.00 (ref)	-
2	1.01 (0.97-1.06)	0.5884
3	1.05 (1.01-1.09)	0.0444
4	1.06 (1.01-1.11)	0.0143*
(Most marginalized) 5	1.03 (0.99-1.08)	0.1692
Rural residence		
Yes	1.46 (1.40-1.52)	<0.0001 *
No	1.00 (ref)	-
Hospital Type		
Teaching	1.00 (ref)	-
Paediatric	1.19 (1.11-1.29)	<0.0001 *
Community	1.14 (1.07-1.21)	<0.0001 *
Small	1.91 (1.77-2.07)	< 0.0001 *
Physician specialty in ED		
ER	1.00 (ref)	-
FP/GP + FP/ER	1.04 (0.98-1.10)	0.2269
PEM/Pediatrics	1.35 (1.23-1.47)	<0.0001 *
Orthopaedics	0.76 (0.63-0.91)	0.0025 *
Fiscal Year		
2003	1.00 (ref)	-
2004	1.05 (0.95-1.16)	0.3126
2005	1.10 (0.99-1.21)	0.0688
2006	1.19 (1.08-1.31)	0.0006 *
2007	1.14 (1.03-1.25)	0.0108 *
2008	1.16 (1.05-1.27)	0.0042 *
2009	1.14 (1.04-1.26)	0.0070 *
2010	1.20 (1.09-1.32)	0.0003 *
2011	1.21 (1.10-1.33)	0.0001 *
2012	1.25 (1.13-1.37)	<0.0001 *
2013	1.22 (1.10-1.34)	<0.0001 *
2014	1.20 (1.09-1.32)	0.0003 *
2015	1.06 (0.96-1.17)	0.0001 *

Table 4G:
Sensitivity analysis - Defined outcome of interest as no follow-up AND no x-ray coded in the administrative data for 6 weeks following the wrist fracture

n=70,801		Adjusted RR for best-evidence treatment (95% CI)	p-value
Sex			
	Male	1.00 (ref)	<0.0001 *
	Female	1.11 (1.06-1.16)	
Age		0.99 (0.99-1.00)	0.1387
Patient deprivation quintile			
	(Least Marginalized) 1	1.00 (ref)	-
	2	0.98 (0.92-1.05)	0.5938
	3	1.08 (1.01-1.15)	0.0301 *
	4	1.04 (0.97-1.11)	0.2704
	(Most marginalized) 5	1.08 (1.01-1.16)	0.0226 *
Rural residence			
	Yes	1.59 (1.48-1.70)	<0.0001 *
	No	1.00 (ref)	-
Hospital Type			
	Teaching	1.00 (ref)	-
	Paediatric	1.26 (1.15-1.38)	<0.0001 *
	Community	0.71 (0.65-0.77)	<0.0001 *
	Small	1.22 (1.09-1.36)	0.0004 *
Physician specialty in ED			
	ER	1.00 (ref)	-
	FP/ER	1.02 (0.93-1.11)	0.6829
	FP/GP	1.04 (0.95-1.14)	0.4157
	Pediatrics	1.35 (1.21-1.52)	<0.0001 *
	PEM	2.06 (1.81-2.35)	<0.0001 *
	Orthopaedics	0.58 (0.42-0.80)	0.0009 *
Fiscal Year			
	2003	1.00 (ref)	-
	2004	1.07 (0.93-1.23)	0.3601
	2005	1.03 (0.90-1.19)	0.6481
	2006	1.11 (0.96-1.28)	0.1547
	2007	1.06 (0.92-1.22)	0.4357
	2008	1.10 (0.95-1.27)	0.2159
	2009	1.01 (0.88-1.17)	0.8559
	2010	1.02 (0.88-1.18)	0.7755
	2011	1.05 (0.91-1.21)	0.5334
	2012	1.15 (0.99-1.33)	0.0505
	2013	1.08 (0.93-1.24)	0.3177
	2014	1.11 (0.96-1.28)	0.1497
	2015	0.93 (0.80-1.08)	0.3559

Appendix G

Glossary of abbreviations

Abbreviation	**Description**
AFP	Alternate Funding Plan
AIC	Akaike Information Criteron
BIC	Bayesian Information Criterion
CCFP	Certification in the College of Family Physicians
CCI	Canadian Classification of Health Interventions
CCP	Canadian Classification of Diagnostic, Therapeutic, and Surgical Procedures
CI	Confidence Interval
CIHI	Canadian Institute for Health Information
CME	Continuing Medical Education
CPSO	College of Physicians and Surgeons of Ontario
DAD	Discharge Abstract Database
ED	Emergency Department
ER	Emergency medicine trained physician - FRCPC
FP/GP	Family Practitioner or General Practitioner - CCFP
FP/ER	General practitioner or family practitioner with emergency medicine certification - CCFP
FRCPC	Fellow of the Royal College of Physicians of Canada
FRCSC	Fellow of the Royal College of Surgeons of Canada
ICD-9	International Classification of Diseases, ninth revision
ICD-10CA	International Classification of Diseases, tenth revision, Canadian adaptation
ICES	Institute for Clinical Evaluative Sciences
IKN	ICES Key Number
IPDB	ICES Physician Database
MOHLTC	Ministry of Health and Long Term Care
NACRS	National Ambulatory Care Reporting System
OCR	Ontario Cancer Registry

Abbreviation	Description
OHIP	Ontario Health Insurance Plan
OPHRDC	Ontario Physician Human Resource Data Centre
Ortho	Orthopaedic surgeon - FRCSC
PCP	Primary Care Physician
Peds	Pediatrician - FRCPC
PEM	Subspecialty paediatric emergency medicine - FRCPC
RCT	Randomized Control Trial
RPDB	Registered Persons Databse
RR	Risk Ratio
SDS	Same Day Surgery
UK	United Kingdom
VIF	Variance Inflation Factor

Appendix H

Definition of terms

Term	Definition
Buckle fracture	Most common low-risk distal radius fracture. The bone cortex "buckles" on itself.
Best-evidence treatment/care	For the purpose of this study, defined as no follow-up visit for a low-risk distal radius fracture
Community hospital	Hospital not considered academic, paediatric, or small
Complete fracture	Fracture type where the break extends from one side of the bone to the other and does not involve the growth plate
Emergency medicine	Physician having completed a residency training program in emergency medicine
Family practitioner or general practitioner (FP/GP)	General practitioner or physician having completed a family medicine residency program without additional emergency medicine training
General practitioner/Family practitioner with emergency medicine certification (FP/ER)	General practitioner or physician having completed a family medicine residency program plus either certification or fellowship training in emergency medicine
Greenstick fracture	Fracture type where the break breaches only one side of the bony cortex
Level 1 evidence	Randomized control trials and systematic reviews
Low-risk distal radius fracture	Fracture with less than 15 degrees of angulation at presentation. Predominantly buckle fractures. May also include Salter-Harris 1 fractures, greenstick fractures, and complete fractures of the distal radius.
Orthopaedic surgery	Physician having completed a residency training program in orthopaedic surgery
Paediatric hospital	Hospital having a paediatric only emergency department
Paediatrician	Physician having completed a residency training program in paediatrics
Salter-Harris fracture	Fracture involving the distal radius growth plate
Small hospital	Single community provider hospital with an annual weighted case load under 2700
Subspecialty paediatric emergency medicine (PEM)	Physician has completed a residency program in either paediatrics or emergency medicine plus either certification or fellowship training in paediatric emergency medicine
Teaching hospital	CAHO member hospitals not including paediatric designated hospitals

Appendix I

Keywords used in search strategy

buckle

torus

greenstick

salter-harris

distal radius

AND fracture

p(a)ediatr$

children$

treatment

care

cast$

cost

splint

plaster

follow$

clinic

visit$

x-ray$

radiograph$

minimal$

simpl$

alternative

removable

evidence

trial

emergency