PATTERNS OF INTERVENTIONS FOR ANALGESIA FOR CHILDREN PRESENTING TO A PEDIATRIC EMERGENCY DEPARTMENT WITH SUPRACONDYLAR HUMERUS FRACTURE

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Patterns of Interventions for Analgesia for Children Presenting to a Pediatric Emergency Department with Supracondylar Humerus Fracture

by

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ABSTRACT

Objective: To describe practice patterns for analgesic treatment in children presenting with supracondylar humerus fracture to the Janeway Children's Health and Rehabilitation Centre Emergency Department (ED) in the Canadian Province of Newfoundland and Labrador.

Design: Retrospective cohort study.

Methods: A consecutive sample of 160 children treated by emergency physicians for supracondylar humerus fracture at the Janeway ED was obtained. Injuries were classified as non-severe or severe, and cases were compared with respect to analgesic measures undertaken.

Results: The proportion of children treated with an analgesic at any time during their ED visit was 35% (57 cases). Severe cases were more likely to be given an analgesic than non-severe. Treatment with an analgesic early in the visit was very uncommon.

Conclusion: Timely analgesic treatment in the ED for children with supracondylar fracture is low, even for more severe injuries. A multi-faceted approach to this problem is required.

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List of Abbreviations

PO	By mouth (per os)
IV	Intravenous
IM	Intramuscular
SC	Subcutaneous
ED	Emergency Department
CI	Confidence interval
CTAS	Canadian Triage and Acuity Scale
BAEM	British Association for Emergency Medicine
EP	Emergency Physician
PACS	Picture Archiving and Communications System
ID	Identification
OR	Odds ratio

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Chapter 1 Introduction

Chapter 1.1 Physiology of Pain

Chapter 1.1.1 Basic Physiology

Pain has been defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage (1)." Physiologically, pain is mediated peripherally by stimulation of sensory receptors classified as nociceptors. These are peripheral sensory terminals of neurons that have their cell bodies in the corresponding cranial nerve nuclei (in the case of cranial nerves) or in the dorsal root ganglia (in the case of spinal nerves). Second order neurons synapse with the peripheral nerves in the dorsal root ganglia and ascend to the brain. Many of these synapse in the thalamus, from which information is further transmitted to higher cerebral centres. Neither transmission of pain-related impulses nor the perception of pain is a simple process. Modulation of pain transmission occurs at the levels of the nociceptor, the dorsal root ganglia (where descending neurons from the spinal cord and brain act) and the brain (2) (3). The requisite emotional component of pain is affected by multiple factors, including past experience, and is particularly complex in children (4) (5).

Chapter 1.1.2 Fracture Pain

While the mechanisms involved in fracture pain have not been fully elucidated, it is known that bone marrow, mineralized bone and the layer of periostium surrounding the mineralized bone are innervated by a diverse array of afferent sensory neurons capable of transmitting pain, as well as sympathetic neurons (6). It appears that stimulation of mechanosensitive nociceptors in the periostium and mineralized bone is of prime importance in the initial generation of the fracture pain. This is followed very quickly by an influx of hematological and inflammatory cells, which stimulate chemosensitive nociceptors via mediators such as bradykinin, nerve growth factor and prostaglandins. Other processes may take place as well: the aforementioned mediators may induce the proliferation of mechanosensitive nociceptors, which results in perception of normally

non-painful stimuli as pain; and central sensitization may develop, whereby changes in the spinal cord and brain enhance the transmission and perception of pain. Depending in part on the severity of injury, these changes may be permanent; in these cases, inappropriate interactions between sensory and sympathetic neurons may be involved in a complex regional pain syndrome (7).

Clinically, the initial pain of fracture is very severe and is diminished by immobilization at the fracture site, returning with excruciating intensity with any movement. This pain profile is consistent with the avoidance of use and voluntary guarding of an acutely fractured extremity and is the basis for initial pain control by immobilizing the fracture site (7), an intervention also designed to minimize soft tissue damage.

Chapter 1.2 Pain in Children: General Principles

Chapter 1.2.1 Ethical and Medical Imperatives to Treat Pain in Children

The reality of young children and infants experiencing pain is now well established (8), and treating pain is the standard of care and an important facet of current medical practice. There is evidence that there are long lasting negative effects of painful procedures in children, including altered responses to subsequent painful stimuli as well as medical fear and avoidance of health care in adulthood (9) (10) (11). Pain is closely related to suffering, which physicians have been expected to relieve since antiquity (12). Recently, a jointly issued statement on pain assessment and management by the American Academy of Pediatrics and the American Pain Society stated that "an important responsibility for physicians who care for children is eliminating or assuaging pain or suffering where possible (13)."

Chapter 1.2.2 Pain Assessment in Children

Pain assessment is recognized as an important component of patient care. Such an assessment should include a determination of the existence, intensity and nature of the pain (14). The standard for capable children is a self-report of pain intensity; if this is not

possible due to factors such as age or developmental level, an assessment should be done based on the child's behavior and details of the clinical situation (15). Available pain scales include FLACC (a behavioural scale assessing the face, legs, activity, cry and consolability of a child; useful at any age), the Wong-Baker FACES pain scale (utilizing cartoons of faces corresponding to different levels of pain; useful ages three years and older), a visual analog scale (useful ages eight years and older) and a verbal numeric scale (pain scored from 1 to 10; useful ages eight years and older) (16). Unfortunately, not only is pain assessment underutilized in many populations (including children), evidence linking formal assessment of pain to improved patient outcomes is lacking (8) (17).

Chapter 1.2.3 Modalities for Treatment of Pain in Children

Pain relief (and prevention) can be achieved using multiple modalities, both pharmacological and non-pharmacological. In choosing a particular treatment, there are a number of considerations, including safety, efficacy, cost and onset of action of the agent used (18). Even though evidence from rigourous studies on the safety and efficacy of pharmacological agents for pain management in children, particularly under the age of twelve, is lacking, clinical experience and knowledge of pediatric physiology has allowed the development of guidelines in this area (5). There are many generally accepted pharmacological choices for management of pain in children, including topical and locally infiltrated anesthetics as well as systemic analgesics (18). Systemic analgesics can be administered by many routes, including by mouth (PO), rectal, intravenous (IV), intramuscular (IM), subcutaneous (SC), and intranasal. Intramuscular administration of analgesics in children is not preferred; the onset of action is unpredictable and the injection is painful at the time of injection and for a considerable period of time thereafter (18) (15).

Analgesics may be classified as opioid or non-opioid, the latter generally being reserved for mild to moderate pain (4). Commonly utilized non-opioid analgesics include acetaminophen and the non-steroidal anti-inflammatory drug, ibuprofen. Opiods in use include codeine, morphine, meperidine, fentanyl and oxycodone (19) (20). For

musculoskeletal trauma in children, ibuprofen may be superior to either acetaminophen or codeine (21). Codeine has the additional disadvantage of having variable metabolism to morphine (it's active metabolite), and its safety and efficacy in treating pain in children has been questioned (22).

Non-pharmacological options for analgesia include psychological methods, physical methods (including splinting an extremity or applying a burn dressing when appropriate) and a child-friendly emergency department (ED) environment. The latter might include a treatment area for children separate from the adult treatment area, availability of material for distraction and having frightening medical equipment hidden from sight or camouflaged (23).

Chapter 1.3 Practice Patterns of Pain Treatment in Children

The literature has consistently demonstrated that treatment of pain in pediatric patients is inadequate or nonexistent in many settings, including the ED. Key determinants of this situation may include communication problems between children and providers, inadequate pain assessment and staff inexperience (8).

In a chart review of 112 children and 156 adult emergency patients with one of three conditions known to be painful (sickle cell crisis, lower extremity fracture and second or third degree burns), 60% of patients received no pain medications at all and children under two years of age were less likely to receive analgesia than older children (24).

In another study, an analysis of the records of 2828 adults and children was done to describe analgesic use and to compare analgesic use between adults and children with moderate to severe pain. These children were treated at EDs for either closed upper extremity fracture or clavicle fracture. A lower proportion of children than adults received either any analgesic or a narcotic analgesic (as defined by the US Food and Drug Administration National Drug Code Directory of Drug Classes). This was most noticeable in children younger than four years old, who were less likely than patients sixteen to

twenty-nine years of age to receive any analgesic (54% versus 67%) or a narcotic analgesic (21% versus 47%). Interestingly, children treated in pediatric EDs were about as likely to receive either any analgesic (adjusted RR 1.1; 95% confidence interval (CI) 0.9, 1.3) or a narcotic analgesic (adjusted RR 0.9; 95% CI 0.6, 1.2) as children treated in other EDs; similar proportions in pediatric and other EDs had moderate to severe pain when pain severity scales were used (adjusted RR 1.1; 95% CI 0.6, 1.9) (25).

Children identified as being at risk for multiple trauma, particularly involving head injury, have been shown to have low rates of analgesic administration. In a series of 99 children who had presumably painful fractures of the pelvis, long bones, ankle, wrist or clavicle, who were at risk for associated multiple other injuries, only 53% received an analgesic. Concomitant minor head injury was associated with an especially low rate of analgesic use (26).

Chapter 1.4 Supracondylar Humerus Fracture as a Painful Condition

Supracondylar fracture of the humerus is a common painful childhood injury. Supracondylar means "above the condyle," and in the context of an elbow injury, supracondylar fracture refers to a fracture immediately proximal to the humeral condyles. From here on in "supracondylar fracture" will refer to such an injury. Due to children's anatomy and normal bone development, this region is relatively weak and vulnerable to fracture (27). These injuries are the most common type of fracture about the elbow in children and the second most commonly seen limb fracture in children (28).

Supracondylar fractures are most common among school-age children, with a peak incidence between five and nine years, consistent with normal bone development (29) (27). The injury is usually the result of a fall on an outstretched arm with the elbow in full extension (27). Though most commonly the result of mild to moderate mechanisms of trauma, supracondylar fracture is a potentially serious injury, occasionally being associated with neurovascular compromise (30).

Depending on the degree of angulation and displacement, among other factors, these fractures may be treated conservatively with immobilization and orthopedic follow up (31). Alternatively, they may require more invasive treatment, typically either closed reduction in the ED (normally under sedation) or operating room (under general anesthesia), followed by casting. If a fracture is not stable after closed reduction, it is treated by pinning in the operating room with Kirschner wires (K-wires) to hold the position after a closed reduction. Sometimes it is necessary to surgically reduce the fracture prior to pinning (32).

All children with supracondylar fracture require radiography, and, unless appropriate precautions are taken (immobilizing the fracture), this may involve manipulation causing very severe pain at the fracture site. A study comparing oxycodone with codeine for analgesia for suspected forearm fractures noted that radiography was the most painful portion of the ED visit for 55% of children (33). This is likely to apply equally to other fractures, highlighting the need for early immobilization and analgesic administration.

Children with even undisplaced supracondylar fractures have been shown to have moderate pain on presentation, with one study of two different treatment groups showing initial pain scores of 65 mm and 50 mm on a 100 mm visual analog scale in the two groups, with interquartile ranges of 30 – 80 mm and 40 – 60 mm respectively (34). This supports the inference of the presence of significant pain in this condition even in the absence of a standardized pain assessment.

Chapter 1.5 Time to Analgesic Treatment for Children with Supracondylar Fracture

Children presenting to Canadian EDs are triaged according to the Canadian Triage and Acuity Scale (CTAS) Paediatric Guidelines and assigned a CTAS level ranging from 1 (most acute) to 5 (least acute). According to the guidelines, children with acute severe pain (8 – 10 on a 10 point scale) should be categorized at CTAS level 2; those with acute moderate pain (4 – 7 on a 10 point scale) triaged CTAS level 3; and children with acute

mild pain (0 – 3 on a 10 point scale) at CTAS level 4 (35). This corresponds to a time to medical care goal of 15 minutes for CTAS level 2 patients, 30 minutes for CTAS level 3 patients and 60 minutes for CTAS level 4 patients (36). Pain is only one consideration in the triage process, and another modifier, such as mechanism of injury, might necessitate a more acute triage level. The CTAS guidelines supplement the goals for time to medical care with fractile response goals of 95%, 90%, 85% and 80% for levels 2, 3, 4 and 5, respectively (36). This means that in patients triaged at CTAS level 3, for example, time to medical care should be within 30 minutes of triage 90% of the time. Table 1-1 summarizes CTAS recommendations for time to care for patients in each of the five triage categories.

The British Association for Emergency Medicine (BAEM) Clinical Effectiveness Committee Guideline for the Management of Pain in Children sets the standard for the timeliness of treatment for moderate or severe pain at 20 minutes from arrival in the ED or earlier (37).

Given that evidence suggests that children with supracondylar fracture generally experience pain of at least moderate intensity (34), it would be consistent with CTAS guidelines and within striking distance of the BAEM guidelines if treatment were initiated in the majority of patients within 30 minutes. In general, administration beyond 60 minutes may be inappropriately delayed.

Chapter 1.6 Rationale for this Study

In evaluating the adequacy of the treatment of pain in children, a number of process outcomes may be examined. These include the efficacy and safety of any analgesic medication used as well as the appropriateness of the dosage and route. The relevant outcome from a child's point of view is whether or not the complex phenomenon of pain is relieved. However, even to achieve this important patient-oriented outcome is not sufficient. Relief of pain after hours of suffering is less desirable than pain relief early in the process of care. In keeping with this, the process outcome of early administration of

an analgesic is important, as no drug, regardless of its onset of action, will be effective until it is administered. While the adage, "better late than never," is no doubt accurate in this case, "better early than late" is also true.

Research on the timeliness of provision of analgesia to children in the ED is limited. A recent prospective observational study conducted in seventeen EDs in the United States and Canada examined analgesic treatment for patients presenting with moderate to severe pain. Sixty percent of patients received an analgesic but the median time to analgesic administration was 90 minutes, with a range of zero to 962 minutes. This study excluded children younger than eight years old; the median age was 34.5 years (38). Another study examining the association of ED crowding with quality of analgesia retrospectively examined the electronic medical records of children with isolated long bone fractures presenting to a large (48 bed) pediatric emergency department in the United States. Poor timeliness of analgesia was defined as no analgesic within one hour of arrival in those for whom analgesia was indicated (any non-zero pain score). Only 12.7% of these patient received an analgesic within this time frame even though 94.9% had a pain score done within an hour of arrival (39).

The purpose of this project was to examine retrospectively the timeliness of pediatric pain management in cases of upper extremity trauma, and whether or not timeliness is affected by the severity of the trauma. While more severe trauma would logically be associated with more severe pain and a more aggressive approach to its treatment, there might be factors associated with more severe cases that delay the provision of early appropriate analgesia for these patients. While the primary mode of analgesia of interest was pharmacological, immobilization of a fracture with a plaster or fibreglass backslab is also important, and was examined in this study.

To examine the relationship between injury severity and timeliness of analgesia, supracondylar humerus fracture was chosen for analysis. There are a number of characteristics of this particular injury that make it a good candidate for this study. First

of all, it is a common injury, so performing the study at a single institution is feasible. Secondly, there is a wide range of severity, ranging from very subtle fractures to severely displaced fractures which can sometimes result in permanent neurovascular damage. The management of displaced or angulated fractures is quite different from that of less severe injuries, and this marker of severity can be easily abstracted from the medical record. Finally, the severe cases are expected to represent a significant proportion of the cases, facilitating statistical comparison between the two groups.

Chapter 1.7 Study Objectives and Research Questions

The objectives of this study were as follows:

1. To compare timely analgesic administration in children 0 to 12 years of age presenting to a children's ED with acute supracondylar fractures of a non-severe (as defined by injuries for which definitive treatment was cast immobilization only) and severe nature;
2. To describe patterns of use of systemic analgesics and backslab immobilization in this population;
3. To describe the mechanisms of injury for supracondylar humerus fracture in this population.

The primary research question was as follows:

What are the proportions of children with non-severe and severe fractures who received a systemic analgesic within 30 minutes of triage?

The hypothesis was that the proportion in children with non-severe fractures would be statistically different from the proportion in children with severe fractures. Thus, the null hypothesis may be expressed H_0: $p_1 = p_2$, and the alternative hypothesis expressed H_1: $p_1 \neq p_2$, where p_1 and p_2, respectively, are the proportions of non-severe and severe cases receiving an analgesic within the first 30 minutes from triage.

The CTAS, which correlates to some extent with pain intensity, was the starting point for the choice of the 30 minute time frame. Most cases were expected to be coded at least level 3 (correlating with moderate to severe pain and associated with a recommended time to medical care goal of 30 minutes). While some might be coded level 4 (recommended time to medical care of 60 minutes), analgesic administration may occur prior to formal contact with medical personnel, by means of a medical directive for analgesic administration (not in place at the studied ED) or by a verbal order. After broad consultation, 30 minutes was considered to be a reasonable time frame to examine for analgesic administration in this injury.

It was expected that a pain score would not be consistently recorded and that factors other than pain intensity might influence the assigned triage code. Therefore, the primary outcome did not take into account the different triage codes assigned within the groups.

Non-severe fractures would be expected to differ from severe ones in a number of ways, including CTAS code assigned, location placed by the triage nurse, likelihood of being initially assessed by the attending emergency physician (EP) and likelihood of initially being allowed nothing by mouth. Comparison of non-severe and severe groups was chosen as a way of examining the effect of these factors, in addition to pain intensity, on quick pain treatment. While the number of possible contributing factors to the primary outcome would likely preclude definitive conclusions about specific factors, the comparison might still yield important information useful to characterize pain treatment and to guide future research.

Chapter 1.8 Tables

Table 1-1 Time to medical care goals for CTAS categories

CTAS Category	Time to medical care goal (minutes)	Fractile response (%)
1	Immediate	98
2	15	95
3	30	90
4	60	85
5	120	80

Chapter 2 Methods

Chapter 2.1 Study Design

This was a retrospective cohort study.

Chapter 2.2 Study Population

The Janeway Children's Health and Rehabilitation Centre is an academic tertiary care children's hospital located in St. John's, Newfoundland and Labrador. The Janeway ED has an annual census of approximately 30,000 visits. The population of interest was children presenting to the Janeway ED for whom an EP was the initial most responsible physician and who had a history of acute trauma and a final diagnosis of supracondylar humerus fracture as determined by radiology report.

Chapter 2.3 Definitions

For the purposes of this study, an analgesic was defined as any medication with analgesic properties given by any route for the purpose of decreasing pain, or any medication given parenterally for procedural sedation.

A backslab was defined as moldable plaster or fibreglass applied to the injured extremity and subsequently hardening to immobilize the fracture site.

The cases were classified as either "non-severe" or "severe" based on the type of definitive treatment used for the fracture. Cases treated with casting only were classified as non-severe. Any case where treatment involved physical manipulation of the fracture (reduction) in the ED or any procedure in the operating room (closed reduction, percutaneous pinning, or open reduction and internal fixation) was classified as severe.

Chapter 2.4 Inclusion and Exclusion Criteria

Inclusion Criteria:

1. Attendance at the Janeway ED from 1 January 2005 to 31 December 2009;

2. History of acute trauma (injury within 24 hours);
3. Age 0 to 12 years;
4. Diagnosis of supracondylar humerus fracture (visible on the initial radiograph; not simply a joint effusion with a suspicion of an underlying supracondylar fracture) as determined by radiology report.

Limiting the age of cases to 12 years was designed to capture the vast majority of supracondylar fractures (29) while ensuring the feasibility of sample selection for the study. While many of the cases with an initial radiograph showing only a joint effusion likely had a supracondylar fracture, whether or not this was the case for an individual patient would not be known at the initial visit; therefore it was decided that a visible fracture would be necessary for inclusion.

Exclusion criteria were as follows:

1. Children referred from another centre and already immobilized with a backslab;
2. Direct referral to orthopedics;
3. Intubation on arrival or during the ED visit.

Chapter 2.5 Outcomes

Chapter 2.5.1 Primary Outcome

The primary outcome for the study was the proportion of children in the sample who received an analgesic during the first 30 minutes from ED triage.

Chapter 2.5.2 Secondary Outcomes

Secondary outcomes were:

1. The proportion of children who received an analgesic within 60 minutes of triage;
2. The proportion of children who received an analgesic at any time during their ED visit;
3. The proportion of children who received an analgesic prior to radiography;
4. The proportion of children who had a backslab applied prior to radiography.

The variable "age in months" was dichotomized to "age ≤ five years" and "age > five years" and its association with secondary outcome 2, the proportion receiving an analgesic at any time during the ED visit, examined. In addition, the association of the variable "initial medical contact" with secondary outcome 4, the proportion who had a backslab applied prior to radiography, was examined.

Chapter 2.6 Sample Size

Sample size was calculated using the following parameters: $\alpha = 0.05$; $\beta = 0.8$; probability of the primary outcome in non-severe cases = 0.6; and probability of the primary outcome in severe cases = 0.3. The probabilities of the primary outcome in the different groups were based, in part, on clinical experience suggesting that analgesics, while more frequently administered in severe cases, would often be delayed in this group. From a pilot review of a limited number of cases, it was estimated that the ratio of non-severe to severe cases would be 5:1. This scenario required a sample size of 150 cases in total. It was estimated that a consecutive sample of all cases seen at the Janeway ED over a five-year period would be required to achieve this sample size.

Chapter 2.7 Selection of Sample

The Eastern Health Picture Archiving and Communications System (PACS) was queried and a list printed of all elbow radiographs ordered from the Janeway ED from 1 January 2005 through 31 December 2009. Each entry on this list was reviewed by the author to select cases that were candidates for inclusion in the study (Appendix A). Candidate cases were first identified by the unique accession number of the radiographic study, recorded as the PACS Screening Identification (ID) Number. If the following criteria were met after review of the radiographs and other information available on the PACS, the case was given a Study Screening ID Number (a number not connected to the medical record): age less than or equal to twelve years; radiograph ordered by an EP (as opposed to an orthopedic specialist); injury due to acute trauma (within 24 hours); and a radiographic diagnosis of supracondylar fracture. If the only evidence of a supracondylar fracture was

an elbow joint effusion, the case was excluded even if a subsequent examination did show a supracondylar fracture. This screening process involved the exclusion of a large number of examinations, primarily normal examinations, examinations showing an effusion but no fracture, and those that were follow-up examinations for a known fracture. For all cases given a Study Screening ID Number, the radiographs were examined by the author to determine if there was an immobilizing backslab in place at the time of the radiograph. Finally, for each case given a Study Screening ID Number, the medical record was examined, either in electronic or paper format (the records for the earlier years were not available electronically), to determine whether inclusion criteria determined from PACS were accurate and that no exclusion criteria were present. This data was recorded on page one of the Chart Review Data Collection Sheet (Appendix B). Cases meeting all inclusion criteria with no exclusion criteria were given a Study Enrolment ID Number and the medical record further examined to extract predetermined data.

Chapter 2.8 Data Extraction and Handling

Using the Chart Review Data Collection Sheet (Appendix B), the following data were recorded for each eligible case: age in months; gender; weight in kilograms; site of injury (left or right); CTAS level; classification as non-severe or severe (and if severe, details of treatment); details of any analgesic administered prior to arrival at the ED; details of first, second and third analgesic medications administered in the ED; whether the first analgesic given in the ED preceded radiography; whether a backslab was applied prior to radiography; whether initial contact was with the EP or a member of the house staff; location of the child after triage (examination room, observation room or trauma room); and whether the child was admitted to the hospital. The following timings were recorded, if available: registration; triage; initial contact with medical personnel; administration of medications; radiography; and discharge from the ED. The registration time from the ED computer system was automatically recorded on the chart. Time of radiography was automatically recorded by the diagnostic imaging computer system. Other timings were recorded by hand on the medical record by medical, nursing or administrative personnel in the ED. This data was entered into a Microsoft Access® database developed by the

author, and exported into IBM SPSS® Statistics Version 19. The mechanism of injury was also recorded and entered into the SPSS data file.

Chapter 2.9 Statistical Analysis

All analyses were done using IBM SPSS Version 19. Comparison of proportions was done using a chi-square statistic or Fisher's exact test, depending on expected cell frequencies. Continuous variables were compared using the Student's t-test for independent variables. Survival data were analyzed with a Cox proportional hazards model. Results with p values < 0.05 were considered to be statistically significant.

Chapter 2.10 Ethical Considerations

A proposal for the present study was given ethics approval by the Human Investigations Committee of Eastern Health and Memorial University of Newfoundland. Institutional approval was also granted by Eastern Health's Research Proposal Approval Committee. All study documents are kept locked securely, as required. None of the paper or electronic study records can be connected to a specific patient without the use of a paper document linking Medical Care Plan numbers to the Study Enrolment ID Numbers. This is stored securely and separately.

Chapter 3 Results

Chapter 3.1 Selection of Sample

In total, 1758 radiographic elbow examinations were screened from a PACS printout of all such examinations from 1 January 2005 to 31 December 2009. From information available on the printout and in the PACS database, 171 possibly eligible cases were identified. Review of the complete medical records for these cases resulted in exclusion of 11 cases and a consecutive sample of 160 eligible cases for the time period. This is summarized in Figure 3-1.

Chapter 3.2 Characteristics of Cases

Chapter 3.2.1 General Characteristics of Patients

Patients ranged in age from 13 to 150 months, with a mean age of 70.4 months and a median age of 68 months. The distribution of ages did not grossly deviate from normal using a Q-Q plot or a histogram (Figure 3-2). However, it did fail the Shapiro-Wilk test for normality with a significance level of 0.011.

Males comprised 58.1% of cases (95% CI 0.504, 0.659). Weight was available for 158 patients and ranged from 11 kg to 55 kg, with a mean of 23.7 kg and a median of 22.0 kg.

Chapter 3.2.2 Characteristics of Injuries

The left elbow was injured in 58.1% of cases (95% CI 0.504, 0.659). Of the 160 cases, 116 (72.5%) were non-severe (casting treatment only) and 44 (27.5%) were classified as severe (requiring a procedure in the ED or operating room). Of the severe cases, 39 (88.6%) were treated in the operating room with pinning after closed (36 cases) or open (three cases) reduction, and five cases (11.4%) were treated successfully in the ED with closed reduction and casting. Of those treated in the operating room, seven (17.9%) were initially treated in the ED with attempted closed reduction. In cases where it might be unclear from the medical record whether a closed reduction or simply a cast application

was done in the ED, the determining factor was whether or not a post-reduction radiograph was done following the procedure. A post-hoc review of the medical records for the severe injuries revealed that they were all closed fractures (skin overlying the fracture was intact). Characteristics of the cases are summarized in Table 3-1. Treatments are summarized in Figure 3-3.

Mechanism of injury was determinable in 156 of the 160 cases. These mechanisms were classified as falls from standing, falls from a stationary object and falls from a moving object (any object whose movement added momentum to the child's fall). Falls from stationary and moving objects were further sub-classified. The most common mechanism of injury was a fall from a stationary object (45.0%), followed by a fall from standing (30.6%), a fall from a moving object (21.9%) and an undetermined mechanism (2.5%). The largest proportion of falls from stationary objects were from household furniture (18.1% of total cases), followed by stairs (6.9%), climbing equipment (6.3%) and playground slides (5.0%). Other stationary objects from which children fell included fences (three cases), trees (two cases) and numerous other objects, each representing a solitary case. Falls from moving objects were most commonly from trampolines (6.3% of total cases) and bicycles (5.6%). Details of mechanisms of injury are summarized in Tables 3-2, 3-3 and 3-4.

Chapter 3.2.3 Characteristics of Emergency Department Visits

Of the 160 eligible cases, 26 were seen in 2005, 38 in 2006, 32 in 2007, 29 in 2008 and 35 in 2009. Of the total, 68.1% registered during the day (8 am to 4 pm), 31.3% during the evening (4 pm to midnight) and 0.6% (one case) between midnight and 8 am. CTAS categories assigned at triage were recorded for all patients as follows: C2 (8 cases; 5.0%); C3 (127 cases; 79.4%); and C4 (25 cases; 15.6%). No child had a formal pain assessment recorded. After triage, 84.4% of patients were placed in an examination room and 15.6% in the observation room. In 55.6% of cases, initial medical contact was with a member of the house staff (resident or clinical clerk), and the remainder (44.6%) with the EP. Thirty-eight cases (26.3%) were admitted to hospital from the ED. A further four cases were

discharged home from the ED and subsequently admitted for management. Only seven children had received an analgesic for the index condition prior to the ED visit (four received acetaminophen and three ibuprofen). In no case was the dose of a pre-hospital analgesic recorded. These characteristics are summarized in Table 3-1.

While registration time was available for all cases, discharge time was missing in 26 cases (all but one of these were non-severe cases). Of the 134 remaining cases, time spent in the ED ranged from 43 minutes to 1141 minutes. The visit with a duration of 1141 minutes was an outlier (the only case with a duration of visit greater than 400 minutes). The mean duration of visit was 153.8 minutes and the median was 122.5 minutes.

Chapter 3.3 Outcomes

Table 3-5 summarizes the primary and secondary outcomes. Of the 160 cases, 56 (35.0%) received an analgesic at some time during the ED visit, and in 5 cases (3.1%) more than one dose of analgesic was given during the visit. In 24 (15%) and 8 (5%) cases, respectively, was a dose of analgesic administered within 30 minutes and 60 minutes from triage. In 12 (7.5%) cases was an analgesic medication administered in the ED prior to radiography. Of the 68 children five years of age and younger, 24 (35.3%) received an analgesic during the ED visit; the corresponding number for the 92 children greater than five years old was 32 (34.8%).

An immobilizing backslab, another analgesic measure, was provided prior to radiography in 46 cases (28.7%).

Chapter 3.4 Details of First Administered Analgesics

Details of first analgesics administered in the ED were well documented in the medical record and are summarized in Table 3-6. Of the 56 cases receiving an analgesic, the most commonly administered first drug was ibuprofen (18 cases), followed by meperidine and morphine (nine cases each) and acetaminophen (seven cases). Other medications used first line were acetaminophen with codeine alone (three cases), codeine (two cases) and

fentanyl (two cases). The medication was given parenterally (IV, IM or SC) in 44.6%; administration in the remainder was PO. Weight was available for all children who received an analgesic during their ED visit. Dosages of medication on a milligram-per-kilogram basis were, on the whole, consistent with recommended dosages (20).

Chapter 3.5 Comparison of Non-severe and Severe Cases

Chapter 3.5.1 Patient Characteristics and Mechanisms of Injury

Table 3-7 presents a comparison of some of the features of cases with non-severe and severe injuries. Gender was not statistically different between the groups, nor was site of injury (left or right). Children in the severe group were older ($p = 0.011$); however, weight was not significantly different between the two groups ($p = 0.080$). The proportions of non-severe and severe cases accounted for by the different mechanisms of injury were different ($p = 0.018$ for differences among falls from standing, stationary object, moving object or undetermined mechanism), with falls from moving objects accounting for 15.5% of non-severe injuries and 38.6% of severe injuries. Administration of a pre-hospital analgesic was not different between the two groups (one case in the severe group (2.3%) and seven cases in the non-severe group (5.2%); $p = 0.675$).

Chapter 3.5.2 Emergency Department Visits

Those with severe injuries were more likely to be placed in the observation room and more likely to be admitted from the ED rather than discharged. CTAS levels assigned were significantly different between the non-severe and severe groups ($p = 0.000$), with a higher proportion of non-severe cases assigned level 4 and a higher proportion of severe cases assigned level 2. In both non-severe and severe injuries, the majority were assigned level 3 (78.4% and 81.8% respectively). There was no significant difference in the likelihood of having initial medical contact with a member of the house staff or an EP (Table 3-7).

Chapter 3.5.3 Outcomes

Table 3-8 shows the differences between non-severe and severe cases with respect to analgesic measures undertaken during the ED visit. The proportion of non-severe cases receiving an analgesic during the ED visit was 27.6% versus 54.5% in the severe group. The odds ratio (OR) for receiving an analgesic during the ED visit for the severe cases versus the non-severe cases was 3.150 (95% CI 1.524, 6.469); p = 0.001. With respect to the primary outcome, the proportion treated within 30 minutes of arrival, 2.6% were treated in the non-severe group and 11.4% in the severe group. The OR for being treated within 30 minutes for the severe cases versus the non-severe cases was 4.829 (95% CI 1.103, 21.148); p = 0.037. Thus, for the primary outcome, the null hypothesis, that that there is no difference between the severe and non-severe cases in terms of early analgesic administration, was rejected. The number of cases treated in each group in this time frame was very small: three in the non-severe group and five in the severe. For treatment within 60 minutes of triage, the proportion treated in the non-severe group was 12.9% versus 20.5% in the severe group: in this instance the OR for being treated in the severe cases versus the non-severe cases was 1.731 (95% CI 0.696, 4.305); p = 0.320.

To correct for age and include a time to event component, a Cox proportional hazards analysis was done. Because treatment beyond 60 minutes was considered inappropriately delayed, all cases not treated within this time interval were censored. Age and classification (as non-severe or severe) were included in the model and the ENTER method was used. The overall model was significant (p = 0.013); classification was significant (p = 0.004) but age was not (p = 0.858); exp(B) for classification was 2.197 (95% CI 1.282, 3.765) (Figure 3-4). Separate survival function curves (one minus survival) for the different values for classification are shown in Figure 3-5. Log minus log curves for the model showed good proportionality of hazards (Figure 3-6). To test whether practice patterns had changed significantly over the time period examined in the study, separate Kaplan-Meier survival curves were computed for the first 80 cases (chronologically) and the last 80 cases (Figure 3-7). The log-rank test for these two samples was not significant (p = 0.924).

When the time from triage to radiography was calculated, there were five cases in which radiography appeared to have occurred before triage by a maximum of six minutes (four non-severe cases and one severe case). It is clear that some sort of triage took place prior to radiography, so the time from triage to radiography was set to zero for these cases. Using this data, the time from triage to radiography ranged from zero to 247 minutes, with a mean of 38 minutes and a median of 31 minutes. Mean time in minutes was significantly different between non-severe and severe cases (41.2 versus 30.0; $p = 0.013$).

The proportion treated with an analgesic prior to radiography was 4.3% in the non-severe group and 15.9% in the severe group. The OR for receiving an analgesic prior to radiography in the severe cases versus the non-severe cases was 4.200 (95% CI 1.257, 14.035); $p = 0.020$. Again, the numbers treated were small: five in the non-severe group and seven in the severe.

Application of a backslab prior to radiography occurred in 16.4% of children with non-severe injuries versus 61.4% of those in the severe category. The OR for being immobilized prior to radiography in the severe cases versus the non-severe cases was 8.108 (95% CI 3.713, 17.707); $p = 0.000$.

Chapter 3.5.4 Characteristics of First Administered Analgesics

The first analgesic administered in the ED was less likely to be an opioid (31.3%) in the non-severe group than the severe group (62.5%); OR 3.667 (95% CI 1.203, 11.174) for treatment with an opioid in the severe cases versus the non-severe; $p = 0.020$. Parenteral doses of medication were much less frequent in the non-severe group than the severe group (12.5% versus 87.5%; $p = 0.000$). Of interest, of the 21 severe cases who received a parenteral analgesic (all of whom eventually required an IV line), more than half (57.1%) received their analgesic by other than the IV route.

Chapter 3.6 Effect of Age of the Child

In addition to the Cox proportional hazards model described in Chapter 3.5.3, the cases in the two predefined age groups were compared directly. There was no difference in the proportions of children in the five-years-and-younger group and the older-than-five-years group who received an analgesic at any time during the ED visit (35.3% versus 34.8%; p = 0.947), an analgesic in the first 30 minutes of their visit (2.9% versus 2.2%; p = 0.759) or an analgesic in the first 60 minutes (13.2% versus 9.8%; p = 0.494). More cases in the younger group had severe injuries (20.6% versus 32.6%), but this did not reach statistical significance (p = 0.092).

Chapter 3.7 Comparison of Backslab Application Prior to Radiography in Children Initially Seen by a Member of the House Staff versus a Staff Emergency Physician

Children whose initial contact was with an EP were more likely to have a backslab applied prior to radiography (40.8% versus 19.1%; p = 0.003). The proportion of cases where the injury was classified as severe was higher in the EP group than the house staff group; however, this did not reach statistical significance (33.8% versus 22.5%; p = 0.111). When the likelihood of having a backslab applied prior to radiography in the EP and house staff groups was analyzed for the non-severe and severe groups separately, there was no difference between the EP and house staff groups for the non-severe cases (23.4% versus 11.6%; p = 0.092), but a significant difference for the severe cases (75.0% versus 45.0%; p = 0.042).

Chapter 3.8 Tables

Table 3-1 Characteristics of cases of supracondylar fracture

$n = 160$

Characteristic	Value
Male: *n* (%)	93 (58.1)
Age in months: mean (standard deviation)	70.4 (29.2)
Weight in kilograms: mean (standard deviation)	23.7 (9.2)
Site left elbow: *n* (%)	93 (58.1)
Initial medical contact EP: *n* (%)	71 (44.4)
Location observation room: *n* (%)	25 (15.6)
Presentation day shift (8 am to 4 pm): *n* (%)	50 (31.3)
Presentation evening shift (4 pm to midnight): *n* (%)	109 (68.1)
Presentation night shift: (midnight to 8 am) *n* (%)	1 (0.6)
Admitted for management of injury: *n* (%)	42 (26.3)
Admitted directly from the ED: *n* (%)	38 (23.8)
Pre-hospital analgesic: *n* (%)	7 (4.4)
Triage code 2: *n* (%)	8 (5.0)
Triage code 3: *n* (%)	127 (79.4)
Triage code 4: *n* (%)	25 (15.6)
Severe injury: *n* (%)	44 (27.5)

Table 3-2 Mechanisms of injury for cases of supracondylar fracture

$n = 160$

Mechanism	Total: *n* (% of total cases)	Severe: *n* (% of severe cases)
Fall from standing	49 (30.6)	10 (22.7)
Fall from stationary object	72 (45.0)	16 (36.4)
Fall from moving object	35 (21.6)	17 (38.6)
Undetermined	4 (2.5)	1 (2.3)

Table 3-3 Supracondylar fractures as a result of falls from stationary objects: specific objects

$n = 72$

Object	Total: *n* (% of total cases)	Severe: *n* (% of severe cases)
Household furniture	29 (18.1)	4 (9.1)
Stairs	11 (6.9)	3 (6.8)
Climbing equipment	10 (6.3)	3 (6.8)
Playground slide	8 (5.0)	1 (2.3)
Fence	3 (1.9)	1 (2.3)
Tree	2 (1.3)	1 (2.3)
Boat trailer	1 (0.6)	0 (0.0)
Gymnastics bars	1 (0.6)	1 (2.3)
Log	1 (0.6)	0 (0.0)
Patio	1 (0.6)	0 (0.0)
Picnic table	1 (0.6)	0 (0.0)
Playhouse	1 (0.6)	0 (0.0)
Rope ladder	1 (0.6)	1 (2.3)
Truck	1 (0.6)	0 (0.0)
Window ledge	1 (0.6)	1 (2.3)

Table 3-4 Supracondylar fractures as a result of falls from moving objects: specific objects

$n = 35$

Object	Total: *n* (% of total cases)	Severe: *n* (% of severe cases)
Trampoline	10 (6.3)	3 (6.8)
Bicycle	9 (5.6)	3 (6.8)
Swing	4 (2.5)	4 (9.1)
All-terrain vehicle (electric)	2 (1.3)	1 (2.3)
Scooter	2 (1.3)	1 (2.3)
Toboggan	2 (1.3)	1 (2.3)
Inflatable castle	1 (0.6)	0 (0.0)
Person (piggyback)	1 (0.6)	1 (2.3)
Pony	1 (0.6)	1 (2.3)
Snowboard	1 (0.6)	0 (0.0)
Seesaw	1 (0.6)	1 (2.3)
Wagon	1 (0.6)	1 (2.3)

Table 3-5 Outcomes for all cases of supracondylar fracture

$n = 160$

Outcome	Value
Any analgesic during the ED visit: *n* (%)	56 (35)
More than one dose of analgesic in ED: *n* (%)	5 (3.1)
Analgesic ≤ 30 min: *n* (%)*	8 (5.0)
Analgesic ≤ 60 min: *n* (%)	24 (15.0)
Analgesic pre-radiography: *n* (%)	12 (7.5)
Analgesic during ED visit age ≤ 5 years: *n* (%)	24 (35.3)
Analgesic during ED visit age > 5 years: *n* (%)	32 (34.8)
Backslab pre-radiography: *n* (%)	46 (28.7)

*primary outcome

Table 3-6 Analgesics administered in the emergency department for supracondylar fracture*

Drug	Number of cases	Route(s)	Dose (mg/kg)	Recommended dose (mg/kg)
Ibuprofen	18	PO	9.25	5 – 10
Morphine	9	IM (1); IV (1); SC (7)	0.097	0.05 – 0.10
Meperidine	9	IM (8); PO (1)	0.86	1.0 – 1.5
Acetaminophen	7	PO	14.68	15
Acetaminophen with codeine	3	PO	0.42†	0.468†‡
Codeine	2	PO	0.66	0.8 – 1.5
Fentanyl	2	IV	0.425§	0.5 – 1.0§

*first administered analgesics only; excludes sedatives and sedative/analgesics

†millilitres per kilogram

‡based on acetaminophen (limiting component)

§micrograms per kilogram

Table 3-7 Comparison of characteristics of non-severe and severe supracondylar fracture cases

$n = 160$

Characteristic	Non-severe group ($n = 116$)	Severe group ($n = 44$)	p-value
Male: *n* (%)	70 (60.3)	23 (52.3)	0.355
Age in months: mean (standard deviation)	66.8 (27.5)	79.9 (31.8)	0.011
Weight in kilograms: mean (standard deviation)	22.9 (8.5)	25.7 (10.6)	0.080
Site left elbow: *n* (%)	70 (60.3)	23 (42.3)	0.355
Initial medical contact EP: *n* (%)	47 (40.5)	24 (54.5)	0.111
Location observation room: *n* (%)	9 (7.8)	16 (36.4)	0.000
Admitted: *n* (%)	2 (1.7)	40 (90.9)	0.000
Admitted directly from ED: *n* (%)	2 (1.7)	36 (81.8)	0.000
Pre-hospital analgesic: *n* (%)	6 (5.2)	1 (2.3)	0.675*
Triage code 2: *n* (%)	1 (0.9)	7 (15.9)	0.000†
Triage code 3: *n* (%)	91 (78.4)	36 (81.8)	
Triage code 4: *n* (%)	24 (20.7)	1 (2.3)	
Fall from standing: *n* (%)	39 (33.6)	10 (22.7)	0.018‡
Fall from stationary object: *n* (%)	56 (48.3)	16 (36.4)	
Fall from moving object: *n* (%)	18 (15.5)	17 (38.6)	
Undetermined mechanism: *n* (%)	3 (2.6)	1 (2.3)	

*Fisher's exact test

†for differences among all triage codes (note that 1 cell has expected count < 5)

‡for differences among all mechanisms (note that 2 cells have expected counts < 5)

Table 3-8 Comparison of outcomes for non-severe and severe supracondylar fracture cases

$n = 160$

Outcome	Non-severe	Severe	OR (95% CI)	p-value
Any ED analgesic: *n* (%)	32 (27.6)	24 (54.5)	3.150 (1.524 – 6.469)	0.001
Analgesic ≤ 30 min: *n* (%)	3 (2.6)	5 (11.4)	4.829 (1.103 – 21.148)	0.037*
Analgesic ≤ 60 min: *n* (%)	15 (12.9)	9 (20.5)	1.731 (0.696 – 4.308)	0.320
Analgesic pre-radiography: *n* (%)	5 (4.3)	7 (15.9)	4.200 (1.257 – 14.035)	0.020*
Backslab pre-radiography: *n* (%)	19 (16.4)	27 (61.4)	8.108 (3.713 – 17.707)	0.000

*Fisher's exact test

Chapter 3.9 Figures

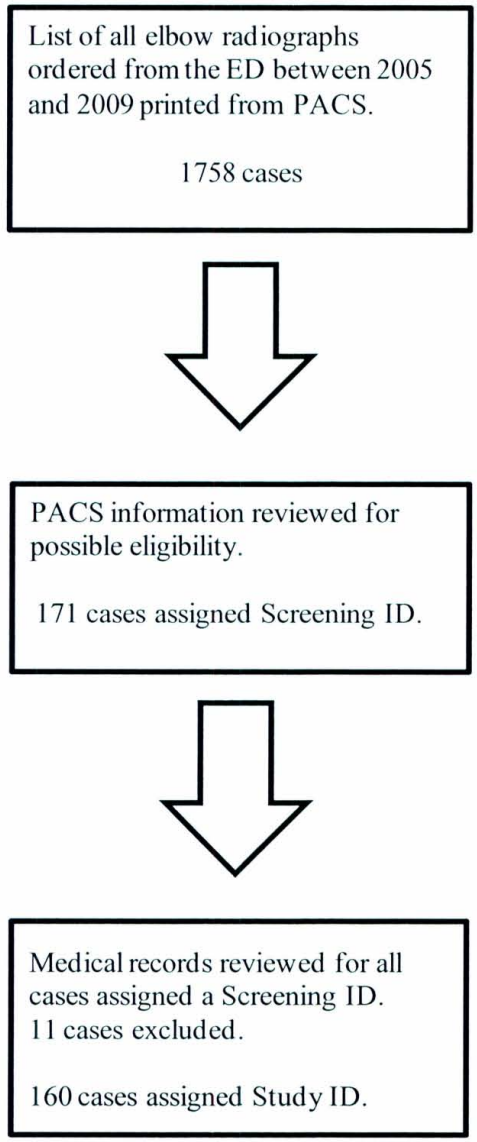

Figure 3-1 Sample selection

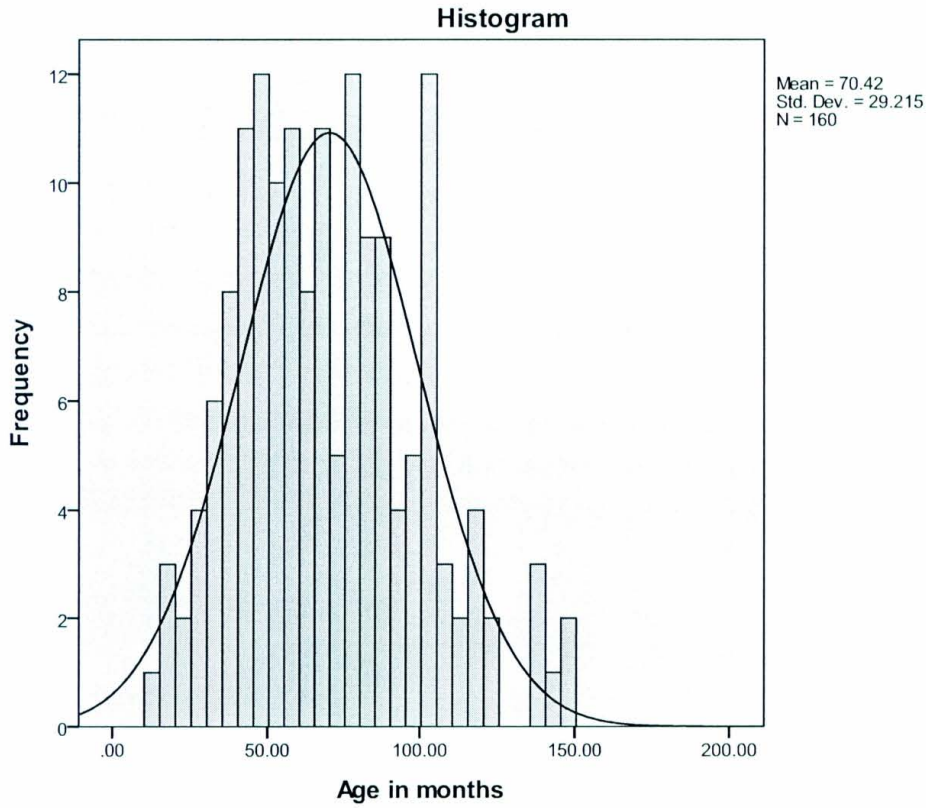

Figure 3-2 Age distribution of cases of supracondylar fracture: 2005 - 2009

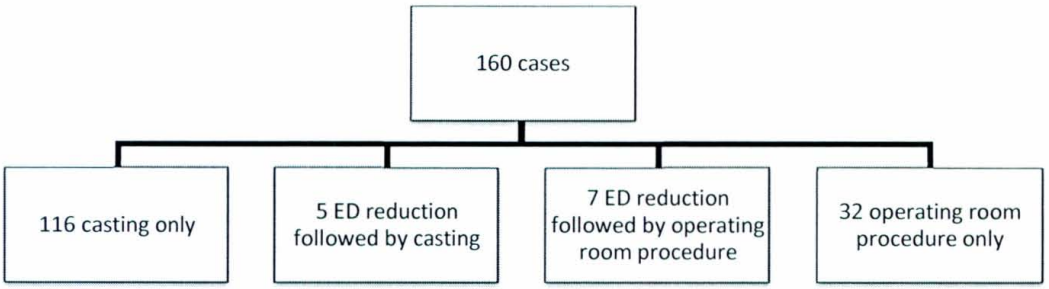

Figure 3-3 Summary of definitive treatment for cases of supracondylar fracture: 2005 - 2009

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
546.664	8.752	2	.013	7.846	2	.020	7.846	2	.020

a. Beginning Block Number 1. Method = Enter

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
Classification	.787	.275	8.196	1	.004	2.197	1.282	3.765
Age_in_months	-.001	.005	.032	1	.858	.999	.990	1.008

Figure 3-4 Output from Cox proportional hazards model for time to administration of first analgesic (cases with time > 60 minutes censored)

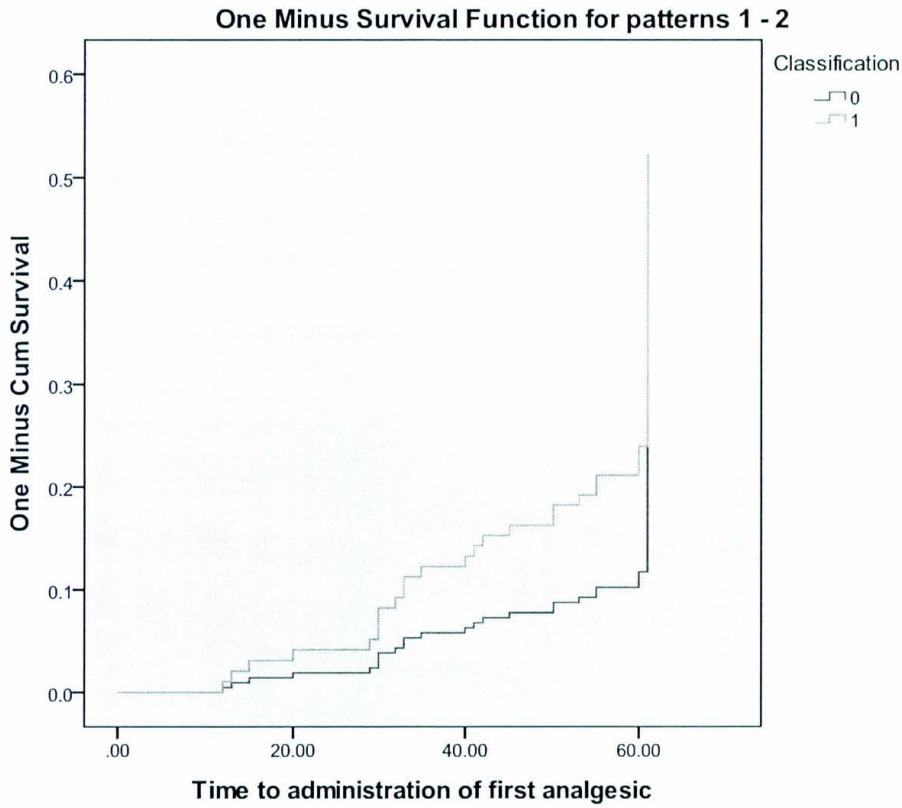

Figure 3-5 One minus survival curves for non-severe and severe cases of supracondylar fracture (cases with time > 60 minutes censored; curve for severe is closer to top of graph)

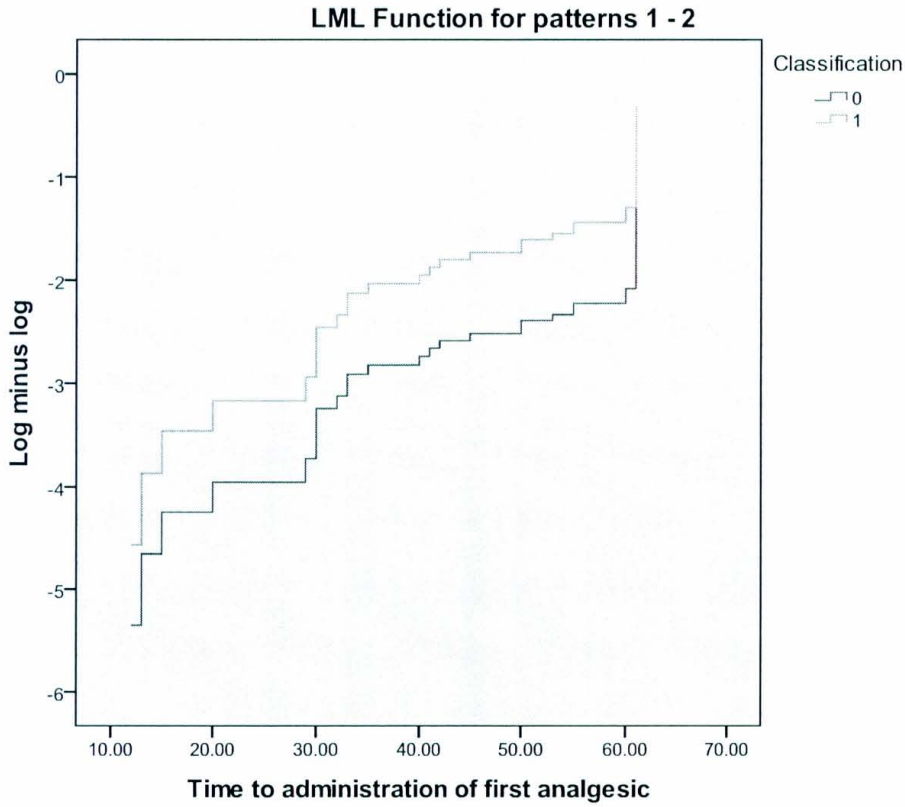

Figure 3-6 Log minus log functions for classifications non-severe and severe (cases with time > 60 minutes censored; curve for severe is closer to top of graph)

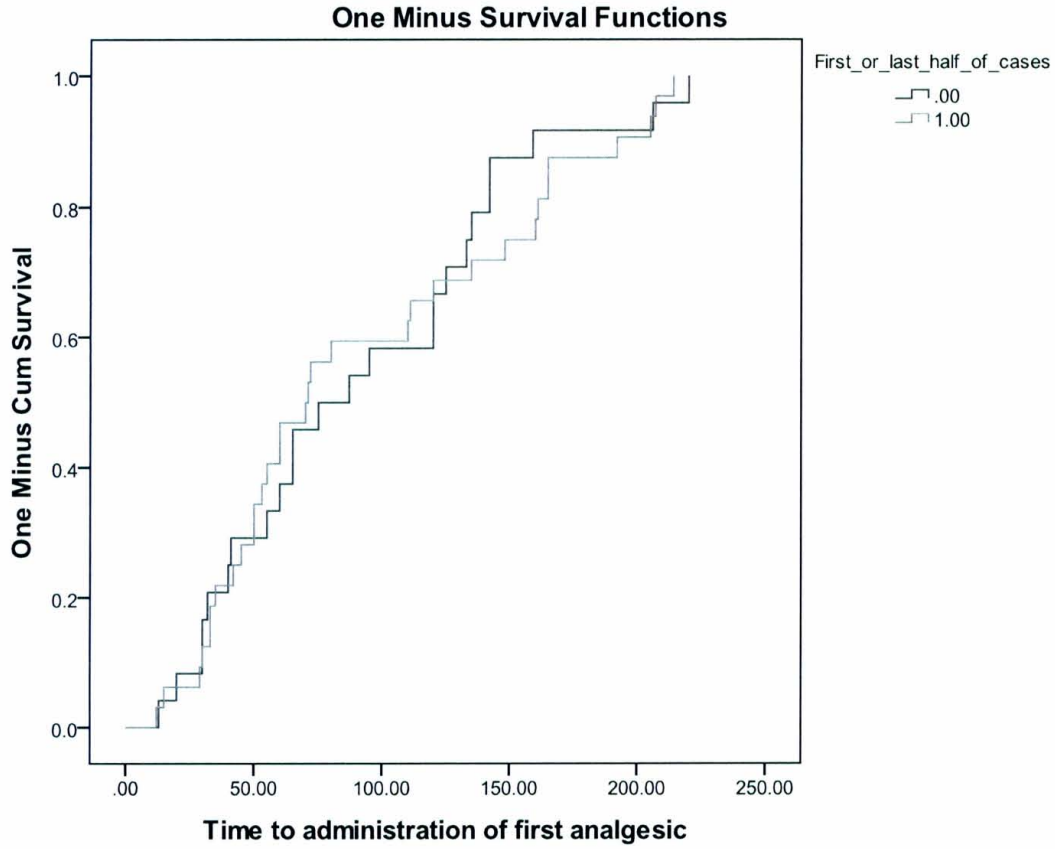

Figure 3-7 Kaplan-Meier survival curves for first and last 80 cases in sample (first half of cases = 0; last half of cases = 1)

Chapter 4 Discussion

Chapter 4.1 Characteristics of Patients and Emergency Department Visits

The age distribution and male predominance of patients with supracondylar fractures is consistent with previously reported data (29) (40), although one study reported a higher incidence in girls (30). The vast majority of the patients presented to the ED during the day (68.1%) or evening (31.3%), as expected for children in this age group. Most were triaged as a CTAS level 3 (79.4%) or level 2 (5.0%). If they were triaged solely on the basis of pain, it would indicate that over 80% of these children presented with moderate to severe pain (4 - 10 on a 10 point scale). There may have been other considerations, such as concern about the neurovascular status of a limb or perceived need for urgent immobilization; however, in these cases it is unlikely that pain would have been mild in intensity. Unfortunately, as no child had a formal pain assessment, intensity of pain must be inferred from the triage codes and the existing literature on the painfulness of this condition (34).

Chapter 4.2 Mechanisms of Injury

The most common mechanism of injury was a fall from a stationary object, followed by a fall from standing and a fall from a moving object. Falls from stationary objects most commonly involved household furniture, whereas more than half of the falls from moving objects involved trampolines or bicycles. Trampolines accounted for ten injuries: seven boys and three girls, ranging in age from 40 to 138 months. Three of these were severe injuries, requiring closed reduction in the ED in one case, and closed reduction and pinning in the operating room in the other two. Trampolines have been associated with many types of injury, including pediatric cervical spine injuries and death (41), and the Canadian Pediatric Society has recommended against trampoline use in home settings (42). In one study of trampoline injuries, 38% were upper limb fractures (43). Of the nine bicycle injuries, three were severe, and required pinning in the operating room after closed reduction. Thus, in this study, trampoline and bicycle use contributed a similar number of fractures, of which similar proportions were severe. Detailed data on the types

of activities contributing to falls from standing was not extracted. However, as a group, these activities accounted for more injuries and more severe injuries than trampoline use and bicycling combined.

Only three cases in the five-year period of this study required open reduction in the operating room. The mechanisms of injury for these cases were as follows: a fall from a swing in a 91-month-old girl; a fall from an electric all-terrain vehicle in a 44-month-old boy; and a fall from standing in a 35-month-old boy.

The mechanisms involved in the injuries in this study are generally related to common activities for children (climbing, walking, running, bicycling, trampoline use, etc.), and some injuries resulting from seemingly benign mechanisms were severe. It is important to note that the design of this study does not allow any conclusions about the risk of any activity. For example, while the numbers of fractures related to trampoline use and bicycling were similar, the time spent doing either activity is unknown.

The number and variety of specific mechanisms involved in these injuries make it unlikely that any one specific preventive intervention will have a large impact on the incidence.

Chapter 4.3 Comparison of Characteristics of Non-severe and Severe Cases

The children with injuries classified as non-severe were younger than those with severe injuries (mean age of 66.8 months versus 79.9 months). The mechanisms of injury were also different between the non-severe and severe groups, with a higher proportion of severe injuries resulting from a fall from a moving object. These differences might reflect the types of risky activities in which the older children participated, resulting in higher forces transmitted to the bones during a fall. The tendency for more significant trauma and an increased likelihood of displacement with increasing age in supracondylar fracture has been previously reported (44).

There was no significant difference in mechanism of injury between the five-years-old-and-younger and the older-than-five-years groups ($p = 0.083$). However, this does not rule out different mechanisms of injury accounting for the older age of children with severe injuries. First or all, the study was not designed to address this question. Secondly, the classification of mechanism of injury used might not correlate well with the forces involved in a fall.

Higher weight is unlikely to have been a factor in generating higher forces in older children, as there was no significant difference in the mean weight between the two groups. Other factors, such as age-related differences in bone development, might contribute to the higher frequency of severe injuries in the older children. It is also possible that the likelihood of intervention in an injury with a given degree of angulation or displacement may itself depend on the age of the child. Thus, conclusions based on the correlation of age and severity in this study are preliminary.

The observed difference between the proportions of non-severe and severe cases with initial medical contact with an EP versus a member of the house staff was not statistically significant. However, the trend is toward more of the severe cases being seen directly by the EP initially, as expected.

Chapter 4.4 Measures for Analgesia

Chapter 4.4.1 Analgesic Administration

The relatively frequent administration of ibuprofen as a first analgesic is consistent with evidence demonstrating favourable efficacy of this medication compared with other oral analgesics (19). Acetaminophen with codeine and codeine alone were used very infrequently, in keeping with concerns about codeine's safety and efficacy (22).

The most notable finding with respect to analgesic administration in this study is its complete absence in many cases. One hundred and four children did not receive an analgesic during the ED visit; of these, only six had received an analgesic prior to arrival.

Therefore, 98 of 160 children with an injury known to be associated with moderate to severe pain were discharged from the ED having received no analgesic at all since the injury. Twenty of these children had an injury severe enough to require intervention, either in the ED or operating room. Of the 98 children with no treatment for pain, time spent in the ED ranged from 93 to 299 minutes (there was missing data on discharge time for one non-severe and one severe case in this group of children), with an average time of 179.8 minutes. All of these children also had radiography performed with no analgesia.

Of the 56 children who did receive an analgesic in the ED, only 8 received the medication within 30 minutes of triage, only 24 within an hour and only 12 prior to having elbow radiographs. Thus, in those who did receive analgesia, it was frequently given relatively late.

While the literature suggests that younger children are less likely to be treated for pain than older children (24) (45), this was not confirmed in the present study. This may be due to evolving practice patterns in pediatric emergency medicine, and an increasing awareness, on the part of physicians and nurses, of the need to treat pain in young children. Alternatively, the lack of demonstration of an association with age might be due to the small number of cases receiving an analgesic.

Chapter 4.4.2 Comparison of Analgesic Use in Non-severe and Severe Cases

The primary hypothesis reflected a suspicion on the part of the author that factors related to injury severity (other than pain intensity) might play a significant role in determining whether patients receive early analgesic treatment. For example, rigid adherence to a policy of giving nothing by mouth to patients likely to require sedation or general anesthesia might delay analgesic administration until an IV line is established or the course of treatment becomes clearer. Additionally, children with more severe fractures might be more likely to have concomitant injuries, the assessment and care of which might divert attention from appropriate analgesia. In fact, the severe cases were more likely to receive an early ($\leq$ 30 minutes from triage) analgesic than were the non-severe

cases. This was presumably related to an awareness of physiological and behavioural cues to increased pain intensity in the severe cases, either through an undocumented standardized pain assessment or through a more qualitative assessment of the general condition of the child. When the proportions receiving an analgesic medication ≤ 60 minutes from triage were compared, more severe cases were treated, but the difference was no longer statistically significant. It may be that, in some of the severe cases, an urgent need for analgesia was identified by the triage nurse and attended to quickly, whereas in the ones not flagged in this way, a delay to medical care contributed to delayed analgesic treatment.

According to the Cox proportional hazards analysis (censoring cases where the analgesic was given more than 60 minutes from triage), correcting for age, in the time period for which analgesic administration might be considered appropriate, the instantaneous relative risk for being treated with an analgesic in the severe group was 2.197. This is consistent with more aggressive treatment of more severe injuries, but, as previously mentioned, this is in the context of a very low treatment rate in the comparison (non-severe) group.

As expected, treated children with more severe injuries were more likely to receive an opioid analgesic than those with non-severe injuries. The medications given early in the severe group were morphine (three cases, all by the SC route) and meperidine (two cases, both by the IM route). In fact, of the 24 severe cases treated with an analgesic during the ED visit, the route of drug administration was SC or IM in half of the cases. A possible reason for giving IM or SC medications to a child who went on to require an IV line is that the precise nature of the injury may have been uncertain prior to radiography, and therefore the disadvantages of giving a dose of IM or SC medication may have been judged to be offset by possibly avoiding an IV line in some children. Admittedly, the insertion of an IV line in a child is not necessarily an easy procedure and may require multiple attempts (as opposed to an IM or SC injection, which is reliably successful on the first attempt). However, in 5 of these 12 cases, the drug was administered after the

radiographs were done, when the need for an IV line for the purposes of sedation or anesthesia is more likely to have been determined. Another factor which may have come into play is the human resources situation in the ED. Insertion of an IV line in a child may require multiple personnel, especially if the child needs physical restraint. If a child was not ready for sedation or a procedure in the operating room (for example, not fasting), the priority may have been given to quick analgesia followed by more elective IV line insertion, when there was less ED activity. In addition, a child who has received an IV opioid requires closer monitoring and might need to be accompanied by a health care professional to the diagnostic imaging department. These possible factors should be explored in order to better provide timely and optimal care to these children.

For the purposes of the analysis, medications given as part of a procedural sedation protocol were considered to be analgesics. While these medications may not have been considered to be administered for analgesia, some do have analgesic properties, and administering another drug for analgesia at the time of sedation might not be considered appropriate or necessary. There were only two drugs in this category: propofol (one case), a potent sedative-hypnotic agent (46); and ketamine (five cases), which, while altering level of consciousness, also has a profound analgesic effect (47). Propofol has no direct analgesic properties; however, it can induce a deep level of sedation and is sometimes used without an analgesic (48). While considering these drugs as analgesics increased the number treated in the severe group, none of these agents was given within an hour of triage, so the numbers treated with an analgesic within 30 and 60 minutes are unaffected.

One troubling detail is that, of the twelve children treated with manipulation of the fracture in the ED, three were treated with morphine alone (one SC and one IM) and one with no sedation or analgesia. This likely reflects a number of factors, including availability of human resources for appropriate sedation and analgesia.

Chapter 4.4.3 Immobilization of the Fractured Extremity

Just over a quarter of cases were immobilized appropriately prior to radiography. Appropriate immobilization was much more common in the severe group of patients (over 60% versus approximately 16%). The low rate in non-severe injuries may have, in part, been related to cases where the injury was subtle and the suspicion of fracture low. More concerning is the number of severe cases (almost 40%) not immobilized prior to radiography. Standard radiographs taken for a suspected elbow fracture are a lateral view with the elbow at 90 degrees of flexion and an anterioposterior view in full extension. Children with supracondylar fractures hold the joint in a position of comfort, typically between 20 and 30 degrees of flexion (27). While the absence of the backslab will potentially allow better positioning and finer detail to be visible (the backslab itself, whether fibreglass or plaster, will obscure detail to some degree), it is likely that a child with mild to moderate pain in the ED will have excruciating pain if positioning of the fracture for radiography is attempted (7). In addition, lack of immobilization puts the child at risk of neurovascular damage if the elbow is positioned for radiography, underscoring the critical importance of proper immobilization as part of initial management of these injuries (27). It is worth noting that all of the cases were immobilized at some stage, as immobilization is a final common pathway for treatment of these injuries; the only disadvantage of early application is suboptimal radiograph quality. This can be ameliorated by removing the backslab and repeating the radiographs with manual immobilization in equivocal cases.

A smaller proportion of patients seen initially by house staff had application of a backslab prior to radiography when compared to patients seen directly by the EP. This difference was most marked in cases with more severe injuries. The house staff involved included residents of various disciplines as well as medical students. In the case of medical students, a physician order (normally by the attending EP) would be required for a radiograph, whereas EP involvement in ordering radiographs in patients seen by residents is likely to have been variable. It is likely that, for children seen initially by house staff, examination by the EP prior to radiography was not a consistent practice. It is important

to note that even in severe injuries seen directly by the EP, 25% had radiography without immobilization. Therefore, any attempt to improve the appropriate use of backslabs must involve education and policies directed not simply at house staff, but at staff EPs as well.

One method of partial immobilization of an upper extremity fracture is sling placement. This was not examined in this study. Unlike placement of a backslab (which can be determined by examination of the radiographs), sling placement might be uncertain, as it might not be consistently documented. In addition, unless the sling is accompanied by a backslab, it has the disadvantage of being easily removed for positioning for radiography.

Chapter 4.5 Biases and Limitations

The method of selection of the cases for this study was such as to reliably provide a consecutive sample of cases seen in the ED by EPs. Exclusion of cases referred directly to an orthopedic surgeon has potential to bias the sample by excluding more severe than non-severe injuries; however, the predominant factor determining the initial attending physician in the studied ED is not the severity of injury. Rather, it is whether the injury occurred in the catchment area of the ED or in a more distant region (where the child might first be assessed in a peripheral hospital prior to being transferred to the ED). Given that the ED is the only one treating children in the St. John's region, it is likely that the sample approximates very well the number and types of injuries seen in the local population. While including direct referrals would provide more data, it would also add a level of complexity to the study, as these patients are different from others in that they arrive at the ED when an attending physician may not be in the ED or even in the building.

The purpose of this study was to look at the timeliness of analgesic administration. As such, the accuracy of recorded times is critical. This is a potential source of error, as different electronic clocks recorded the times of registration and radiography, and these were not synchronized. Other times were recorded by medical, nursing or administrative personnel, and are subject to the errors of personal timepieces and the ED clocks.

However, there is no expected pattern to these errors and it is unlikely that they would affect the outcomes of the study to a significant degree. In addition, the application of a backslab before radiography was determined solely by visualization of a backslab on the initial radiographs, without reference to specific times.

A weakness of this study is the absence of a record of formal pain assessments, a result of the local ED practice pattern. Without such assessments, the study relies heavily on the inference of the presence and severity of pain from the literature. Had formal pain assessments been consistently performed and recorded, the results would have been strengthened. However, it is important to realize that such assessments may also have affected the outcomes, so the study does provide a good picture of pain treatment in an ED without routine formal pain assessment.

This is a single centre study, and the generalizability of the results is weakened by this design. There are important characteristics of the ED studied that are significantly different from some other EDs in Canada. The lack of routine documented standardized pain assessments and a medical directive permitting nurses to administer analgesics without a physician's order preclude generalizability of the results to institutions with either of these in place. The ED studied is a pediatric ED in a university-affiliated hospital, and the findings may not reflect practices in EDs where both children and adults are seen. In addition, during part of the period from which the sample was drawn, there was no certified pediatric emergency medicine physician on staff; this is not expected to be the case in other Canadian pediatric EDs. The findings of this study are not generalizable to settings other than EDs.

The fact that a single painful condition was studied potentially limits the generalizability of the findings. However, there is no unique feature of supracondylar fracture that is likely to preclude generalizability to other upper extremity injuries and orthopedic injuries in general.

Confounding factors that might affect the non-severe and severe cases differently could include differences in the consistency of documentation of analgesic administration in the ED, and in rates of undocumented pre-hospital analgesic administration. However, institutional policy dictates that all medications administered in the ED be documented in the medical record, and that each patient have details of any pre-hospital medications documented on the triage record (there is a specific line on the triage record for this to be documented). The rate of administration of pre-hospital analgesia was very low in this study. It is possible that some parents may have interpreted questioning about medication history as an enquiry into regular medication use and not medication taken acutely for pain, especially an over-the-counter product. The absence of information on the dosage of pre-hospital analgesics may reflect a combination of uncertainty on the part of the parents and lack of inquiry or documentation.

Other than for the most severe injuries, there are likely to be some differences in practice patterns among the orthopedic surgeons. These differences might include the amount of deformity considered acceptable to be treated with casting and follow-up alone, or acceptable position after a closed reduction. As a consequence, some injuries treated with closed reduction in the ED might have been treated with simple casting by another surgeon, and some (more serious) injuries treated with closed reduction in the ED might be treated in the operating room by another surgeon. It is also possible that treatment at the studied institution differed significantly from treatment at other institutions.

This study used the type of definitive treatment as a proxy for injury severity. An alternate method of determining severity of injury would be to use the well-known Gartland radiographic classification system. However, the Gartland classification is not always reported by radiologists, and significant inter-observer variability in grading by orthopedic surgeons has been demonstrated (49). In addition, correlation of the Gartland classification with the need for intervention is imperfect, and the method used in this study was designed to allow analysis of factors associated with intervention that might impact analgesic use.

Finally, classification of the injuries as supracondylar fractures was on the basis of radiologists' reports. Particularly for the more severe and complex fractures, there is likely to be variability in nomenclature applied by different radiologists, leading to some inconsistency in inclusion of cases.

Chapter 4.6 Strengths of the Study

This study has a number of strengths. A consecutive sample was used and few cases were excluded after examination of the medical record, limiting selection bias. The fact that the sample includes children presenting over a number of years adds to the rigour of the study and also allows demonstration of the consistency of practice patterns during that period of time.

Limiting the sample to children with a single type of injury has provided an opportunity to study the details of pain management in an important pediatric condition. Not only have different modalities for analgesia (immobilization and systemic analgesics) been studied for children with the same diagnosis, but pain management in different severities of injury has been explored in this well-defined condition. The results suggest significant opportunities for improvement and should inform knowledge translation efforts and policy development for supracondylar fracture specifically, and painful orthopedic conditions in general.

Chapter 4.7 Future Knowledge Translation and Research

Clearly, the low incidence and poor timeliness of analgesic measures demonstrated in this study is unacceptable; equally clear from the literature is that change in this area is challenging. Pain assessments are universally recommended, but even when they are done consistently, excellent outcomes are still difficult to achieve (39). That fact notwithstanding, mandatory formal pain assessment and reassessment will be an important measure to institute in the studied ED in an attempt to address inadequate analgesia in the pediatric population. Another measure that will be promoted is the

institution of a medical directive allowing triage nurses to administer appropriate analgesia at triage. For residents and medical students rotating through the ED, information regarding the importance of appropriate pain management, including immobilization of painful or unstable fractures, will be included in their orientation materials.

Communication of the results of this study to EPs and ED nurses in an attempt to raise awareness will also be helpful. Posters in the triage and treatment areas of the ED may serve as reminders of the importance of pain treatment as part of the overall management of traumatic and other conditions.

A reassessment of pain management practices in children with supracondylar fracture, a year after the institution of routine pain assessments and triage-nurse-administered analgesics, is also planned. Documented pain assessment and timely analgesic administration should be quality indicators for the ED and published on a regular basis.

Future research should focus on further understanding the barriers to timely analgesia and consistent use of non-pharmacological methods of pain control, as well as determining the most effective methods to overcoming these barriers and translate existing knowledge to the busy ED environment. This may involve qualitative research as well as measuring the effectiveness of interventions.

Chapter 4.8 Conclusions

This study shows that, in the particular setting studied, proven methods of reduction of pain in children are underutilized. By limiting the study to a single injury type, some of the variability associated with diverse injuries was eliminated, and an attempt was made to determine if any other factors, including severity of injury, were associated with analgesic measures in the ED.

While addressing overall analgesic use, this study attempted to focus on early analgesic measures. This is a more appropriate indicator of performance than overall administration rate, which has previously been documented to be low in a number of settings. Even though this study addresses a specific painful injury, the injury is similar in many ways to other painful injuries encountered in the ED, and it is likely that pain management would be similar in those cases.

Physicians and nurses who care for children do not wish to see them suffer needlessly, and one would expect those working in an ED environment to both understand the moral and clinical imperatives to adequately treat pain, and possess the requisite knowledge and skills to do so. Yet children experience more pain than necessary, and the need for this aspect of care to change, through translation of existing knowledge, is acute. This change may require education of staff, development of protocols and changes in attitudes (15). Education about pain assessment and treatment as priorities must be integrated into curricula beginning at the medical, nursing and pharmacy school levels, and must continue through continuing education for clinicians. Emphasis on pain control as an important clinical goal may help to change attitudes, so that physicians and nurses are not only more comfortable administering analgesic measures in children, but give this a higher priority. The development and implementation of protocols requiring mandatory assessment and documentation of children's pain in the ED may increase utilization of treatments proven to reduce pain. Also, medical directives, whereby analgesics may be administered by triage nurses, may obviate one barrier to treatment in a busy emergency department: excessive time to physician assessment. As these changes occur, attitudes may change as better treatment becomes the norm.

Quality improvement methods have shown efficacy in improving the timeliness of acute pain treatment in children (50). An interesting approach to the problem of pain under-treatment is to treat it as a medical error (51). Normally, an excessive dose of analgesic inadvertently administered would be treated as a medical error and addressed from a quality assurance perspective. Likewise, a medical error has occurred in a situation where

no analgesic measures are taken when they are indicated; or when an inappropriately low (or late) dose of analgesic is administered; or when a fracture is inappropriately radiographed with no prior immobilization. Treating these situations from a quality assurance point of view and bringing to bear the associated procedures and infrastructure, might succeed where other efforts have failed.

As reflected in the results of this study, optimal treatment of acute pain in children in a busy ED, where children of all ages present with often undiagnosed conditions, remains a challenge. However, through continuing research and perseverance in translating existing knowledge of pharmaceutical, physical and psychological methods of treatment and prevention of pain, practice can change.

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Appendix A

Supracondylar Fracture Registry

Patterns of Interventions for Analgesia in Children Presenting to a Pediatric Emergency Department with Supracondylar Humerus Fracture

SupraCondylar Fracture Registry

PACS Screening ID #	Date Of Radiograph (DD/MM/YY)	Time of Radiograph (24 hr clock)	Ages≤12yrs (Y/N)	ERP (Y/N)	Acute Trauma (Y/N)	Supracondylar Humerus Fracture (Y / N)	Eligible (Y/N)	Radiograph Through plaster (Y/N)	Screening ID #	Study Enrolment #

Appendix B

Chart Review Data Collection Sheet (page 1)

Use of Analgesics and other Interventions for Treatment of Supracondylar Fractures in the ED

Screening ID # _____

Exclusion Criteria (all answers must be NO)

Referred from elsewhere with backslab	_____ Yes	_____ No
Referred directly to orthopedics	_____ Yes	_____ No
Intubated on arrival or during ED visit	_____ Yes	_____ No

Eligible _____ Yes _____ No

Study Enrolment ID # _____

Chart Review Data Collection Sheet (page 2)

Study Enrolment ID # _____

Demographics

Age (in months) _____ months

Gender _____ male _____female

Weight (kg) _____

History

Date of ED visit (DD/MM/YY) _____

Time of ED visit (24 hour clock) _____

Triage code (CTAS) _____

Triage time (24 hour clock) _____

Triage pain assessment (scale 1-10) _____ Not documented on chart _____

Site of injury _____ Lt arm _____ Rt arm

Time seen by medical staff (24 hour clock) _____ Not documented _____

Time radiograph taken (24 hour clock) _____

Analgesia measures pre-hospital

Analgesia given pre-hospital _____ Yes _____ No

Analgesic drug name _____ Not documented _____

Dosage (mg) _____ Not documented _____

Time (24 hour clock) _____ Not documented _____

Chart Review Data Collection Sheet (page 3)

Study Enrolment ID # _____

Analgesia Measures in the ED

1st analgesic given in the ED

Drug name (generic) _____

Drug class _____ Narcotic _____ Non-narcotic

Dose (mg) _____

Route _____ oral

_____IM

_____SC

_____IV

Time given (24 hour clock) _____

2nd Analgesic given in the ED

Drug name (generic) _____

Drug class _____ Narcotic _____ Non-narcotic

Dose (mg) _____

Route _____ oral

_____IM

_____SC

_____IV

Time given (24 hour clock) _____

3rd analgesic given in the ED

Drug name (generic) _____

Drug class _____ Narcotic _____ Non-narcotic

Dose (mg) _____

Route _____ oral

_____IM

_____SC

_____IV

Time given (24 hour clock) _____

Chart Review Data Collection Sheet (page 4)

Study Enrolment ID # _____

Timeline for Analgesia

Analgesia given pre-radiograph _____ Yes _____ No

Backslab applied pre-radiograph _____ Yes _____ No

Patient 1st seen by _____ ED Physician

_____ House staff (clinical clerk, intern, resident)

Patient location post triage _____ observation room

_____ trauma room

_____ examination room

Closed reduction in ED _____ Yes _____ No

OR required _____ Yes _____ No

OR procedure _____ Yes _____ No (closed reduction)

_____ Yes _____ No (pinning)

_____ Yes _____ No (open reduction and internal fixation)

Injury classification _____ Severe _____ Non-severe

Discharge date from ED _____

Discharge time from ED _____

Admitted _____ Yes _____ No

_____ _____

Research personnel (print) Signature Date