An inconvenient truth: Treatment of displaced paediatric supracondylar humeral fractures

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ABSTRACT

The need for emergent management of displaced paediatric supracondylar humeral fractures is being questioned in the literature. Open reduction rates of up to 46% have been reported in the non-emergent management of these injuries. At our institution these fractures are managed as operative emergencies by senior personnel. To examine the ongoing need for this policy we reviewed our results. All patients managed over a five year period with Gartland type IIB or III paeditric supracondylar humeral fractures were identified and a comprehensive chart and radiographic review undertaken. The mean time from injury to fracture reduction and stabilization was 6.6 h. Consultants performed or supervised 90% of cases. Open reduction was necessary in 5% of cases. Complications included a perioperative nerve injury rate of 6% and a superficial pin site infection rate of 3%. This study suggests that, despite the challenge to trauma on-call rostering, the emergency management of these injuries is advantageous to patients in units of our size. Based on the data presented here we continue our practice of emergent management. We suggest that units of a similar size to our own would show a benefit from an analogous policy albeit an inconvenient truth.

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Introduction

Supracondylar fractures of the humerus are a common elbow injury in children.[1] Many methods of treatment, both conservative and operative, have been described however it would appear that no one method is suitable for all fractures, nor has any method gained universal acceptance.[2] Accepted treatment of displaced supracondylar fractures of the humerus includes reduction and stabilised with wires, although there is some disagreement regarding the timing of treatment and the level of surgical experience needed to treat these fractures.[3–7] This study was undertaken in a regional orthopaedic trauma unit with eight consultant staff performing 5000 trauma cases per annum and serving a population of 480,000. The trauma services are centralised at our institution, serving four peripheral hospitals within a radius of 100 km. The agreed policy within the unit dictates treating these fractures as emergencies, meaning immediate transfer from the referring hospital to our trauma theatre. The service is consultant provided rather than consultant led, meaning senior trauma surgeons manage these fractures, with the assistance of orthopaedic trainees.

The policy of senior staff providing early treatment is being debated in the literature.[3–10] Such a policy places significant demands on surgical, anaesthetic, nursing and ambulance staff. The aim of this study was to examine the clinical course

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of displaced supracondylar humeral fractures in children treated as emergencies by a senior surgeon. Our hypothesis was that fractures managed in this way would have a superior outcome to those that underwent delayed treatment.

Patients and methods

This was a retrospective chart and radiographic review of all paediatric supracondylar fractures managed at our unit over a consecutive 5 year period. Patient details were retrieved from the hospital inpatient enquiry system (HIPE) and the theatre register. The details were recorded by trainees, independent of the senior author. Demographic details such as age and sex, mechanism of injury and place of injury were recorded. Likewise temporal factors including 'time of injury', and 'time to surgery' were documented and thus time from 'injury to surgery' was calculated.

The fractures were classified using the Gartland classification and all pre-operative neurovascular and concomitant injuries were noted.[11] This study included uncomplicated displaced extension type fractures. Patients with Gartland I or IIA fractures, open fractures, pulseless limbs, flexion type fractures and fractures with intercondylar extension were excluded. The operative notes recorded the surgeon, the method of reduction, the wiring configuration and the duration of surgery (Fig. 1). Charts and radiographs were reviewed to record mal-reduction and post-operative complications. The majority of patients (110 of the 133) were reviewed at Waterford Regional Hospital; 14 others were sent a questionnaire regarding complications and parental satisfaction and 9 were lost to follow-up. The average time from injury to this chart review was 4 years with a minimum duration of follow-

up of 32 months, so any residual complications such as progressive deformity would have been evident at the time of writing this paper.

Statistical analyses

Analysis of variables (ANOVA) and chi-square tests were used to determine statistical differences between groups. ANOVA, which assesses differences between groups by comparing the variance within each group to the variance of the means of the groups, was used to compare quantitative measurements between groups. Chi-square tests were used to compare compartmentalized measurements. Chi-square tests compare the expected number of elements within each compartment with the observed number of elements within each compartment and assess whether the difference between the two is statistically significant. Statistical significance was assumed at the $p < 0.05$ level.

Results

There were 222 supracondylar fractures identified over the five year period, of which 55(24.8%) were classified as Gartland I or IIA, 15(6.8%) were flexion type fractures, 9(4%) had vascular compromise, 3(1.4%) were open and 3(1.4%) had intercondylar extension. In 4(1.8%) patients the charts were unavailable for review. Of the remaining 133 uncomplicated extension type injuries, 69(52%) were classified as Gartland IIB with 64(48%) Gartland III fractures (Fig. 1). The majority (110 of 133) had their clinical and radiographic follow up in
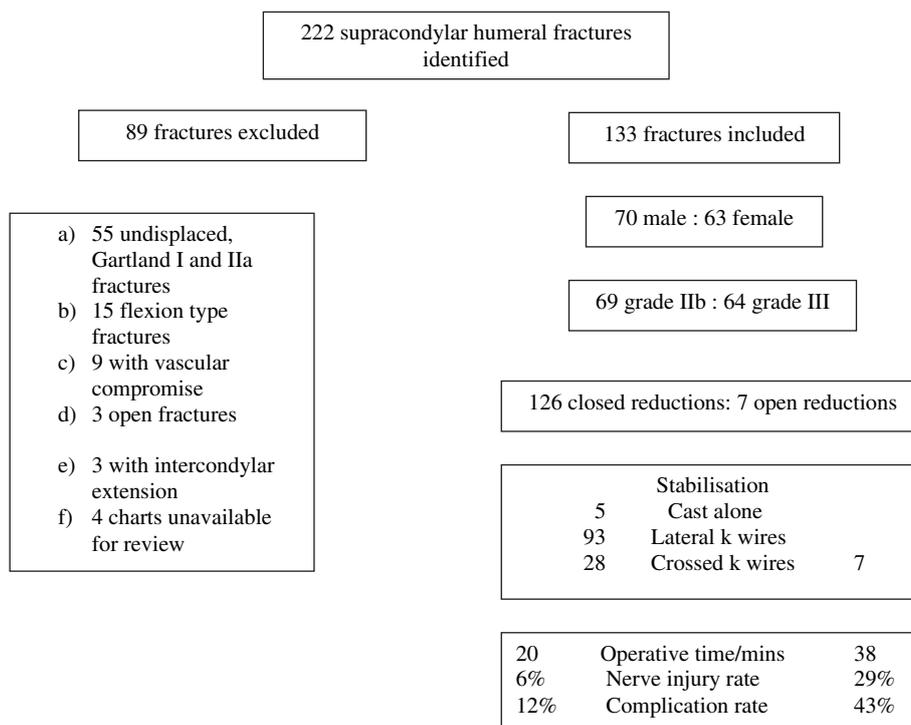

Fig. 1 – Flow diagram for 222 supracondylar humeral fractures.

Waterford. A further 14 patients were contacted by letter and 9 patients were lost to long-term follow up (Table 3).

The male to female ratio was 70:63 with a mean age of 5.9 years (range: 1.5−15 years). The left limb was injured in 65% of children and the right in 35% ($p < 0.001$). The mechanism of injury was a fall from furniture within the home in 32 cases (24%), fall from a swing, slide or see-saw (SSS) in 24 cases (18%) and a simple fall while walking or running in 24 cases (18%). Concomitant injuries were recorded in 7(5%) children and always involved the ipsilateral upper limb. Six children sustained an associated distal radial fracture and the remaining child sustained a fracture of the midshaft of the radius and ulna. As is typical, 45% of injuries occurred in the summer months (June/July/August).

The 'time of injury' was divided into four '4 h' periods, namely 8am to midday, midday to 4pm, 4pm−8pm, and 8pm to midnight. Over the five year period, no fracture occurred between midnight and 8am. Fourteen per cent of fractures occurred between 8am and midday, 38% occurred between midday and 4pm, 38% occurred between 4pm and 8pm with only 10% occurring between 8pm and midnight. Thus 90% of fractures occurred before 8pm each day. 'Time of surgery' was divided into four six hour periods, namely 6am to midday, midday to 6pm, 6pm to midnight and midnight to 6am. Twelve per cent of patients had their surgery between 6am and midday, 12% between midday and 6pm, 59% between 6pm and midnight and 17% had their surgery between midnight and 6am. Thus, 76% of fractures were stabilized outside normal working hours.

To test the policy of early treatment, the time from 'injury to surgery' was calculated. In accordance with our policy, 88(66%) children had their surgery within 6 h of their injury and 89% within 12 h of their injury (Fig. 2). The average time from 'injury to surgery' was 6.6 h (range: 2−27 h). Thus, the combination of the typical time of injury (before 8pm) and the policy of immediate transfer to the operating room (average 6.6 h) does obviate the need for surgery after midnight in the majority of cases, 83% having their surgery before midnight. Consultants either performed or supervised 90% of the cases, while the remaining 10% were performed by senior specialist trainees, thus no child was managed by a junior trainee.

The average duration from injury to writing this paper was 4 years, with a minimum duration of 32 months. The average duration of clinical and radiographic follow-up at outpatients was 16 weeks (range, 3−60 weeks). Children were discharged from the clinic when the surgeon and family were satisfied. All patients were advised of an 'open door' policy to return if they had any concerns.

Table 2 − Analysis of outcomes comparing fractures treated with open reduction with those managed by closed means.

Reduction type	Duration surgery (mins)	Inpatient (Days)	Nerve injury	Complications
Open	38.6	1.43	29%	43%
Closed	20.6	1.12	6%	12%
	$P = 0.001^*$	$P = 0.092$	$P = 0.018^*$	$P = 0.014^*$

* denotes statistically significant difference between groups.

Open reduction was necessary in 7(5%) cases. All 7 cases were managed by consultants and the average time from 'injury to surgery' for these 7 cases was 5.5 h (range 3.5−16.5 h). Thus these cases were not delayed cases and were not managed by less experienced surgeons, suggesting that open reduction will be necessary in some cases. In evaluation of closed versus open reduction, we demonstrate a shorter operative time of 20 min Vs 38 min ($p < 0.001$), no need for tourniquet application, less risk of iatrogenic nerve injury (6% Vs 14%) and a lower overall complication rate (12% versus 43%, $p = 0.014$) (Table 2). Hence we feel there is some validity in using closed versus open reduction as an outcome measure with these fractures.

Complications were noted in 19 of 133(14%) children. Nerve injury was recorded pre-operatively in 3(2%) children, involving one case each of radial, median and ulnar nerve palsies. Iatrogenic post-operative nerve injury was recorded in 8(6%) patients, involving the anterior interosseous nerve (AIN) in 4 cases, the ulnar nerve in 2, with 1 radial and 1 median nerve injury recorded. Of the 126 closed reductions, 121 were stabilized using k-wires. Two lateral divergent k-wires were used for fracture stabilization in 93(77%) cases treated by closed reduction, with one (1%) post-operative radial nerve injury recorded. Crossed k-wires were utilised in 28(23%) cases treated by closed reduction with 6(21%) nerve (3 AIN, 2 ulnar, 1 median) injuries recorded. The remaining AIN injury occurred during one of the 7 cases requiring open reduction, all of which were stabilised with crossed k-wires. All nerve injuries made a complete recovery. In the closed reduction setting this difference in nerve injury rates for lateral versus crossed k-wires was statistically significant ($p = 0.005$). Other complications included 4 pin track infections and 4 cases of re-wiring secondary to loss of reduction. The remaining three cases were one malunion, one infection requiring wound

Table 1 − Analysis of outcomes comparing Gartland type IIB with Gartland type III supracondylar humeral fractures.

Fracture type	Associated injuries	Duration surgery (mins)	Open reduction	Complications
Grade IIB	2%	18	2%	10%
Grade III	9%	24.3	9%	17%
	$P = 0.077$	$P = 0.01^*$	$P = 0.077$	$P = 0.326$

*denotes statistically significant difference between groups.

Table 3 − Analysis of outcomes comparing Gartland type IIB with Gartland type III supracondylar humeral fractures.

Fracture type	Associated injuries	Duration of surgery/ minutes	Open reduction rate	Overall complication rate
Grade IIB	2%	18	2%	10%
Grade III	9%	24.3	9%	17%
	$P = 0.077$	$P = 0.01^*$	$P = 0.077$	$P = 0.326$

*denotes statistically significant difference between groups.

Time to Surgery

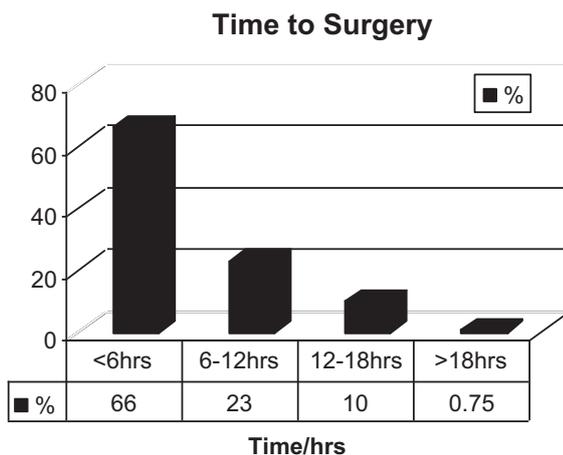| ■ %	66	23	10	0.75
	<6hrs	6-12hrs	12-18hrs	>18hrs

Time/hrs

Fig. 2 − Time from the moment of elbow injury to surgical stabilisation in hours.

debridement and one case of skin blistering of the antecubital fossa. Two patients have developed mild clinical deformity, neither needing corrective osteotomy to date.

Patients were discharged home when the medical staff and parents were happy, the child was ambulant, eating and on oral analgesia only. The average length of hospital stay was 1.13 days (range, 1−4 days). All wires were removed under general anaesthesia at a mean of 4.1 weeks (range, 2.5−8 weeks), with no further complications recorded.

This report includes analysis of outcomes of displaced, Gartland type IIB and III supracondylar humeral fractures. We found no statistical difference in the rates of associated injuries (2% vs 9%), complications (10% vs 17%) or opening rates (2% vs 9%) when separate statistical analyses were performed on grade IIB versus grade III fracture types (Table 1).

Discussion

Although a common injury no single method of management has yet been advocated for all supracondylar factures of the humerus in children.[2,12] Both operative and non-operative management have been reported with successful comparable outcomes.[12,13] Accepted common practice of unstable fractures includes closed reduction followed by percutaneous wire fixation.[14] This is the practice in our unit.

The configuration of the wires for this technique has been debated extensively. A number of wiring configurations being described to find the balance between stability and the risk of nerve injury.[15] Open reduction should be reserved for failed closed reduction. However, the ideal time at which this care should be delivered remains illusive. The dispute is whether these fractures should be managed emergently or whether they can safely undergo a delayed course of treatment. Our hypothesis was that fractures managed emergently would have a superior outcome to those that underwent delayed treatment. We defined emergent as treatment in less than 6 h from the time of injury which is comparable to the literature.[3,6]

While emergent treatment should enable a closed reduction due to minimal elbow swelling, with a consequent lower open reduction rate, a policy of early management necessitates senior surgical and anaesthetic staff availability at night. This study shows that these injuries are typically sustained between midday and 8pm and the majority of these fractures (76%) were treated outside normal working hours, with surgery after midnight in 17% of cases. This has become a significant problem on many trauma rosters. Iyengar et al, allude to this point and commented that the time of fracture occurrence was the main determinant in their study, with children whose fracture occurred after 16:24 much more likely to find themselves in the delayed treatment group.[7] Delayed treatment should ensure senior staff availability the next morning, compliance with fasting recommendations and compliance with 'out-of-hours' operating guidelines (NCEPOD).[16]

Traditional outcome measures such as elbow stiffness, deformity, functional disability and ischaemic contracture are rare. Thus, defining outcome measures to differentiate between the results of early and late reduction are difficult to find. This was highlighted by Gupta who suggested that 6900 patients would be needed to detect a 20% difference in the rate of complications between early and late managed groups.[6] The traditional outcome measures used in the literature are method of reduction (closed or open), neurological injury rate, complication rate and length of hospital stay. This study demonstrates some advantages of closed over open reduction. These include a shorter operative time of 20 min Vs 38 min ($p < 0.001$), absence of tourniquet, reduced iatrogenic nerve injury (6% Vs 14%) and a lower overall complication rate (12% versus 43%, $p = 0.014$) (Table 2). Therefore, we feel there is some validity in using closed versus open reduction as an outcome measure with these fractures.

Complications were noted in 19 of 133 (14%) children, of which 8 were neuropraxias. We documented three pre-operative nerve injuries and eight new post-operative nerve injuries. The post-operative iatrogenic nerve injury rate was statistically higher for fractures stabilised with crossed wires rather than lateral divergent k-wires (21% Vs 1%, $p = 0.005$). While all nerve injuries made a complete recovery, lateral divergent wires are the preferable fixation technique, demonstrating adequate stability and a lower iatrogenic nerve injury rate. Our pin tract infection rate was 3%, comparing favourably with reported rates of 2.4%−6.6%.[3,6] Length of hospital stay is another measure that may help quantify outcome following displaced supracondylar fractures. Kasser et al. found that management in specialist paediatric unit reduced average inpatient stay from 2.2 days to 1.4 days when compared to a general orthopaedic unit.[9] The average length of hospital inpatient stay in our study was 1.1 days (range, 1−4 days) which compares well with these figures.

This paper demonstrates some of the advantages of an early treatment policy, reporting an open reduction rate of 5%. As all children were treated as emergencies, we had no control or delayed group. Iyengar reported no significant difference in open reduction rates when the surgery was undertaken within 8 h of injury or when the surgery was delayed (13% Vs 17%).[7] Similarly, Sibinski et al found no difference in open reduction rates when the surgery was performed within 12 h

of injury or delayed (21% Vs 33%).[10] The open reduction rates in the early groups in these studies (13% and 21% respectively) are high. However, some studies report high open reduction rates, whether these fractures are treated in an early or delayed fashion, whilst others report low open reduction rates despite mean delays approaching 21 h. We believe a significant factor biasing the rate of open reduction is the number of cases encountered per annum.[10,17] Our open reduction rate of 5% compares favourably with other 'low volume' practices. Iyengar reports open reduction rates of between 13%—17% with 58 grade 3 fractures over a 5 year period.[7] Walmsley reports on 5 surgeons managing between 14 and 24 admissions per year and Sibinski on 6 surgeons managing 5.4 admissions per year. These studies show an open reduction rates of between 11% and33%.[10,17] This is in contrast to 'high volume' practices where open reduction rates of 0—2% are achieved with 150 case managed over just seventeen months.[6] Leet et al reported on a 'single specialty tertiary referral centre' with each surgeon managed 8.9 operative supracondylar humeral fractures per year. Their open reduction rate was 0.6%, even though mean time to surgery was 21.3 h.[5] Therefore, although delayed management may yield satisfactory results in 'high volume' practices these data suggest that 'low volume' practices may benefit from adopting an early treatment policy.

This paper presents interesting data in the management of displaced paediatric supracondylar humeral fractures from a large sample size. However there are potential weaknesses of this study. It is a retrospective study and there is a lack of a control group. Our ongoing emergency management policy appears to minimise open reduction rates, hence having a control group would create obvious ethical problems. A further potential weakness may be that because patients with displaced supracondylar humeral fractures in this study were brought emergently to theatre for reduction and stabilisation, we cannot assess whether emergent reduction alone may be the reason for better results. In our institution we do not routinely sedate paediatric patients in the emergency department. This may be the primary confounding variable in the paper by Mehlman et al., which suggested there was no difference when stabilisation was delayed however, a significant number of the delayed group had been reduced 'emergently' in the emergency department prior to splinting and admission.[3] In addition presentation time varies across populations groups with Cheng et al report a significant number of patients presenting after 24 h and so being outside the early management time at presentation.[18]

In conclusion the timing of management of displaced supracondylar humeral fractures in children remains controversial. With difficult to define outcome measures and unattainable numbers in power studies hampering analysis it is unlikely one study will be able to answer this question definitively. This study suggests that, despite the challenge to trauma on-call rostering, the emergency management of these injuries is advantageous to patients in units of our size. Based on the data presented here we continue our practice of emergent management. We suggest that units of a similar size to our own would show a benefit from an analogous policy albeit an inconvenient truth.

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