Grip on recovery after paediatric forearm fractures

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CHAPTER 1

General Introduction

VIRTUAL CASE

Did you ever sustain a fracture as a child?* If so, can you still remember it actually happening, the pain you felt, or the impact of the limitations you experienced thereafter? The answer is probably – and hopefully – only partially. A strictly hypothetical adult can still vividly remember a fall from her bike, the shivering from pain upon arriving at the hospital, and mostly being in tears about her persistent refusal to let the sleeve of her new sweater be cut open. After losing this not-so-lengthy stand she contemplated about the implications the injury could have for swimming during holidays, and realised that breaking the dominant arm could have more far-reaching consequences than breaking the other arm. What in retrospect was presumably a torus fracture was eventually treated by means of a plaster splint, though she can still recall that there was a debate about whether or not she would have to wear a cast. Roughly 30 hypothetical years later, some things have not changed.

INCIDENCE

The overall yearly incidence of paediatric fractures as reported by different epidemiological studies approaches an average of 23/1,000 children (16-36).[1-7] Fractures thus constitute a very common paediatric injury; by the time children reach their 16th birthday approximately 44% of all boys and 28% of girls will have suffered at least one kind of fracture.[1,3-5,7,8] The upper extremity harbours the top-three affected anatomical locations, namely the forearm (23-42%) and hand (17-28%), on which this thesis will focus, followed by the upper arm (6-11%).[1,3-7,9,10] Generally speaking, this means that two-thirds of all sustained paediatric fractures are located in the upper extremity, and one-third is situated in the forearm. Moreover, the incidence of forearm fractures specifically seems to be on the rise, with several studies reporting increases of far over 30% between different cohorts. By contrast, the overall fracture incidence and the rates of femoral and tibial fractures, for example, have decreased.[5,7,8,11,12]

If you answered my first question* with a ‘yes’, chances are high that you are male, as fracture rates are overall higher in boys than in girls.[4,10,11,13] Even though it is difficult to specify exact numbers by gender, as each incidence study has broken these numbers down to slightly different subgroups, fractures of the forearm and hand certainly and consistently form no exception to this rule.[1,3,5,6,9,12,14] Overall, slightly under two-thirds of these fractures seem to be sustained by boys. The incidence of both forearm and hand fractures generally increases steadily until adolescence, before peaking at the age of 12-14 in boys and 10-11 in girls, although bimodal curves with a smaller peak incidence at the age of 5-6 have been described.[1,3,5,7,9,10,12] From the age of 12 onwards, boys thus dominate this fracture population.[7,14]

CHILDREN ARE NOT TINY ADULTS

'Children are not tiny adults, and should not be treated as if they were.'[15] Over the course of my career I have come across different variations of this same code of conduct: to medically emphasise that children are susceptible to different external and internal risks than adults, to carefully take their ever-changing developmental physiology into account, and to weigh their (much) longer life expectancy in clinical decision-making. This is similar in other aspects of the medical profession, when it comes to legislation on their participation in research or the beginner's basics on how to approach a minor patient in daily practise (or how not to). In all circumstances I found this statement to be very true, and it might be particularly accurate in the case of fracture treatment.

Fracture treatment took a giant leap after the introduction of plaster. Although plaster had been previously used for other purposes for thousands of years – including this thesis' cover artwork - it was not until the early 19th century that it was introduced into the treatment of fractures in the Western world.[16] First in liquid form, supposedly by Professor P. Hendriks in Groningen in 1814, later in dry form using 'plaster of Paris' in bandages by A. Mathysen in Haarlem in 1852.[16,17] Although in modern times bandages are often made from synthetic material, the use of plaster of Paris never quite ran out of fashion. Since the 20th century, displaced fractures are generally treated by reduction followed by cast immobilisation, while non-displaced fractures are treated by means of cast immobilisation alone. However, in contrast to adults, achieving perfect anatomic alignment after sustainment of a fracture is not nearly always a necessity in growing children. Depending on their remaining growth potential, children's bones have the unique capability to remodel.

ACCEPT, REDUCE OR OPERATE?

Unfortunately, when it comes to clinical decision-making regarding the management of displaced fractures of the forearm, hand or wrist in children, evidence-based recommendations are lacking. The limits of angular deformations allowing for a conservative, non-operative course are currently based on scarce (mostly retrospective) studies, case reports and expert opinions. Conversely, there is no high-level evidence warranting surgical treatment, nor clear-cut advice on which method of stabilisation is superior in which circumstance.[18-22] So when to accept, reduce or operate (and how) remains largely unanswered. Inexplicably though, surgical intervention is clearly appearing as an increasingly favourable trend, while calls for randomised clinical trials keep being made.[21,23-25] This trend is worrisome, as conducted studies advocate less invasive (conservative) rather than more invasive (operative) courses of treatment.[24,26]

HOLY GRAIL

So why have well-designed randomised multi-centre trials with adequate power not yet been conducted? The answer is probably multifactorial. First, the logistics are a nightmare. Boys and girls with divergent growth potentials, at different ages, with different fractures and varying angulations, undergoing different treatments by a variety of physicians. Either the study population is too heterogeneous or the numbers are too low to ensure adequate statistical power. To make matters even more challenging, all participants have to be measured in narrow time frames to allow for adequate comparison, and the inflow fluctuates tremendously. Second, conducting such a study would raise several medical and ethical dilemmas. It is not feasible to first conduct such a study in adults, then later translate the study protocol for a minor population based on more substantiated expectancies regarding outcome, since adults' bones have lost the capability to remodel. Furthermore, giving consent to participate in a study that allocates children to either conservative or operative treatment and all its possible consequences is an entirely different ball game. The same goes for their parents, who may well take issue with deferring to a randomized choice of treatment. In my personal experience, parents tend to regret doing something rather than doing nothing, and the cosmetic appearance of severely angulated fractures can be frightening. On the other hand, reduction and surgical intervention are likely to be high-impact events for both children and parents. Leaving such important considerations to a flip of a coin is difficult, and this is further complicated by the fact that blinding is not an option. Finally, more on topic for this thesis, there is neither consensus nor uniformity on what should be measured. Outcome measures, as well as how and when they are obtained, vary between studies, time in the consultation room is limited, and function is often eyeballed instead of measured. Yet with difficulty comes opportunity, so it is only natural to bring in a paediatric physiatrist to deal with these kinds of questions.

AIM OF THIS THESIS

The scope of this thesis focuses on functional outcome during the recovery of angulated fractures of the forearm and the hand in children and adolescents. The first aim of the thesis is to provide (inter- and intra-personal) reference values for children on one of the most important parameters of hand function: grip strength. Second aim of the thesis is to provide more insight into how commonly used long-term outcome measures as used in adult studies actually recover in non-reduced and reduced fractures in children. Final goal is to provide an easy and quickly obtainable, yet substantiated and standardised, set of outcome measures for future research.

OUTLINE OF THIS THESIS

Chapters 2 and 3 focus on delivering normative data for grip strength in children based on a large and heterogeneous study population. **Chapter 2** provides reference values by age, gender and dominance, facilitating easy comparison with patient outcomes. These values can be used to evaluate recovery after fractures, as well as to monitor a broader range of other conditions over time. The association between grip strength and age, gender, weight and height is also examined. **Chapter 3** elaborates on the intra-personal differences in grip strength between dominant and non-dominant hand, as earlier research in adults shows the dominant hand to be approximately 10% stronger than the non-dominant hand.[27,28] In Chapter 3 this '10 percent rule' is challenged for both left- and right-dominant boys and girls, shedding further light into the minority of left-dominant children. It additionally allows for a quick calculation of the expected grip strength of one (affected) hand, based on the measured grip strength of the other (unaffected) hand. **Chapters 4, 5 and 6** focus on recovery after actual sustainment of fractures. **Chapter 4** examines recovery after non-reduced forearm fractures, giving a first prospective impression of the progress of fracture remodelling and functional recovery (grip strength and mobility) during the first year post-trauma. Factors influencing remodelling (time post-injury, dominant side affected, type of fracture and involvement of solely the radius or both bones) and the relation between functional outcome and degree of fracture angulation are presented. **Chapter 5** focuses specifically on recovery of strength (grip strength, key grip and three-jaw chuck grip) after sustainment of fractures of the forearm, wrist or hand treated by reduction. The extent of loss of strength compared to the unaffected hand and pattern of recovery of the affected hand are examined by different treatment modalities, namely closed reduction without internal fixation, closed reduction with internal fixation, and open reduction with internal fixation in the first six months after trauma. Lastly, it is ascertained which of the following factors are associated with an increase in the ratio between affected grip strength and expected (unaffected) strength: type of fracture, cast immobilisation, occurrence of complications, and degree of pain. **Chapter 6** evaluates recovery after reduced forearm fractures. The aim of this study is to prospectively evaluate how a set of pre-defined post-traumatic symptoms (namely pain, swelling, discoloration, temperature asymmetry, hypertrichosis, allodynia and loss of sensory function) recover during the first six months after having sustained a paediatric forearm fracture, as well as follow how mobility and dexterity recover over time. Again, outcome measures are evaluated by type of treatment given, and factors of influence on recovery of either mobility or dexterity (treatment, gender, age, and the dominant hand being the affected hand) are examined. Lastly, **Chapter 7** discusses the conclusions of the current thesis and provides suggestions for future research.

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