

Outcomes of Nonoperatively Treated Pediatric Supracondylar Humeral Fractures at the Nkhotakota District Hospital, Malawi

Elijah Mlinde, BSc(Ortho&Trauma), Lahin M. Amlani, BSc, Collin J. May, MD, MPH, Leonard N. Banza, MBBS, FCS(ECSA), Linda Chokotho, MBBS, FCS(ECSA), MPH, and Kiran J. Agarwal-Harding, MD, MPH

Investigation performed at the Department of Orthopaedics, Nkhotakota District Hospital, Nkhotakota, Malawi, and the Harvard Global Orthopaedics Collaborative, Boston, Massachusetts

Background: Displaced supracondylar humeral fractures (SCHFs) benefit from closed reduction and percutaneous pinning. In Malawi, many SCHFs are treated nonoperatively because of limited surgical capacity. We sought to assess clinical and functional outcomes of nonoperatively treated SCHFs in a resource-limited setting.

Methods: We retrospectively reviewed all patients with SCHFs treated at Nkhotakota District Hospital (NKKDH) in Malawi between January 2014 and December 2016. Patients subsequently underwent clinical and functional follow-up assessment.

Results: We identified 182 children (54% male, mean age of 7 years) with an SCHF; 151 (83%) of the fractures were due to a fall, and 178 (98%) were extension-type (Gartland class distribution: 63 [35%] type I, 52 [29%] type II, and 63 [35%] type III). Four patients with type-I fractures were treated with an arm sling alone, and 59 were treated with straight-arm traction to reduce swelling and then splint immobilization until union. All 119 of the patients with Gartland type-II and III or flexion-type injuries were treated with straight-arm traction, manipulation under anesthesia without fluoroscopy, and then splint immobilization until union. A total of 137 (75%) of the patients were available for follow-up, at a mean of 3.9 years after injury. The Flynn functional outcome was excellent for 39 (95%) with a type-I fracture, 30 (70%) with type-II, and 14 (29%) with type-III. The Flynn cosmetic outcome was excellent for 40 (98%) with a type-I fracture, 42 (98%) with type-II, and 41 (84%) with type-III. Forty (98%) of the children with a type-I fracture, 41 (95%) with type-II, and 32 (65%) with type-III returned to school without limitation. Controlling for sex, delayed presentation, medical comorbidities, injury mechanism, and skin blistering/superinfection during traction, patients with type-II fractures were 5.82-times more likely (95% confidence interval [CI], 1.71 to 19.85) and those with type-III fractures were 9.81-times more likely (95% CI, 3.00 to 32.04), to have a clinical complication or functional limitation compared with patients with type-I fractures.

Conclusions: Nonoperative treatment of type-III SCHFs resulted in a high risk of clinical complications or functional impairment. These results illustrate the urgent need to increase surgical capacity in low-income countries like Malawi to improve pediatric fracture care.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Trauma-related mortality and disability are increasing in low- and middle-income countries¹⁻³. Approximately 13% of trauma-related deaths worldwide occur among children <15 years of age⁴. Up to 30 million children and adolescents worldwide are affected by nonfatal injuries annually⁵. Long-term disability and health-care-associated costs over a lifetime make

injuries in children especially devastating, often causing indignity, exclusion, pain, and poverty⁶⁻⁸.

Malawi is a low-income country in sub-Saharan Africa with 18 million people, 44% of whom are children <15 years of age^{9,10}. Malawi has a high and rising incidence of musculoskeletal injury, and one-third of trauma patients are children¹¹⁻¹³. Injury-related

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disability can disrupt children's education and affect future employment, with substantial economic consequences for patients, their families, and communities^{12,14,15}. Surgery can prevent short- and long-term disability, but access remains inadequate in Malawi because of limited hospital infrastructure, skilled staff, and essential resources¹⁵⁻¹⁷.

Supracondylar humeral fractures (SCHFs) are among the most common musculoskeletal injuries in children <16 years of age^{18,19}. For Gartland type-II and III SCHFs, the literature supports surgical treatment with closed reduction and percutaneous pinning²⁰⁻²². Few studies have examined the management and outcomes of SCHFs treated in low- and middle-income countries, where surgery is often unavailable¹⁹. In Malawi, most SCHFs are treated nonoperatively because of limited surgical capacity and expertise²³, and patients' clinical and functional outcomes remain unknown. To improve clinical care and guide surgical system development, we sought to assess outcomes of children with SCHFs treated nonoperatively in a rural Malawian district hospital where only nonoperative treatment was available.

Materials and Methods

Study Setting

Most health care in Malawi is delivered by public hospitals, organized into 3 levels: (1) health centers, providing basic medical and maternity care, and no surgical care; (2) district hospitals staffed by general doctors and clinical officers (nonphysician clinicians), providing nonspecialized surgical care; and (3) central hospitals, with specialist care²³. Nkhotakota District Hospital (NKKDH), in Malawi's Central region, serves a population of approximately 393,000, of whom about 180,000 are children <15 years of age⁹. Orthopaedic care is provided by 2 orthopaedic clinical officers trained in nonoperative treatment. NKKDH has 1 operating theater, mainly for obstetric and general surgical cases. There is no fluoroscope. Plaster for splinting/casting is occasionally unavailable¹⁶. The closest orthopaedic surgeon is in the capital city, Lilongwe, approximately 200 km away.

Study Design and Sample

From NKKDH inpatient records, we retrospectively identified all children with SCHFs treated between January 1, 2014, and December 31, 2016. Patients with pathologic fractures, open fractures, and congenital musculoskeletal conditions were excluded. Children ≤ 3 years of age with transphyseal separations and those ≥ 15 years of age with adult-type distal humeral fractures were excluded. We recorded each patient's sex, age at presentation, home traditional authority (a district subdivision), and medical comorbidities. We documented injury mechanism, injury characteristics, associated injuries, treatment provided, complications during hospitalization, and timeline from injury to hospital discharge.

Treatment Technique

All patients were admitted for at least overnight observation. Patients with minimal swelling and displacement were im-

mobilized in a simple arm sling for 3 weeks. For all others, overhead straight-arm traction of the injured limb was used for fracture immobilization and to reduce swelling. To perform straight-arm traction, strips of medical-grade cloth tape were applied to the skin from the proximal forearm to the wrist. The distal ends of the tape strips were attached with an inelastic cord to an overhead beam, suspending the extremity (Fig. 1). Patients were hospitalized and on bed rest while in traction, which was discontinued once swelling subsided, usually in 3 to 7 days. Post-traction radiographs were made; traction effectively reduced swelling but did not substantially change fracture displacement.

Patients with nondisplaced, Gartland type-I injuries were immobilized in a posterior slab plaster splint in 90° to 100° of elbow flexion. Patients with displaced fractures (flexion-type,



Fig. 1

A child in straight-arm traction. The child fell and sustained a closed type-II supracondylar fracture of the left humerus, for which straight-arm traction was performed at Nkhotakota District Hospital. Cloth tape was applied directly to the skin in long strips from the proximal forearm to the wrist and over-wrapped with gauze bandage. The distalmost ends of the tape strips were fashioned into a loop, from which an inelastic cord was attached to an overhead beam in the inpatient ward, suspending the affected extremity above the patient.

and Gartland type-II or III extension-type injuries) underwent closed manipulations under general anesthesia, without fluoroscopy. Formal post-procedure radiographs were made, and manipulations were repeated for patients with residual displacement. All patients who underwent manipulations were immobilized in a posterior slab splint: flexion-type injuries in 10° to 15° of elbow flexion, extension-type in 90° to 100° of elbow flexion. All patients were immobilized for at least 3 weeks, or until radiographic evidence of fracture union at the time of follow-up.

Follow-up Assessments

We invited patients identified from inpatient records to participate in the follow-up assessment. Patients were contacted by telephone when possible, we made radio announcements, and the first author (E.M.) performed assessments in patients' homes. All patients or their parents/guardians gave informed consent/assent prior to participation.

Patients were evaluated for infection, neurovascular injury, myositis ossificans, amputation, and Volkmann ischemic contracture. Elbow flexion/extension and carrying angle were measured by goniometer and compared with those of the contralateral, uninjured limb using the Flynn criteria (loss of 0° to 5° = excellent, 6° to 10° = good, 11° to 15° = fair, and >15° = poor) to give functional and cosmetic scores²⁴. Patients scored their functional impairment from 0 to 10, with 0 indicating no impairment and 10 indicating complete inability to perform regular activities in the 7 days prior to assessment. Pain was subjectively quantified from 0 to 10, with 0 indicating no pain and 10 indicating the worst pain possible in the 7 days prior to assessment. Patients were also asked whether they had returned to school and chores and whether return to either was limited by their injury.

All patients were referred to NKKDH for new elbow radiographs at the time of follow-up. We evaluated follow-up radiographs for fracture union and measured Baumann angles.

Statistical Analysis

We used Redivis (Redivis, Inc.) to calculate estimated travel time for each patient from their home traditional authority to NKKDH. We grouped patients by an estimated travel time of <20 or ≥20 minutes; the latter has been associated with increased risk of delayed presentation¹⁷. We calculated the time from injury to presentation, treatment start to end, and discharge to follow-up assessment. Patient presentation ≥2 days after injury was considered delayed¹⁷.

We analyzed clinical and functional outcomes of patients who underwent follow-up assessment. We defined a "composite poor outcome" as any clinical complication, including neurovascular impairment, elbow stiffness or deformity (less-than-excellent Flynn functional or cosmetic score), abnormal Baumann angle, or any functional impairment or pain. For patients with isolated, extension-type injuries, we performed bivariate analyses using modified Poisson regression to examine associations between Gartland classification and the following outcomes: less-than-excellent Flynn functional score,

less-than-excellent Flynn cosmetic score, return to school with limitations due to injury, return to chores with limitations due to injury, and composite poor outcome.

We then performed bivariate analyses using modified Poisson regression to examine associations between composite poor outcome and 10 covariates: age, sex, estimated travel time, delayed presentation, medical comorbidities, mechanism of injury, fracture laterality, Gartland type, complications during hospitalization, and inpatient treatment duration. Covariates with bivariate relative risks (RRs) of >1.25 or <0.8, or with *p* values of <0.05, were included in multivariate analysis¹⁷. The parsimonious model was constructed by sequentially excluding the covariate with an RR closest to 1.0 until all covariates were >1.25 or <0.8.

We performed statistical analysis using SAS 9.4 (SAS Institute). The Malawian National Health Sciences Research Committee gave ethical approval (Protocol #19/03/2265).

Source of Funding

This project was supported by a research grant from the AO Alliance Foundation. The funder had no role in the study design or execution, analysis or interpretation of data, or decision to publish.

Results

From January 2014 to December 2016, 182 patients with an SCHF (54% male, mean age of 7 years) were treated at NKKDH. All had closed, unilateral injuries. Most patients (114, 63%) had an estimated travel time of ≥20 minutes, and 17 patients (9%) had delayed presentation. A fall accounted for 151 (83%) of the fractures, 137 (75%) were left-sided, and 178 (98%) were extension-type. Extension-type injuries included 63 Gartland type-I fractures (35%), 52 type-II (29%), and 63 type-III (35%). Two patients had ipsilateral distal forearm fractures. Four patients with type-I fractures were treated with an arm sling alone, and 59 were treated with straight-arm traction and then splint immobilization. All 119 of the patients with Gartland types-II and III or flexion-type injuries were treated with straight-arm traction, manipulation under anesthesia, and then splint immobilization. Patients were hospitalized for a mean of 4.8 days (95% confidence interval [CI], 4.36 to 5.17 days). Eight (4.4%) of the patients had malaria, and 2 (1.1%) had respiratory infections. Skin blistering from tape used for traction and subsequent superinfection—the only reported complication during hospitalization—occurred in 23 (13%) of the patients (Table I).

A total of 137 (75%) of the patients were available for follow-up, at a mean (and standard deviation) of 3.9 ± 0.95 years after injury (median, 4.0 years; range, 2.4 to 5.4 years). Descriptive statistics are summarized in Table I. At the time of follow-up, 1 patient had an anterior interosseous nerve palsy, and 1 had numbness in the ulnar nerve distribution. On follow-up radiographs, 4 (3%) of the patients demonstrated a valgus deformity (Baumann angle of 60° to 62°), and 3 (2%) had a varus deformity (Baumann angle of 82° to 84°) (Table II). Five of the 7 patients with radiographic evidence of malunion had functional limitations/pain at the time of follow-up.

TABLE I Descriptive Statistics*		
Characteristic	Total Cohort	Cohort with Follow-up
No. of patients (% of total cohort)	182 (100)	137 (75.3)
Age (yr)	7.0 ± 2.4	7.0 ± 2.5
Age group		
<6 yr	57 (31.3)	45 (32.9)
≥6 yr	125 (68.7)	92 (67.2)
Sex		
Female	84 (46.2)	60 (43.8)
Male	98 (53.9)	77 (56.2)
Home traditional authority†		
Kafuzira (82 km)	19 (10.4)	16 (11.7)
Kanyenda (62 km)	35 (19.2)	19 (13.9)
Malengachanzi (16 km)	46 (25.3)	28 (20.4)
Mphonde (17 km)	22 (12.1)	19 (13.9)
Mwadzama (65 km)	30 (16.5)	27 (19.7)
Mwansambo (57 km)	30 (16.5)	28 (20.4)
Estimated travel time		
<20 min	68 (37.4)	47 (34.3)
≥20 min	114 (62.6)	90 (65.7)
Time to presentation (days)	0.8 ± 0.8	0.8 ± 0.7
Delayed presentation	17 (9.3)	9 (6.6)
Medical comorbidities		
Malaria	8 (4.4)	5 (3.7)
Pneumonia	1 (0.6)	1 (0.7)
Upper respiratory tract infection	1 (0.6)	1 (0.7)
None	172 (94.5)	130 (94.9)
Mechanism of injury		
Fall	151 (83.0)	113 (82.5)
Road traffic collision	3 (1.7)	3 (2.2)
Sports	28 (15.4)	21 (15.3)
Fracture laterality		
Left	137 (75.3)	104 (75.9)
Right	45 (24.7)	33 (24.1)
Fracture type‡		
Flexion-type	4 (2.2)	3 (2.2)
Extension-type	178 (97.8)	134 (97.8)
Gartland type I	63 (35.4)	41 (30.6)
Gartland type II	52 (29.2)	44 (32.8)
Gartland type III	63 (35.4)	49 (36.6)
Concomitant injuries		
Distal radial/ulnar fracture	2 (1.1)	1 (0.7)
None	180 (98.9)	136 (99.3)
Treatment type		
Straight-arm traction + manipulation	119 (65.4)	96 (70.1)
Straight-arm traction only	59 (32.4)	39 (28.5)

continued

TABLE I (continued)		
Characteristic	Total Cohort	Cohort with Follow-up
Arm sling only	4 (2.2)	2 (1.5)
Early complications		
Skin blisters with superinfection	23 (12.6)	17 (12.4)
None	159 (87.4)	120 (87.6)
Mean duration of hospitalization§ (days)	4.8 ± 2.8	4.8 ± 2.7
Duration of hospitalization		
<5 days	102 (56.0)	77 (56.2)
≥5 days	80 (44.0)	60 (43.8)

*The values are given as the number, with the percentage in parentheses, except for age and duration of hospitalization, which are given as the mean and standard deviation. Percentages may not sum to 100 because of rounding. †Traditional authorities are subdivisions of districts in Malawi. ‡Fracture type was recorded as documented by clinicians in the inpatient record, since initial injury radiographs for most patients were not available for post-hoc review. §Patients were hospitalized while undergoing straight-arm traction, which was used for immobilization and to reduce swelling in the injured arm. When swelling had subsided, all patients who underwent straight-arm traction were transitioned to a splint (after manipulation under anesthesia for patients with displaced fractures) and discharged from the hospital.

Eighty-seven (64%) of the patients had an excellent Flynn functional score, and 127 (93%) had an excellent Flynn cosmetic score. Flynn scores by Gartland type are reported in Table III. Return to school and chores was limited because of injury for 20 (15%) and 32 (23%) of the children, respectively. Most patients (105, 77%) reported no functional impairment, 27 (20%) reported functional scores of 1 to 2, and 5 (4%) reported scores of 3 to 5. Ninety-one (66%) of the patients reported no pain, 25 (18%) reported pain scores of 1 to 2, and 21 (15%) reported pain scores of 3 to 5. Sixty-one (44.5%) of the patients had a clinical complication or functional limitation at the time of follow-up (composite poor outcome) (Table II). Compared with those with type-I fractures, patients with types-II and III fractures were at greater risk for a less-than-excellent Flynn functional score, return to school/chores with limitations due to injury, and a composite poor outcome. Patients with type-III fractures were also at increased risk for a less-than-excellent Flynn cosmetic score (Table IV).

Girls had a 29% increased risk of a composite poor outcome (RR, 1.29; 95% CI, 0.77 to 2.19) compared with boys. Delayed presentation was associated with a 50% increased risk of a composite poor outcome (RR, 1.50; 95% CI, 0.58 to 3.84). Compared with patients without comorbidities, those with medical comorbidities had a 47% greater risk of a composite poor outcome (RR, 1.47; 95% CI, 0.50 to 4.26). Patients injured playing sports had a 50% greater risk of a composite poor outcome (RR, 1.50; 95% CI, 0.79 to 2.85) compared with those injured from a fall or road traffic collision. Patients with skin

TABLE II Outcomes at the Time of Follow-up Evaluation (N = 137)

Outcome Variable	No. (%)
Flynn functional score	
Excellent	87 (63.5)
Good	25 (18.3)
Fair	13 (9.5)
Poor	12 (8.8)
Flynn cosmetic score	
Excellent	127 (92.7)
Good	5 (3.7)
Fair	2 (1.5)
Poor	3 (2.2)
Late complications*	
Cubitus valgus	2 (1.5)
Cubitus varus	4 (2.9)
Elbow stiffness	3 (2.2)
Nerve palsy-anterior interosseous nerve	1 (0.7)
Nerve palsy-ulnar	1 (0.7)
Baumann angle†	
Normal	130 (94.9)
Valgus	4 (2.9)
Varus	3 (2.2)
Return to school	
Without limitations	117 (85.4)
Limited by the injury	20 (14.6)
Return to chores	
Without limitations	105 (76.6)
Limited by the injury	32 (23.4)
Functional score‡	
0	105 (76.6)
1-2	27 (19.7)
3-5	5 (3.6)
Pain score§	
0	91 (66.4)
1-2	25 (18.2)
3-5	21 (15.3)
Composite outcome#	
No clinical complication or functional limitation	76 (55.5)
Any poor clinical or functional outcome	61 (44.5)

*Late complications were based on physical examination at the time of the follow-up evaluation. †Baumann angles were measured on radiographs made at the time of the follow-up evaluation. ‡Functional scores are reported on a scale of 0 to 10, with 0 indicating that the injury had no effect on regular daily activities and 10 indicating that the injury completely prevented the patient from doing regular daily activities in the 7 days prior to the follow-up assessment. §Pain scores were assessed on a scale of 0 to 10, with 0 indicating that the patient had no pain and 10 indicating that the patient had the worst possible pain in the injured extremity in the 7 days prior to the follow-up assessment. #Composite poor outcome refers to any poor clinical or functional outcome, including neurovascular impairment, a Flynn functional or cosmetic score that was less than excellent, abnormal Baumann angle, and functional limitations or pain on return to school or chores.

blisters with superinfection (early complication) had a 42% greater risk of a composite poor outcome (RR, 1.42; 95% CI, 0.71 to 2.82) compared with those who did not experience early complications. Controlling for sex, delayed presentation, medical comorbidities, mechanism of injury, and early complications, patients with Gartland type-II and III fractures had a significantly increased risk of a composite poor outcome compared with those with type-I fractures (type-II: 5.82 times more likely [RR, 5.82; 95% CI, 1.71 to 19.85]; type-III: 9.81 times more likely [RR, 9.81; 95% CI, 3.00 to 32.04]) (Table V).

Discussion

SCHFs are common, but few studies have examined outcomes in low- and middle-income countries, where many patients are treated nonoperatively because of limited surgical capacity^{19,25}. In our retrospective assessment of children with closed SCHFs treated nonoperatively at NKKDH in Malawi, we found that patients with Gartland type-II and III fractures had a significantly increased risk of clinical complications and functional impairment compared with patients with type-I fractures.

In our cohort, 54% of the patients were boys, 75% of the patients had left-sided injuries, and 83% were injured by falling, all of which are similar to rates reported in the literature^{19,25-30}. Delayed presentation among pediatric fracture patients has previously been reported to be as high as 28% in Malawi¹⁷. However, only 9% of our cohort presented late, possibly because of the debilitating nature of SCHFs and the availability of care at NKKDH. Others have reported that 49% of type-III SCHFs can present with neurovascular compromise, and 3% to 15% can present with absent or diminished pulses³¹⁻³³. No neurovascular injuries were documented in the inpatient records of our cohort. Two patients had nerve palsies at the time of follow-up, and no patient had dysvascular limbs/amputation or Volkmann ischemic contracture. Neurovascular injuries may have been inadequately documented in the inpatient record, and patients with severe complications may have been lost to follow-up³⁴. In our cohort, 45% of the patients had a composite poor outcome. This was higher than the 25% of patients with unsatisfactory outcomes reported by Sinikumpu et al., although surgery was available to some patients in that cohort³⁵.

Girls, older children, children who lived farther away from the hospital, those who presented late, and those who had medical comorbidities, early complications, sports injuries, and longer hospitalization all had increased risk of a poor outcome. Other studies in low- and middle-income countries have reported worse outcomes for girls, related to underreporting and inequitable access to care^{36,37}. Older children have less potential for bone remodeling, resulting in persistent deformity³⁸. Delayed presentation may result in early fracture consolidation, greater difficulty with fracture reduction, and worse soft-tissue trauma from delayed immobilization, which could potentially worsen outcomes^{17,39,40}. Pediatric fracture patients in Malawi with sports-related injuries and who live farther from the hospital also have increased risk of delayed presentation¹⁷. Skin blisters with superinfection occurred in 13% of the patients, which is an

TABLE III Flynn Functional and Cosmetic Scores by Gartland Type (N = 133) *

	Type I (no. [%])	Type II (no. [%])	Type III (no. [%])	All (no. [%])
Flynn functional score				
Excellent	39 (95.1)	30 (69.8)	14 (28.6)	83 (62.4)
Good	2 (4.9)	9 (20.9)	14 (28.6)	25 (18.8)
Fair	0 (0)	3 (7.0)	10 (20.4)	13 (9.8)
Poor	0 (0)	1 (2.3)	11 (22.5)	12 (9.0)
Flynn cosmetic score				
Excellent	40 (97.6)	42 (97.7)	41 (83.7)	123 (92.5)
Good	0 (0)	0 (0)	5 (10.2)	5 (3.8)
Fair	1 (2.4)	0 (0)	1 (2.0)	2 (1.5)
Poor	0 (0)	1 (2.3)	2 (4.1)	3 (2.3)

*Three patients with flexion-type injuries and 1 patient with a concomitant ipsilateral distal forearm fracture were excluded from this analysis. The values are given as the number, with the percentage (reported by fracture type) in parentheses.

unfortunate but expected complication of skin traction, and may be associated with longer time in traction. Longer hospitalization may be associated with severity of fracture displacement and/or soft-tissue injury, both of which predispose patients to worse outcomes⁴¹⁻⁴³.

The literature supports nonsurgical treatment of Gartland type-I fractures and closed reduction and percutaneous pinning of types-II and III fractures^{21,22,44,45}. Patients with type-III fractures in our cohort had significantly increased risk of

elbow stiffness, deformity, functional limitation, and pain. Elbow stiffness and deformity are likely due to inadequate reduction and stabilization⁴⁶⁻⁴⁸. Distal humeral physeal injuries may cause abnormal growth and deformity⁴⁹. In Pakistan, Khan et al. reported that 80% of patients with displaced SCHFs treated with manipulation without fluoroscopy and casting had less-than-excellent Flynn scores, compared with 35% of patients treated surgically in the same resource-limited setting⁵⁰. We found similarly poor outcomes of nonsurgical care for displaced

TABLE IV Outcome Frequency and Relative Risks by Gartland Type (N = 133) *

Outcome Variable	Gartland Type	Outcome Frequency	Relative Risk (95% CI)	P Value†
Flynn functional score less-than-excellent	Type I‡	4.9% (2 of 41)	1	<0.001§
	Type II	30.2% (13 of 43)	6.20 (1.49 to 25.79)	
	Type III	71.4% (35 of 49)	14.64 (3.75 to 57.24)	
Flynn cosmetic score less-than-excellent	Type I‡	2.4% (1 of 41)	1	0.013§
	Type II	2.3% (1 of 43)	0.95 (0.06 to 14.75)	
	Type III	16.3% (8 of 49)	6.69 (0.87 to 51.33)	
Return to school with limitations due to the injury	Type I‡	2.4% (1 of 41)	1	<0.001§
	Type II	4.7% (2 of 43)	1.91 (0.18 to 20.24)	
	Type III	34.7% (17 of 49)	14.22 (1.98 to 102.37)	
Return to chores with limitations due to the injury	Type I‡	2.4% (1 of 41)	1	<0.001§
	Type II	14.0% (6 of 43)	5.72 (0.72 to 45.49)	
	Type III	51.0% (25 of 49)	20.92 (2.96 to 147.80)	
Composite poor outcome#	Type I‡	7.3% (3 of 41)	1	<0.001§
	Type II	41.9% (18 of 43)	5.72 (1.82 to 17.98)	
	Type III	79.6% (39 of 49)	10.88 (3.63 to 32.63)	

*Three patients with flexion-type injuries and 1 patient with a concomitant ipsilateral distal forearm fracture were excluded from this analysis. †Type-III p values are reported. ‡Reference group. §Significant. #Composite poor outcome refers to any poor clinical or functional outcome, including neurovascular impairment, a Flynn functional or cosmetic score that was less than excellent, abnormal Baumann angle, and functional limitations or pain on return to school or chores.

TABLE V Bivariate and Multivariate Predictors of Composite Poor Outcome in Modified Poisson Regression Analyses (N = 137)

Variable	Rate of Composite Poor Outcome*	Bivariate†		Multivariate§		Parsimonious Multivariate#	
		RR (95% CI)	P Value†	RR (95% CI)	P Value†	RR (95% CI)	P Value†
Age group			0.003**		0.577		
<6 yr††	26.7% (12 of 45)	1		1			
≥6 yr	53.3% (49 of 92)	2.00 (1.19 to 3.36)		1.21 (0.61 to 2.42)			
Sex			0.067		0.446		0.335
Female	53.3% (32 of 60)	1.42 (0.98 to 2.05)		1.23 (0.72 to 2.11)		1.29 (0.77 to 2.19)	
Male††	37.7% (29 of 77)	1		1		1	
Estimated travel time			0.485				
<20 min††	40.4% (19 of 47)	1					
≥20 min	46.7% (42 of 90)	1.15 (0.77 to 1.74)					
Delayed presentation			0.491		0.443		0.424
No††	43.8% (56 of 128)	1		1		1	
Yes	55.6% (5 of 9)	1.27 (0.69 to 2.35)		1.48 (0.57 to 3.80)		1.50 (0.58 to 3.84)	
Medical comorbidities			0.491		0.617		0.502
No††	43.8% (57 of 130)	1		1		1	
Yes	57.1% (4 of 7)	1.3 (0.67 to 2.55)		1.33 (0.45 to 3.99)		1.47 (0.50 to 4.26)	
Mechanism			0.082		0.244		0.227
Fall or road traffic collision††	41.4% (48 of 116)	1		1		1	
Sports	61.9% (13 of 21)	1.50 (1.00 to 2.23)		1.49 (0.78 to 2.84)		1.50 (0.79 to 2.85)	
Fracture laterality			0.780				
Left	45.2% (47 of 104)	1.07 (0.68 to 1.67)					
Right††	42.4% (14 of 33)	1					
Gartland type‡‡			<0.001**		<0.001**		<0.001**
Type I††	7.3% (3 of 41)	1		1		1	
Type II	41.9% (18 of 43)	5.72 (1.82 to 18.0)		5.44 (1.58 to 18.74)		5.82 (1.71 to 19.85)	
Type III	79.6% (39 of 49)	10.88 (3.63 to 32.63)		8.61 (2.53 to 29.28)		9.81 (3.00 to 32.04)	
Complications during hospitalization			0.021**		0.462		0.334
None††	40.8% (49 of 120)	1		1		1	
Skin blisters with superinfection	70.6% (12 of 17)	1.73 (1.19 to 2.51)		1.32 (0.64 to 2.74)		1.42 (0.71 to 2.82)	
Inpatient treatment duration			<0.001**		0.575		
<5 days††	31.2% (24 of 77)	1		1			
≥5 days	61.7% (37 of 60)	1.98 (1.34 to 2.91)		1.19 (0.65 to 2.17)			

*The values are given as the percentage of patients who had composite poor outcome, with the number in parentheses. †Bivariate analysis was performed for each covariate with composite poor outcome as the outcome measure. ‡Type-III p values are shown for categorical variables. §The multivariate model included categories with an RR of >1.25, an RR of <0.8, or p < 0.05. #The parsimonious model was constructed by sequentially excluding the lowest covariates until all covariates had an RR of >1.25, RR of <0.8, and/or p of <0.05. **Significant. ††Reference group. ‡‡Three patients with flexion-type injuries and 1 patient with a concomitant ipsilateral distal forearm fracture were excluded from analysis of this variable.

SCHFs, underscoring the urgent need to improve access to surgery for patients with type-III fractures.

This study had several limitations. First, initial injury radiographs were not available for review for most patients. We relied on patients/families keeping their hardcopy radiographs

for review or clinicians' documentation of fracture characteristics in the record, which was subject to error. Facilities for storing radiographs, whether in hardcopy or electronic form, would facilitate future retrospective studies. Second, lateral elbow radiographs, which are not obtained routinely by

Malawian radiology departments, were not made at the time of follow-up, making assessment of sagittal-plane deformity impossible. With 95% of the patients in this study having a normal Baumann angle on follow-up anteroposterior radiographs, manipulation without fluoroscopy, traction, and splint immobilization may effectively correct and maintain coronal alignment. However, 71% of patients with Gartland type-III injuries had loss of elbow range of motion; this suggests a high rate of residual sagittal-plane extension malunion, and may explain some of the poor functional results^{43,51-53}. Third, patient outcomes were not documented in the medical record, requiring us to seek out patients for follow-up assessments; 45 patients (25% of the cohort) were lost to follow-up. A prospective study might have improved follow-up rates. Fourth, data were collected from a single district hospital, limiting generalizability. Moreover, the first author (E.M.), who treated all patients initially, performed all assessments. This may have introduced bias toward underreporting complications or functional impairments. Future studies may benefit from independent assessments by research staff who do not participate in initial patient care. Lastly, all patients were treated nonoperatively, so the effectiveness of surgery in Malawi for SCHFs has not been demonstrated. Future studies should examine the feasibility and outcomes of surgical management of displaced SCHFs in Malawi.

In conclusion, despite its limitations, this study demonstrated unacceptable outcomes in Gartland type-II and III fractures treated nonoperatively in a low-resource setting. Without improving access to operative pinning with fluoroscopy, such poor results cannot be expected to change. There is a need to improve pediatric orthopaedic surgical capacity in Malawi and other similar settings. This will likely require standardization of treatment practices, advanced training of local providers, improved resource procurement, and investment in health-system infrastructure^{15,16,54-57}. In Malawi, operative orthopaedic surgical capacity is present only in central hospitals. Surgical capacity at central hospitals should certainly be strengthened, but resources

like Kirschner wires, wire-drivers, and fluoroscopy could also be pooled at select district hospitals, where local providers could be trained to manage SCHFs operatively and offload surgical volume from central hospitals. Future research assessing outcomes and the cost-effectiveness of surgery may further support the need for improvements in surgical capacity and increased access to surgery in countries like Malawi^{58,59}. ■

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Elijah Mlinde, BSc(Ortho&Trauma)¹
Lahin M. Amlani, BSc^{2,3}
Collin J. May, MD, MPH^{2,4,5}
Leonard N. Banza, MBBS, FCS(ECSA)⁶
Linda Chokotho, MBBS, FCS(ECSA), MPH⁷
Kiran J. Agarwal-Harding, MD, MPH²

¹Department of Orthopedics, Nkhotakota District Hospital, Nkhotakota, Malawi

²Harvard Global Orthopaedics Collaborative, Boston, Massachusetts

³Johns Hopkins University School of Medicine, Baltimore, Maryland

⁴Department of Orthopaedics, Boston Children's Hospital, Boston, Massachusetts

⁵Department of Orthopaedic Surgery, Harvard Medical School, Boston, Massachusetts

⁶Department of Orthopedics, Kamuzu Central Hospital, Lilongwe, Malawi

⁷Department of Surgery, Queen Elizabeth Central Hospital, Blantyre, Malawi

Email for corresponding author: kiran.agarwalharding@gmail.com

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