



Tendency towards operative treatment is increasing in children's fractures: results obtained from patient databases, causes, impact of evidence-based medicine

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- Results of numerous studies assessing the national or the local patient databases in several countries have indicated that the overall rate of operative treatment in fractures, as well as the rate in certain upper and lower limb fractures, has significantly increased in children. The most prominent increase in the rate of operative treatment was observed in forearm shaft fractures.
- Results of several survey studies have revealed that there was not a high level of agreement among paediatric orthopaedic surgeons concerning treatment preferences for several children's fractures.
- The reasons for the increasing tendency towards operative treatment are multifactorial and patient-, parent- and surgeon-dependent factors as well as technological, economic, social, environmental and legal factors seem to have an impact on this trend.
- It is obvious that evidence-based medicine is not the only factor that leads to this tendency. A high level of scientific evidence is currently lacking to support the statement that operative treatment really leads to better long-term outcomes in children's fractures. Properly designed multi-centre clinical trials are needed to determine the best treatment options in many fractures in children.

Keywords: children's fractures; evidence-based medicine; operative treatment

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Introduction

Trauma in children has been increasing in the last decades. According to Landin, fractures constitute 10–25% of all injuries in children.¹ About 2% of children sustain at

least one fracture each year.² In 1955, Walter P. Blount in the introductory sentence of the classic textbook *Fractures in children* wrote: 'A book about fractures in children is needed by the general physician, the general surgeon, and, I fear, many orthopaedists'.³ According to Blount, operative treatment in children's fractures was rarely indicated and this belief was based on the metabolic, anatomic and physiologic characteristics of the skeleton in children, which would lead to rapid fracture healing and remodelling with lower rate of complications. Besides, he warned surgeons about having limited knowledge of the non-operative treatment principles and about becoming impetuous to extensively approach the fracture sites and perform internal fixation in children's fractures.³ In 1984, in the first chapter of the textbook *Fractures in children*, John A. Ogden wrote: 'As a general principle, open reduction and internal fixation are contraindicated in children, as such intervention is rarely necessary and may delay normal healing patterns, but certain fractures such as lateral humeral condyle, femoral neck or open fractures are more effectively treated by operative intervention'.⁴ The reported rate of operative treatment in children's fractures remained very low until the 1980s; in the early 1950s it was 1.4% and 4.7% in two different studies^{5,6} and in the early 1980s it was 3.8% in one study.⁷ Thus, 'non-operative treatment dogma' in children's fractures was followed by many surgeons for a long period of time. Kaye E. Wilkins, one of the masters for skeletal trauma in children was one of the first to call attention to specific fractures that would need operative intervention, and he noted that he was criticized by a number of senior orthopaedic surgeons for setting a dangerous example by producing a textbook concerning the operative treatment of upper limb fractures in children in 1990s.⁸ Due to several problems seen in the diagnosis and non-operative treatment of elbow fractures in children, the elbow chapter of the

Mercer Rang's *Children's fractures* textbook started with the statement 'pity the young surgeon whose first case is a fracture around the elbow' in 1983.⁹ Then this statement was revised to 'save pity for the old surgeon unacquainted with the advances that have taken place in the diagnosis and treatment of elbow fractures as modern methods have improved outcome but are more technical' in the 1990s.¹⁰

There has been an increasing reliance upon technology in the 21st century, and significant beneficial technical innovations have been seen in medicine over the years. Besides, changes in recreational activities, a growing trend in participating in sports activities and an increasing rate of motor vehicle accidents have caused certain injury patterns in children.^{11,12} It seems that the strict non-operative treatment preference in children's fractures has lost its past popularity, and surgeons' decisions have become more flexible over the years. Thus, a tendency towards operative treatment has gradually increased over the last three decades. However, two significant questions simultaneously have arisen. First, are surgeons becoming more impetuous and developing a more aggressive way of thinking or producing better results with operative treatment?^{28,13} Second, does evidence-based medicine support the increased tendency towards operative treatment in children's fractures? The age and weight of the patient, site, type and severity of the fracture, associated injuries, social and economic factors and other patient-, surgeon- or institution-dependent factors are currently the most cited factors influencing the choice of treatment in children's fractures.¹⁴

The aim of this study was to examine the increased tendency towards operative treatment in children's fractures by evaluating the results obtained from national or local patient registry systems as well as the conclusions drawn from several surveys assessing surgeons' treatment preferences in children's fractures. In addition, the study aimed to assess the causes of the increased tendency and to determine whether or not this increased tendency has been supported by evidence-based medicine.

Results obtained from national or local patient registry systems

The data in the existing literature for exactly determining the changing treatment trends in children's fractures are somewhat conflicting. The methodologies of the studies in the literature are not homogenous due to significant differences in several variables including age interval of the included patients, types of the admitted patients (inpatient or outpatient), definitions and classifications of the fractures, definitions of the treatments and the geographical areas where the studies were conducted.

Data obtained from the national registry systems of several countries or from local institutional archives contributed to the knowledge concerning changes in the treatment preferences in children's fractures. Most of these observational studies were conducted in the Scandinavian countries and in the United States. The results of three different studies indicated that the overall rate of operative treatment in children's fractures has significantly increased (Table 1).¹⁵⁻¹⁷ It was seen that forearm fractures had a significant impact on the increase in the overall rate of operative treatment in children's fractures (Table 1). In addition, the introduction of minimally invasive techniques to daily practice seemed to contribute to the mentioned increase in the rate of operative treatment (Table 1).

In terms of upper limb fractures, the researchers commonly focused on the changing treatment patterns in forearm fractures which have developed a considerable tendency towards operative treatment over the years (Table 2).¹⁸⁻²¹ While intramedullary nailing was gaining popularity, closed reduction and casting seemed to lose its privilege in the treatment of forearm fractures over the years (Table 2). Non-operative treatment was mostly preferred and a considerable tendency towards operative treatment was not seen in distal radius fractures (Table 2).²² Operative treatment, particularly by closed reduction and percutaneous fixation, became more preferable in humerus distal fractures and the tendency towards operative treatment

Table 1. Overall fracture treatment preferences obtained from national and local institutional patient databases

Source	Content	Results
Medical Records of one centre in Hong Kong between 1985 and 1995 ¹⁵	≤ 16 years, hospitalized for fracture treatment, 6493 fractures in 6389 children	<ul style="list-style-type: none"> – No significant change in the overall rate of limb fractures requiring hospitalization – Closed reduction and percutaneous fixation increased from 3% to 22% and open reduction decreased from 29% to 14% – Distal radius, supracondylar humerus and forearm shaft fractures had the greatest change in treatment pattern
National Hospital Discharge Register data in Finland between 1997 and 2006 ¹⁶	< 18 years, hospitalized for fracture treatment, 37271 fractures	<ul style="list-style-type: none"> – Overall rate of primary fracture surgery increased by 20% – Rates of surgery for upper limb, lower limb and axial fractures increased by 28%, 4% and 11%, respectively – Rate of forearm fracture surgery increased by 62% – Rate of closed reduction and casting did not change significantly
Patient Database of one centre in Norway, between 2004 and 2007 ¹⁷	< 16 years, hospitalized for fracture treatment, 964 fractures	<ul style="list-style-type: none"> – 61% of the fractures were treated by closed reduction and casting, 31% by percutaneous fixation including pinning and nailing and 8% by internal fixation

Table 2. Upper limb specific fracture treatment preferences obtained from national and local institutional patient databases

Source	Content	Results
Kids' Inpatient Database in US between 2000 and 2012 ¹⁸	≤ 20 years, admitted to hospital with closed diaphyseal forearm fractures, 30936 fractures	– 64.12% were treated operatively – Rate of operative treatment increased from 59.3% to 70.0%
Medical Records of one centre in Eastern US between 1997 and 2008 ¹⁹	≤ 16 years, diaphyseal forearm fractures, both inpatients and outpatients, 2297 fractures	– There was a seven-fold increase in operative treatment – Intramedullary nailing was the most preferred fixation method (69%) in the operated patients
National Hospital Discharge Register data in Germany between 2002 and 2017 ²⁰	≤ 19 years, all hospitalized upper limb fractures excluding hand (about 35000 to 38000 fractures per year)	– The number of hospitalized clavicle and forearm fractures increased – This indicated a trend towards operative treatment in clavicle and forearm fractures
Patient database of one centre in Finland between 2000 and 2009 ²¹	< 16 years, forearm middle third both bone fractures, both inpatients and outpatients, 168 patients	– Closed reduction and casting decreased from 87% to 55% – Internal fixation increased from 13% to 45%
Truven MarketScan Commercial Claims and Medicare Supplemental Research Datasets in US between 2010 and 2015 ²²	≤ 17 years, distal radius fractures, both inpatients and outpatients, 27253 patients	– 97% were treated non-operatively – The rate of internal fixation remained the same during the study period
Humana and ING Administrative Claims Databases and NEDS Database in US between 2007 and 2014 ²³	< 15 years, supracondylar humerus fractures, both inpatients and outpatients, 29642 patients	– Operative treatment was performed in 24% of the patients – Closed reduction and percutaneous fixation (CRPF) was performed in 87% of the operatively treated patients – A considerable tendency towards CRPF was seen over time – No significant change in operative rate over time
National Hospital Discharge Register data in Finland between 1987 and 2010 ²⁴	< 19 years, hospitalized patients with distal humerus fractures, 12585 hospitalizations	– 44% were operatively treated – Rate of closed or open reduction with internal fixation increased five-fold in patients aged ≤ 6 years, two-fold in patients aged 7–12 years and did not change in patients aged 13–18 years
National Hospital Discharge Register data in Finland between 1987 and 2010 ²⁶	≤ 16 years, hospitalized patients with humerus shaft fractures, 1165 hospitalizations	– Internal fixation was performed in 28% – The rate of operative treatment remained steady – The rate of operative treatment was lowest in the 0–6 year age group and highest in the 13–16 year age group
Patient database of one centre in Finland between 2005 and 2015 ²⁵	< 16 years, proximal humerus fractures, both inpatients and outpatients, 300 patients	– Non-operative treatment was commonly preferred – Operative treatment rate changed from 0% to 16%
PearlDiver Patient Records Database in US between 2007 and 2011 ²⁷	10–19 years, clavicle shaft fractures, both inpatients and outpatients, 14683 fractures	– A significant increase in operative treatment was seen – This increase was more evident in the 15–19 year age group

Table 3. Lower limb specific fracture treatment data obtained from nationwide and local patient databases

Source	Content	Results
Kids' Inpatient Database in US between 1997 and 2012 ²⁸	< 8 years, admitted to hospital with closed femur shaft fractures, 22054 fractures	– The absolute increases in internal fixation were 35% and 58% in 4-year-old and 5-year-old patients, respectively
National Hospital Discharge Register data in Sweden between 1987 and 2005 ²⁹	≤ 14 years, hospitalized femur shaft fractures (pathologic and neuromuscular ones excluded), 4984 patients	– The rate of traction treatment decreased from 60% to 9% – The rate of intramedullary nailing increased from 5% to 34% – The average length of hospital stay was reduced by 81%
Kids' Inpatient Database in US between 2000 and 2012 ³⁰	≤ 20 years, admitted to hospital with tibia shaft fractures, 24166 fractures	– 64.7% were treated operatively – Rate of operative treatment increased from 57.3% to 74.3% – The greatest increase (about two-fold) was seen in the 5–9 year age group
Medical Records of two centres in Finland between 2010 and 2015 ³¹	< 16 years, tibia shaft fractures, both inpatients and outpatients, 296 patients	– 69.6% of fractures was treated non-operatively – Operative treatment was commonly preferred in open or multiple fractures

was more marked in younger children with such fractures (Table 2).^{23,24} A tendency towards operative treatment was even seen in humerus shaft, humerus proximal and clavicle shaft fractures in which non-operative treatment was commonly preferred (Table 2).^{20,25–27} While operative treatment was more preferable in adolescent patients with humerus and clavicle shaft fractures,^{20,26,27} the exact reason for the increasing rate in operative treatment remained unclear in humerus proximal fractures.²⁵

In the lower limb, it was noted that the rate of operative treatment, particularly by intramedullary nailing, significantly increased in femur shaft fractures and that even younger children with femur shaft fractures were increasingly treated by operative means (Table 3).^{28,29} The data about the rate of operative treatment in tibia fractures were conflicting, however, school-aged children, open and multiple fractures were increasingly treated by operative means (Table 3).^{30,31}

Results obtained from surveys

A couple of survey studies about the treatment preferences of paediatric orthopaedic surgeons in different fractures in children, exist in the literature. In one survey, non-operative treatment was commonly preferred in all patterns of adolescent midshaft fractures by paediatric orthopaedic surgeons; however, the tendency towards operative treatment increased in older adolescents.³² In two other survey studies, substantial variations about the treatment methods of medial epicondyle³³ and distal radius³⁴ fractures in children were seen among paediatric orthopaedic surgeons.

What are the causes of the increasing tendency towards operative treatment?

The increasing tendency towards operative treatment in children's fractures is a shift that has occurred slowly over the years. The causes are multifactorial and can be summarized as follows:

1. Impressive and continuous innovations in the medical technology have allowed surgeons to use minimally invasive operative techniques and to fix fractures with biologically compatible and stable instruments such as flexible intramedullary nails.^{8,12,35} This can be seen in the data presented in this review (Tables 1, 2 and 3). Easier availability and effective advertising of the new technologies may push surgeons to perform more operations using newer implants.³⁶
2. Parents and patients are currently aware of recent advances in the treatment modalities. They are increasingly asking their physicians whether or not more aggressive methods are preferable for obtaining perfect results and for efficiently regaining daily functionality or returning to sports activities as early as possible.^{36,37} This may push surgeons to prefer operative treatment in fractures.
3. Many fractures can cause significant morbidity in children and can be a social burden on families.¹¹ Longer hospital stays due to traction therapy or a longer casting period which avoids mobilization may lead to emotional disturbances and psychological stress in children^{8,38} as well as difficulties in adapting to a normal life for families.³⁹ Operative treatment may provide shortened hospital stays, early mobilization and rapid recovery³⁵ and these are also beneficial from an educational perspective for children.^{37,39} On the other hand, it should be kept in mind that operative treatment may initially cause more anxiety and depressive reaction than non-operative treatment does in older children and adolescents.⁴⁰

A longer hospital stay or prolonged sickness period of their children may increase the business, economical and psychological stress of the parents.^{8,37,39} Such pressures may force surgeons to operate.

4. Health services have improved in many countries and injured children can currently be treated in specialized paediatric medical centres by specialized surgeons who are probably more prone to operative treatment.⁴¹ Besides, outpatient fracture care facilities are improving, particularly for low-energy isolated limb injuries treated using both open and percutaneous procedures. This may lead to an increase in the operative treatment rate, particularly in ambulatory surgery centers.⁴²
5. Operative treatment may be more convenient than non-operative treatment in particular treatment settings where the use of conscious sedation is limited or in geographical areas where a close follow-up is not available.³⁶
6. The training programmes of orthopaedic residents and fellows have become more and more focused on operative techniques.³⁶ The training of non-operative skills in children's fractures seems to be underestimated in these programmes.⁸
7. Industry provides considerable financial and scientific support to surgeons for developing and utilizing new surgical implants and techniques. This may be considered as the 'surgeon's bias', and may influence the choice of treatment in certain circumstances.³⁶
8. A litigious environment may influence the choice of treatment particularly in elbow, forearm, wrist and hand fractures.^{37,43} The reported devastating vascular complications⁴⁴ and an increased risk of a secondary hospital treatment⁴⁵ in several fractures initially treated non-operatively may push surgeons to operate such fractures to avoid malpractice claims, arbitration or court procedures. On the other hand, non-indicated operative treatment may cause similar claims and procedures.⁴³
9. Childhood obesity is becoming a serious problem in many countries. Obesity can influence the efficacy of non-operative treatment and the rate of failure in cast immobilization can be higher than expected in obese children.⁴⁶ Therefore, obese children with upper and lower limb fractures are more prone to undergo operative treatment.⁴⁷

Does evidence-based medicine support the increasing tendency towards operative treatment?

Humerus supracondylar fractures, femur shaft fractures and forearm fractures can be considered as the three paediatric fractures in which surgical treatment has gained

more and more popularity over the years.^{8,37} Fixation of the humerus supracondylar fractures by percutaneous K-wire fixation, and closed reduction and fixation of the forearm and femur shaft fractures by flexible intramedullary nails have become worldwide popular over the years and encouraging results have been reported in many studies about the mentioned topics. However, most of the knowledge about the treatment of children's fractures has been drawn from level IV and V studies. Although a significant tendency towards operative treatment of children's fractures exists, the use of non-operative treatment in many fractures cannot be underestimated. Clinical guidelines are available for several fractures, but it is not possible to state that all these guidelines are dependent on high-level scientific evidence.⁴⁸ On the other hand, it should always be kept in mind that performing prospective randomized double-blind controlled clinical trials in the field of children's fractures may have particular ethical limitations.

It was reported that the scientific data obtained from the majority of the paediatric upper extremity fracture studies presented at the annual meetings of the Pediatric Orthopaedic Society of North America and American Academy of Orthopaedic Surgeons between 1993 and 2012, could not strongly support the increasing aggressive treatment trend in such fractures. More aggressive treatment modality was recommended in only one fourth of these studies and was commonly favoured in case series not in comparative studies and in studies with small sample sizes not with large sample sizes. It was concluded that there was a divergence between the evidence-based medicine and clinical practice in the treatment of children's upper limb fractures and that it was not possible to state that the tendency towards operative treatment was primarily based on high-level scientific evidence.³⁶

Distal third forearm fractures are the most common fractures in children and most of these fractures can be treated using closed reduction and casting. The scientific evidence on whether percutaneous fixation has better long-term functional outcomes than closed reduction and cast immobilization in displaced distal radius fractures is limited.⁴⁹ Although the rate of operative treatment in forearm fractures has increased over the years, closed treatment by casting still results in satisfactory results. It is still controversial whether the long-term functional outcome of operative treatment is really superior to that of non-operative treatment because the literature is primarily focused on complications in forearm shaft fractures in children.^{11,50,51} Thus, the limited comparative literature cannot clearly show the benefits of operative treatment over non-operative treatment and more comparative trials are needed to enhance evidence-based practice in forearm fractures.^{11,18}

A moderate level of scientific evidence currently exists for the benefits of pinning of displaced humerus supracondylar fractures primarily by closed means; however, high-quality scientific data are still limited.^{48,52} Scientific evidence to guide the best treatment for isolated medial epicondyle fractures in children is still limited.⁴⁸ There is no high-level scientific evidence on the optimal treatment of midshaft clavicle fractures in children and adolescents.^{27,48} Interestingly, the evidence in adult literature concerning the treatment of clavicle shaft fractures was reported to influence the choice of treatment in the adolescent age group.³²

It is widely accepted that internal fixation by either closed or open means leads to good outcomes in children's hip fractures but high-level scientific evidence to support this position is limited.⁵³ There is insufficient evidence to determine whether operative treatment has more beneficial effects on long-term functional results than non-operative treatment in children with femur shaft fractures.⁵⁴ Besides, high-level scientific evidence regarding the best choice of treatment for femoral shaft fractures in different age groups seems to be limited.⁴⁸ Most paediatric tibia shaft fractures can successfully be treated non-operatively, although an increased rate of flexible intramedullary nailing use has been noted. Besides, most tibia shaft fractures in children, whether treated non-operatively or operatively, have excellent radiographic and functional outcomes.⁵⁵

Conclusions

The tendency towards surgical treatment in children's fractures has gradually increased over the last three decades. Numerous factors including patient-, parent- and surgeon-dependent ones as well as technological, economic, social, environmental and legal ones may have an impact on this trend. It is obvious that evidence-based medicine is not the only factor that leads to the tendency towards operative treatment. High-level scientific evidence seems to be currently limited on the statement that operative treatment definitely leads to better long-term outcomes in children's fractures. Properly designed multicentre prospective randomized double-blind controlled clinical trials with high numbers of patients and long-term follow-up are needed to determine the best treatment options in many fractures in children. On the other hand, it is not so easy to conduct precise prospective randomized double-blind controlled clinical trials in the paediatric age group, primarily due to ethical issues. Nevertheless, it is neither the case that preferring non-operative treatment in most children's fractures is a sign of 'narrow-mindedness', nor that preferring operative treatment in most children's fractures is a sign of 'modernity'. The treatment of each fracture in childhood

needs to be individualized and then planned in line with the current literature, the level of personal clinical experience, the level of institutional facilities and the expectations of parents and patients.

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