Archives of Orthopaedic and Trauma Surgery (2025) 145:39
https://doi.org/10.1007/s00402-024-05644-4

RESEARCH

The first analysis of a multicentre paediatric supracondylar humerus fracture (SCHF) registry by fracture type

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Received: 25 June 2024 / Accepted: 25 October 2024

Abstract

Introduction Supracondylar humerus fractures (SCHFs) represent a significant segment of paediatric bone injuries, posing unique challenges due to their potential for severe complications. This study aims to provide a detailed analysis of the surgically treated SCHF cases recorded in our registry.

Materials and Methods Prospectively collected data from seven institutes were retrospectively analysed using the Hungarian SCHF Registry, with data about surgically treated paediatric patients with SCHFs. We created three groups based on fracture type (Gartland IIA, IIB and III), and compared their preoperative, operative, and postoperative data. We analysed differences between the groups using the Chi-Squared test or Fisher's Exact test for categorical variables. The Kruskal-Wallis rank sum test was performed for continuous variables. If there was a significant difference between the groups, we conducted Dunn's post-hoc analysis.

Results The fracture type was available for 214 patients (Gartland IIA group contained 31, IIB 121, and III 62 children). Our investigation highlighted notable patterns: lower oxygen saturation levels at initial assessment correlated with higher fracture severity ($p=0.0125$); Body Mass Index (BMI) did not significantly influence the type of fracture ($p=0.2254$); neither the mechanism of injury (flexion vs. extension) ($p=0.5606$), nor the initial radial pulse ($p=0.0647$) showed significant difference; the complexity of fractures was directly proportional to operative time ($p<0.01$); less severe fractures required longer time to heal before pin removal ($p=0.0125$); while severe fractures showed a tendency towards neurological complications, the overall complication rates did not vary significantly across different fracture types ($p=0.0988$).

Conclusions Our study emphasizes the significance of initial oxygen saturation levels as potential indicators of fracture severity. It also stresses the need for detailed attention to neurological complications and the prolonged use of pins, thereby highlighting the importance of customized treatment strategies in paediatric SCHFs.

Level of evidence II.

Keywords Paediatric · Supracondylar · Humerus · Fracture · Registry · Multicentre

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Abbreviations

SCHF	Supracondylar humerus fracture
BMI	Body Mass Index
CRT	Capillary Refill Time
AP	Anteroposterior
K-wire	Kirschner-wire
STROBE	STrengthening the Reporting of OBservational studies in Epidemiology
FDR	False Discovery Rate
CRPP	Closed Reduction and Percutaneous Pinning

Published online: 12 December 2024

Introduction

Supracondylar humerus fractures (SCHFs) remain a constant threat to the paediatric population, due to their high frequency and various complications [1]. The vast majority of these injuries occur (~95% of all cases) when a child falls and protectively outstretches an arm [2]. Children are most at risk on holidays when playing with playground equipment, especially trampolines [2]. Flexion-type injuries constitute less than 5% overall, and they predominantly transpire in the non-dominant arm of older children, while falling on a flexed limb [3].

Their estimated incidence varies between 3.3 [4] and 17.9% [5]. Consequently, SCHF injuries are the most common fractures involving the elbow in paediatric patients [6]. The mean age of patients is generally between 4.7 [7] and 7.2 [8] years old. In many studies males are affected more often [4, 8], but there are also examples of the opposite [9].

Upon physical examination, the typical signs of a fracture are often present e.g. swelling, pain, bruising, or limb length discrepancy [10]. The distal sensory and motor functions must always be assessed, due to the high rate of neurological injuries. Anterior interosseus nerve palsy is the most common in extension-type traumas and ulnar paresis is frequently found in flexion-type fractures, but the median and radial nerves could be also affected [11]. Vascular damage is prevalent as well, and generally, the brachial artery is involved [12]. Hence, the assessment of the radial and ulnar pulses is critical, together with the examination of the ipsilateral arm's capillary refill time (CRT), colour, and temperature.

Anteroposterior (AP) and lateral radiographs are needed to confirm the fracture type, displacement, comminution, and rotational deformities [13].

SCHFs can be categorized according to the displacement of the bone fragments. The most commonly used is the Gartland classification system modified by Wilkins [14]. Type I injuries are non- or minimally displaced (<2 mm) fractures. Type II traumas are displaced (2<mm) with an intact posterior cortex or hinge (IIA), and additional malrotation (IIB). Complete displacement characterizes Type III and IV injuries, along with disrupted posterior hinge (III) and multidirectional instability (IV).

Management of these conditions should be conservative in Type I fractures [15], involving immobilization in above elbow backslabs or collar and cuffs [16], and operative in Type III and IV fractures. Gartland II injuries can be treated non-operatively if there are no contraindications, such as excess swelling, medial column comminution, or posterior displacement [17, 18]. Elevated straight-arm traction may be an effective method, where resources are limited [19], but the clinical experience of the surgeon, or other factors such as associated injuries, comorbidities, skeletal maturity or obesity also influence the treatment options [15]. For displaced and closed SCHFs, the optimal surgical management consists of closed reduction, then insertion of 2 mm wide, lateral, or crossed percutaneous Kirschner-wires (K-wire) [20, 21], usually two or three of them [15]. Open wounds or neurovascular tissue entrapment necessitate open reduction, combined with the same pinning techniques [22]. Ventral incision is advocated, since it allows access to potentially injured nerves or vessels, though the radial, ulnar, and dorsal approaches can also be practical [23].

This research aimed to analyse the characteristics of children with SCHF, whose data were collected in our registry. We have compared their demographic distribution and the outcomes of the applied interventions to the results reported in the international literature.

Methods

We utilized the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guideline to report our research [24]. The registry was ethically approved by the Scientific and Research Ethics Committee of the Medical Research Council (35335-2/2018/EKU).

Data source and quality

Prospectively collected data were retrospectively analysed using the Hungarian paediatric SCHF Registry, with data from seven institutes about patients operated on between September 5, 2018, and March 25, 2021.

To ensure the proper data quality, all information uploaded to the registry had to go through a four-level quality check performed by administrators and surgeons.

Categorization by fracture type

Classification of the fracture was performed by the operating surgeon based on anteroposterior and lateral radiographs, therefore categorization to Gartland IV was not possible, Gartland IV being an intraoperative diagnosis. Three types were identified: Gartland type IIA (displacement is only in one plane and there is still a connection between the fragments), Gartland type IIB (there is also rotational displacement with some bone connecting the ends), and Gartland type III (there is no connection between the bones). The different outcomes were analysed by creating and comparing three groups based on these fracture types.

Analysed endpoints

We aimed to statistically evaluate the following parameters to identify potential differences between the three groups: age, sex, body mass index (BMI), type of injury (flexion vs. extension), radial pulse and oxygen saturation at the first inspection, and results of the hand function assessment. We also assessed pre- and postoperative antibiotic use, the competence level of the surgeon (not specialist, young specialist (specialist for less than 10 years), senior specialist (specialist for ≥ 10 years)), type of fracture reduction, open reduction type, type of intraoperative fixation, number, and diameter of pins, intra- and postoperative analgesic usage, pain killer prescribed for home use, operative time, early complications (occurring before the patient was emitted from the hospital), late complications (reported after the patient was emitted from the hospital, including all the control examinations that followed), and weeks until pins were removed.

We considered the following problems as complications: skin irritation, superficial skin infection, synovitis, wound healing problems, elbow swelling, fever, loss of movement, deep infection, vascular or neurological injury, bone-related complications (misalignment, redislocation, delayed union, non-union), and compartment syndrome. Early complications were documented after surgery but before emission, while late complications were recognized on the following control examinations.

Statistical analysis

We used an Excel sheet (Office 365, Microsoft, Redmond, WA, USA) to gather all the available data from the registry. All analyses were performed using R statistical software, version 4.0.2 (R Core Team, 2020, Vienna, Austria). Differences between the groups were analysed utilizing the Chi-Squared test or Fisher's Exact test for categorical variables. If there was a significant difference between the groups, Fisher's pairwise tests of independence for nominal data post hoc analysis was conducted (p-values adjusted by FDR method for multiple comparisons (Benjamini–Hochberg false discovery rate)). The Kruskal-Wallis rank sum test was performed for continuous variables followed by Dunn's post hoc test [25] with Holm-Šídák p-value correction used to evaluate differences between groups.

$P < 0.05$ was determined as statistically significant, except for Dunn's post-hoc test, where $p < 0.025$ was considered statistically significant. We were able to analyse almost every patient from the registry (214 out of 217), therefore representativeness analysis was not performed. The registry contained data about 217 patients, but 3 of them did not have fracture classification available and therefore could not be included in the comparative analysis.

Results

Preoperative data summary

There were data about 217 patients, the mean age was 6.52 years (6.08 for females, 7.03 for males). 53.46% (116) of the children were female, 46.54% (101) were male. We identified 214 cases in the registry with available SCHF classified into one of the three groups. The Gartland IIA group consisted of 31 patients, the Gartland IIB group of 121, and the Gartland III group of 62 patients. There was a significant difference regarding sex ($p = 0.001$), and the post-hoc analysis showed that the main difference was between the Gartland IIA and the Gartland IIB groups ($p = 0.0008$) (Gartland IIA f/m: 2.58/7.42, vs. Gartland IIB f/m: 6.28/3.72).

190 patients had their BMI recorded; the mean was 16.36. Oxygen saturation on the injured limb at first inspection was available in 137 cases, the mean was 97.83%. At the first inspection, oxygen saturation on the injured limb also reached the level of significance ($p = 0.0207$), it was significantly lower in the Gartland III group (Gartland IIB mean 98.19%, Gartland III mean: 96.78%) ($p = 0.0110$).

The type of injury was documented in 214 cases: 195 (91.12%) were extension types, and 19 (8.88%) were flexion-type injuries. Radial pulse at the time of first inspection was documented in 215 cases: 196 (91.16%) were palpable, 17 (7.91%) were not palpable but had good microcirculation, and two (0.93%) were not palpable and had insufficient microcirculation.

Results of hand function assessment were available in 204 cases: 138 (67.65%) had total function, 63 (30.88%) could not be assessed objectively because of pain, and one patient (0.49%) showed signs of median nerve dysfunction, one of radial, and one of ulnar nerve dysfunction.

Preoperative antibiotic utilization was documented in 210 cases: 190 (90.48%) patients received preoperative antibiotics, and 20 (9.52%) did not. In 190 cases the distribution of preoperative antibiotic was as follows: cefazolin in 167 (87.89%), amoxicillin and clavulanic acid in 20 (10.53%), and clindamycin in three (1.58%) medications (See Fig. 1).

Due to the low sample size in different subgroups, statistical analysis was not possible in the following outcomes: radial pulse at the time of first inspection, and results of hand function assessment.

The following outcomes did not show significant differences between either of the groups: age distribution ($p = 0.7934$), BMI ($p = 0.2254$), type of injury (flexion vs.

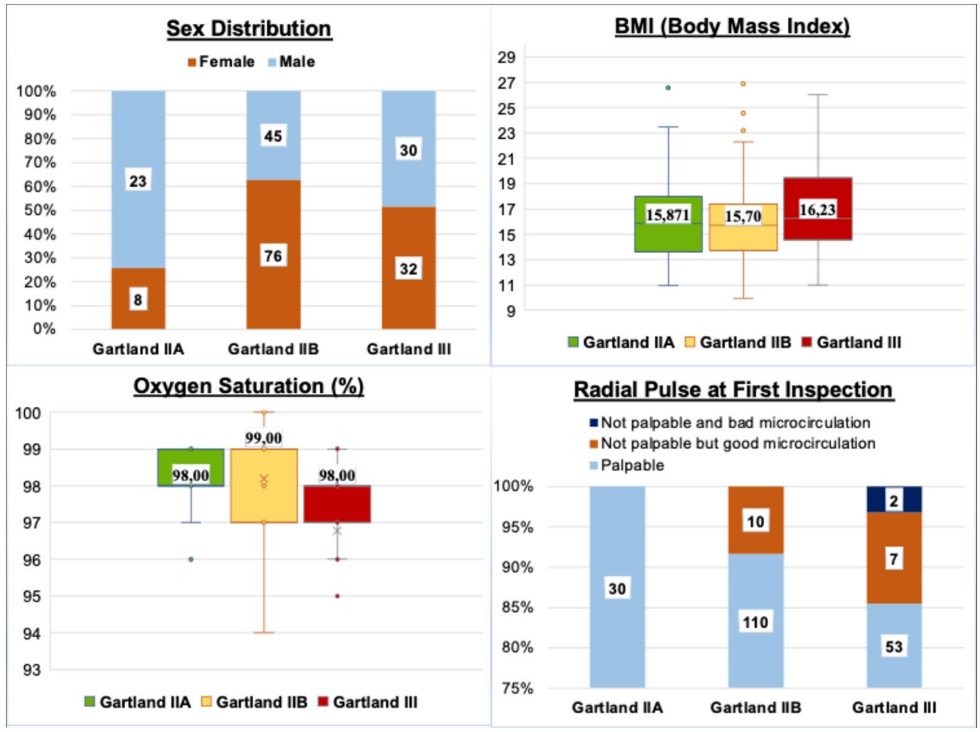

Fig. 1 Preoperative data by fracture type groups: a column chart comparing sex distribution, a box chart comparing BMI (body mass index), a box chart comparing oxygen saturation, and a column chart comparing radial pulse at first inspection. On the box plots the numbers show the median value of the specific outcomes. All comparisons are between Gartland IIA, Gartland IIB and Gartland III groups

extension) ($p = 0.5606$), and preoperative antibiotic use ($p = 0.3533$).

Operative data summary

Of 216 records, 102 patients were operated on by a senior specialist (47.22%), 59 by a junior specialist (27.31%), and 55 by a surgeon who is not yet a specialist (25.46%). Competence level of the surgeon (not specialist, young specialist, senior specialist) did show a significant difference ($p = 0.0228$), but the post-hoc analysis was not able to identify the groups responsible for this result (Gartland IIA/Gartland IIB: $p = 0.0955$, Gartland IIA/Gartland III: $p = 0.0633$, Gartland IIB/Gartland III: $p = 0.0955$).

The fracture reduction method was documented in all 217 cases. There were 150 closed reductions (69.12%), while five were closed, then converted to open because of radial artery dysfunction (2.3%), and nine began as closed, and were then converted to open due to other reasons (4.15%). Additionally, there were 25 closed reductions where a percutaneous tool was used to reduce the fracture (11.52%), one that was closed via the joystick method (utilizing fixateur externe rods or pins) (0.46%), and 27 were primarily open surgeries without attempting closed reduction (12.44%).

Open reduction was necessary in 41 cases, where the surgical approach distribution was: 21 ventral (51.22%), 8 radial (19.51%), 6 ulnar (14.63%), 3 ventral and radial (7.32%), 2 ventral and ulnar (4.88%), and 1 ventral, radial and ulnar (2.44%).

The intraoperative fixation method was documented in 207 cases: 204 were carried out with pinning (97.6%), 3 with fixateur externe (1.44%), and 2 used intramedullary fixation (0.96%). Of the 204 cases using pins, the number of pins was: two in 153 (75%), three in 35 (17.16%), four in 15 (7.35%), and five in one (0.49%) case. The diameter of pins was recorded in 194 patients: 2 mm in 129 (66.49%) cases, 1.8 mm in 35 (18.4%) cases, 1.5 mm in 24 (12.37%) cases, and 2.2 mm in six (3.09%) cases. Pin diameters used for the fixation ($p = 0.1556$) did not show significant differences among the groups.

In, addition, intraoperative local analgesic use was recorded in 216 cases: it was administered in 109 patients (50.46%), whereas 107 patients did not receive any (49.54%). No significant differences were found based on intraoperative local analgesic use ($p = 0.3404$) between any groups.

In the 207 reported cases, the mean operative time was 48.19 min (ranging from 10 to 300 min). There was a significant difference in operative time in minutes ($p < 0.005$) between all separate groups (Gartland IIA/Gartland IIB: $p < 0.005$, Gartland IIA/Gartland III: $p < 0.005$, Gartland IIB/Gartland III: $p < 0.005$), (Gartland IIA mean: 29.3, Gartland IIB mean: 44.57, Gartland III mean: 65.19).

Due to the low sample size in many subgroups correct statistical comparison was not possible for the following outcomes: type of fracture reduction, type of open reduction, type of intraoperative fixation, and number of pins used (See Table 1).

Table 1 Statistics and results of Gartland IIA, Gartland IIB and Gartland III groups

	Gartland IIA (number of cases)	Gartland IIB (number of cases)	Gartland III (number of cases)
Age (years)	6.55 ± 2.54* (31)	6.40 ± 2.44* (121)	6.61 ± 2.50* (62)
Sex			
Female	25.81% (8)	62.81% (76)	51.61% (32)
Male	74.19% (23)	37.19% (45)	48.39% (30)
BMI#	16.34 ± 3.61* (28)	15.96 ± 3.07* (111)	17.18 ± 3.77* (48)
Type of injury			
Flexion	3.23% (1)	9.92% (12)	9.68% (6)
Extension	96.77% (30)	90.08% (109)	90.32% (56)
Initial radial pulse			
Palpable	100% (30)	91.67% (110)	85.48% (53)
Not palpable but good microcirculation	0	8.33% (10)	11.29% (7)
Not palpable and bad microcirculation	0	0	3.23% (2)
Initial oxygen saturation	98.29% ± 0.85* (17)	98.19% ± 1.28* (83)	96.78% ± 4.96* (36)
Initial hand function assessment			
Total function	81.48% (22)	67.83% (78)	59.32% (35)
Could not be assessed objectively because of pain	18.52% (5)	30.43% (35)	38.98% (23)
Median nerve disfunction	0	0	1.69% (1)
Radial nerve disfunction	0	0.87% (1)	0
Ulnar nerve disfunction	0	0.87% (1)	0
Preoperative antibiotic use (yes)	86.12% (25)	90.08% (109)	94.74% (54)
Type of fracture reduction			
Closed	93.55% (29)	71.9% (87)	50% (31)
Closed using a percutaneous tool	3.23% (1)	11.57% (14)	16.13% (10)
Closed using the joystick method	0	0.83% (1)	0
Primarily open	3.23% (1)	9.09% (11)	24.19% (15)
Closed, then converted to open because of radial artery disfunction	0	2.48% (3)	3.23% (2)
Closed, then converted to open because of other reasons	0	4.13% (5)	6.45% (4)
Type of open reduction			
Ventral	0	42.11% (8)	61.9% (13)
Radial	0	21.05% (4)	19.15% (4)
Ulnar	100% (1)	21.05% (4)	4.76% (1)
Ventral and radial	0	5.26% (1)	9.52% (2)
Ventral and ulnar	0	5.26% (1)	4.76% (1)
Ventral, radial, and ulnar	0	5.26% (1)	0
Number of pins			
2	80.65% (25)	72.91% (83)	75.86% (44)
3	19.35% (6)	19.3% (22)	12.07% (7)
4	0	7.89% (9)	10.34% (6)
5	0	0	1.72% (1)
Intraoperative local analgesic use (yes)	38.71% (12)	52.07% (63)	54.1% (33)
Postoperative antibiotic use (yes)	3.23% (1)	4.13% (5)	12.7% (7)
Early complications			
No early complications	96.77% (30)	90% (108)	81.97% (50)
Neurological	3.23% (1)	8.33% (10)	14.75% (9)
Vascular	0	1.67% (2)	1.64% (1)
Bone-related	0	0.83% (1)	1.64% (1)
Late complications			
No late complications	88.89% (24)	80.53% (91)	80.33% (49)
Neurological	3.7% (1)	7.96% (9)	11.47% (7)
Vascular	0	0	1.64% (1)
Bone-related	0	4.42% (5)	1.64% (1)
Superficial infection	3.7% (1)	3.54% (4)	1.64% (1)
Deep infection	0	0.88% (1)	0
Wound healing problem	3.7% (1)	1.77% (2)	0

Table 1 (continued)

	Gartland IIA (number of cases)	Gartland IIB (number of cases)	Gartland III (number of cases)
Pin protrusion	0	6.19% (7)	1.64% (1)
Loss of movement	0	4.42% (5)	0
Elbow swelling	0	1.77% (2)	0
Fever	0	0.88% (1)	0
Weeks until pins were removed	$6.27 \pm 4.76^{*}$ (26)	$5 \pm 4.88^{*}$ (106)	$4.66 \pm 1.29^{*}$ (59)

*(mean ± SD) SD = Standard Deviation, BMI# = Body Mass Index

Postoperative data summary

Postoperative fixation type was reported in all 217 cases: 168 patients received a dorsal cast with U-extension (elbow at 90 degrees) (77.42%), 46 were treated with a dorsal cast (elbow at 90 degrees) (21.2%), in two cases no external fixation was applied (0.92%) and one patient was given an orthosis (0.46%).

211 cases had data about postoperative analgesic usage: 202 patients got some form of analgesics (95.73%), and nine did not get analgesics postoperatively (4.27%). Painkillers prescribed for home use were reported in 204 cases, of these 139 did get one (68.14%), and 65 did not get a prescription (31.86%). Postoperative antibiotic usage was documented in 213 cases: 200 patients did not (93.9%), and 13 did get antibiotics postoperatively (6.1%).

Moreover, 191 out of 215 patients did not report early complications after surgery (88.48%), while 24 reported some form of early complication (11.16%). There were 20 cases with early neurological complications (9.3%), while early vascular complications occurred in three (1.4%), and early bone-related complications were reported in two cases (0.93%).

We had data about 204 cases regarding late complications, out of these 167 did not (81.86%), while 37 did report some form of late complications (18.14%), of which 17 were neurological (8.33%), one was vascular (0.49%), six were bone-related (2.94%), six were superficial infections (2.94%), one was deep infection (0.49%), and three were wound healing problems (1.47%). In eight cases they had to remove the pins earlier because of pin protrusion (3.92%), five cases reported loss of movement in the elbow (2.45%), there were two instances of significant elbow swelling (0.98%), and a fever was documented in one case (0.49%). There was no report of compartment syndrome.

We found no statistically significant difference, when examining the effect of preoperative antibiotic use ($p = 0.5981$), postoperative antibiotic use ($p = 0.7353$) and operative time ($p = 0.2448$) on infection. Every patient who got an infection after surgery (seven cases, of which six infection was superficial) got antibiotics preoperatively, neither of them got antibiotics postoperatively. The operative time for these patients was between 20 and 45 min. Lasting complication was not registered due to infection.

The only examined postoperative outcome that showed a significant difference was the weeks until pins were removed ($p = 0.0125$), where the main difference was between the Gartland IIA and Gartland IIB groups ($p = 0.0053$) (Gartland IIA mean: 6.27, Gartland IIB mean: 5.0, Gartland III mean: 4.66). According to Dunn's post hoc test, the difference between Gartland IIA and Gartland III groups was close to being significant ($p = 0.0477$, but here $p < 0.025$ was considered statistically significant).

Additionally, there was no significant difference when comparing early complications ($p = 0.0988$), painkillers prescribed for home use ($p = 0.384$), and late complications ($p = 0.6403$).

Due to the low sample size in different subgroups, statistical analysis was not possible in the following outcomes: type of postoperative fixation, analgesia and antibiotic use, as well as early vascular, neurological, and bone-related complications.

Discussion

Using the data of a prospective multicentre registry, in our study we examined the demographics and different preoperative, operative, and postoperative aspects of surgically treated paediatric SCHF patients, based on fracture types. Three fracture categories were identified based on anteroposterior and lateral radiographs: Gartland type IIA, type IIB, and type III. The information we gathered was statistically analysed by comparing the three groups.

Our main findings were that the oxygen saturation at the first inspection was significantly lower in the more severe fractures, the influence of BMI was not significant on the fracture type, the difference in early or late complications was not significant, and the pins were left in for longer in the group with the most benign fractures.

Our research contributes a critical piece to the puzzle of paediatric trauma care, advocating for a dynamic, evidence-based approach that adapts to the evolving landscape of medical knowledge and patient needs.

The average age in our study was 6.52 years, which is older, than in many studies [2, 7, 13, 26], but younger than in some other studies [4, 8]. We also found that there was a difference between the severities when comparing sex distribution: there were more males in the Gartland IIA group, while the Gartland IIB consisted of more females. The Gartland III patients did not show a significant difference between the sexes. Overall female ratio was 53.46% in our study. When comparing the different studies, there is a high variety in sex differences. The most common result consists of male predominance [4, 8, 27, 28], while there are examples of the opposite too [9]. Some are similar to ours, where the sex variance was found to be small [2, 29, 30].

We did not find a statistically significant association between BMI and fracture type. This result is supported by the studies of Peña-Martínez V. et al. [31], and Mitchelson AJ. et al. [32]. In contrast, Seeley MA. et al. [33] found a positive correlation between BMI and more severe fractures, and more frequent complications, while Suganuma S. et al. [34] found that high BMI was a significant factor in causing malrotation.

However, we found that oxygen saturation at the first inspection was slightly lower, and the difference was statistically significant when comparing Gartland II to Gartland III fractures (Gartland IIA mean: 98.29%, IIB mean: 98.19%, III: 96.78%). One could argue that the difference is too small, but we should keep in mind the study of Zhu T. et al. [35], which compared well-perfused hands with poorly-perfused hands. There, in the poorly perfused group, the oxygen saturation was above 95% in all (76 patients) of the cases. This might indicate that, in children, smaller differences in oxygen saturation could suggest a vascular compromise. There are studies, where they examined circulation with a pulse oximeter by observing the waveforms, but not the saturation [36, 37].

Operative times did differ significantly: more complex fracture types required more time to correct. In the study of Suganuma S. et al. [34] they found that obesity and open reduction are factors leading to longer operative time and that high BMI was a factor in malrotation. Due to the low sample size in the different subgroups, we were not able to statistically compare closed pinning to open reduction in the three groups, but within the Gartland IIA patients, there was only one case (3,23%) of primarily open reduction without attempting closed reduction. Additionally, in Gartland IIB patients, there were 11 cases (9,09%), and in the Gartland III group, we found 15 instances (24,19%) with primarily open reduction, which suggests a trend with an increased demand for open reduction in complex fracture types.

Intraoperative local analgesic use was statistically similar between the groups. This proposes that the analgesic administration depends on the surgeon's preference and local habits, rather than the fracture type.

A remarkable result was that the surgeons left the pins in for the longest in the Gartland IIA group (mean 6.27 weeks (43.89 days)), while pins were removed the earliest in Gartland III patients (mean 4.66 weeks (32.62 days)). In the study by Zusman NL. et al. [38] they removed the pins after closed reduction and percutaneous pinning (CRPP) on average at 23.8 days after surgery, which is strangely the same number as in the study of Garg S. et al. [39]. In contrast, in the study of Badin D. et al. [40] this happened after 32 days on average. Our results show that in our country we tend to remove the pins later in less severe fractures. A possible reason for this result might be in correlation with the need for open reduction. More severe fractures needed open reduction more often, and it is possible that the fracture reduction and fixation seemed more precise in the operating room this way, thus the surgeon was more confident that there would be no redislocation. Another possible reason could be that surgeons with less experience left in the pins for a longer time in fear of redislocation. When we look at Fig. 2, we can see that very few Gartland III fractures were operated by not specialists. However, the Gartland IIA fractures were fixed by senior specialists most of the time, while there is a higher percentage of not specialist/junior specialist surgeons in the Gartland IIB group. Therefore, we cannot provide a definitive answer for this result. Further studies might provide more insight. We must add that the registry collected the data in weeks, which could somewhat distort the comparison.

No significant difference was found between Gartland IIA, Gartland IIB, and Gartland III fractures when examining the early or late complications after surgery. Nevertheless, there was a trend suggesting more complications in more severe fracture types, most of which represented some form of neurological deficit. Overall, we found neurological complications after surgery in 9.3% of the reported cases, which is similar to the findings of LiBrizzi CL. et al. [30]. Their reported ratio of patients with neurological injury was 9.5% in all patients (treated both conservatively and surgically). A meta-analysis of Babal JC. et al. [11] pooled together data about 5154 paediatric SCHFs with dislocation and found neurapraxia in 11.3% of patients. There are studies where they found fewer [9, 41], or more [42] patients with neurological deficits (See Fig. 3).

Limitations

Our main restraint was that the data evaluated was national and therefore may not be generalizable to other countries. Furthermore, not all results were reported in all cases, consequently, there were endpoints representing less than the

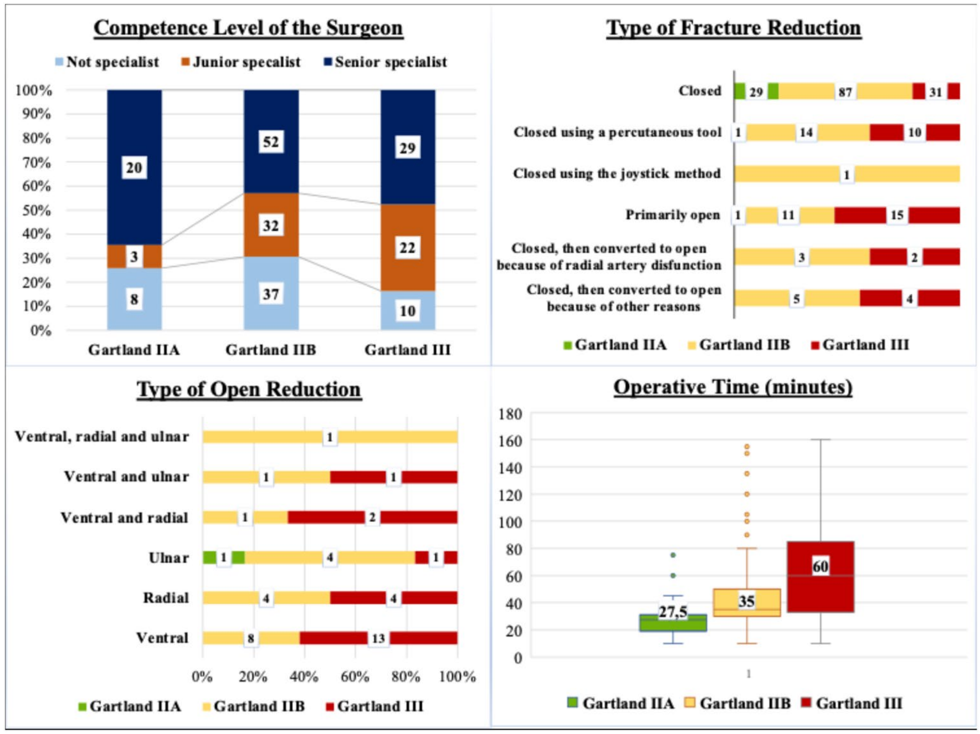

Fig. 2 Operative data by fracture type groups: a column chart comparing the competence level of the surgeon, a column chart comparing the type of fracture reduction, a column chart comparing the type of open reduction, and a box chart comparing the operative time in minutes. On the box plots the numbers show the median value of the specific outcomes. All comparisons are between Gartland IIA, Gartland IIB and Gartland III groups

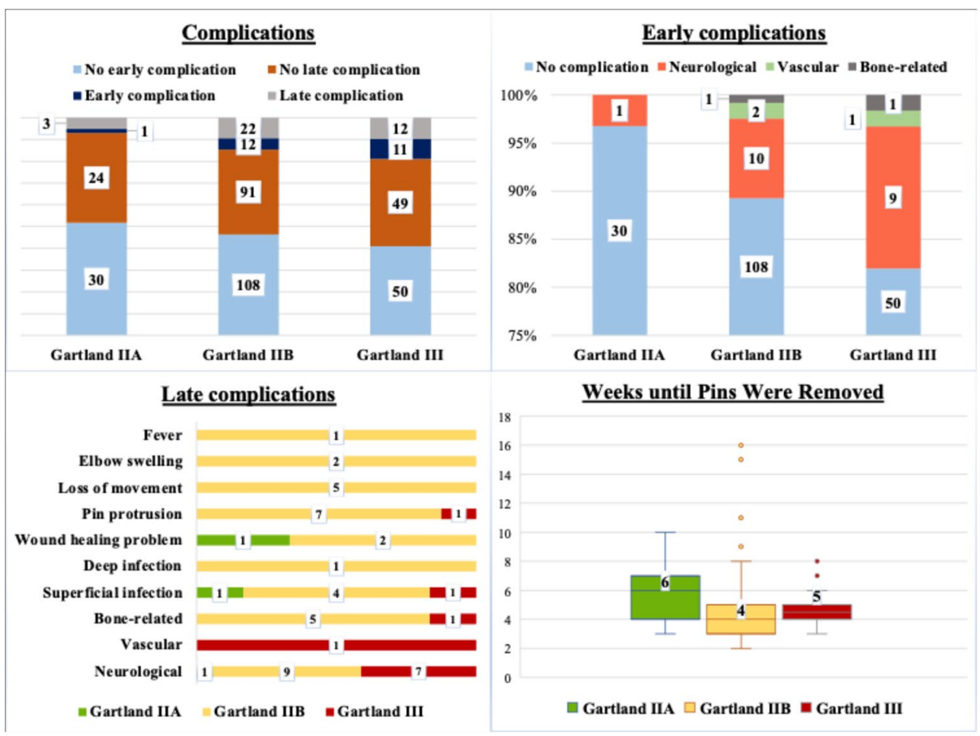

Fig. 3 Postoperative data by fracture type groups: a column chart comparing the early and late complication rates, a column chart comparing the early complication rates in detail, a column chart comparing the late complication rates in detail, and a box chart comparing the time passed until the pins were removed from the patients. On the box plots the numbers show the median value of the specific outcomes. All comparisons are between Gartland IIA, Gartland IIB and Gartland III groups

whole cohort. There were examined outcomes, where many subgroups were created in the registry, and despite the large study size this led to difficulties in the statistical analysis due to the low sample sizes in the subcategories. Even though the data to the registry was collected prospectively, surgeons were not required to perform uniformly timed follow-ups, leading to hardships in the analysis. Also, the database does not contain patient reported outcome measures.

Our study is not a prospective randomized trial, therefore causal relationships between different interventions could not be examined.

Conclusion

Our study emphasizes the significance of initial oxygen saturation levels as potential indicators of fracture severity. It also stresses the need for detailed attention to neurological complications and the prolonged use of pins, thereby highlighting the importance of customized treatment strategies in paediatric SCHFs.

Acknowledgements The authors thank the hard work of everyone involved in creating and maintaining the registry.

Authors' contributions M.V., L.Szak., T.K. and G.J. conceptualized the study; M.V. performed the data extraction; L.Szab. performed the statistical analysis; M.V. and A.L. drafted the manuscript; A.L, L. Szak., Á.Z., T.K. and G.J. provided critical appraisal of the manuscript; Á.Z. and G.J. contributed equally as last authors.

Funding No funding was received for conducting this study.

Data availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Scientific and Research Ethics Committee of the Medical Research Council (35335-2/2018/EKU).

Consent to participate Written informed consent was obtained from the parents.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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