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Secondary fracture displacement after early pin removal in pediatric supracondylar humeral fractures: a longitudinal retrospective cohort study

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Abstract

Purpose

Supracondylar fractures of the distal humerus represent 15% of pediatric fractures and are among the most common childhood injuries. For unstable fractures, closed reduction with pinning and splinting is standard. However, optimal pin removal timing remains unclear. This study assessed complications, particularly secondary displacement after early pin removal, in children treated for unstable supracondylar fractures.

Method

We retrospectively reviewed pediatric patients surgically treated for supracondylar humeral fractures at our institution between January 2015 and December 2024. Collected data included demographics, Rigault-Lagrange fracture stage, duration of pin immobilization, and complications, including pin tract infection and secondary displacement after pin removal.

Results

A total of 211 patients were included (mean age 6.5 ± 2.3 years). According to the Rigault-Lagrange classification, 87 fractures were stage 2, 54 were stage 3, and 70 were stage 4. The mean duration of pin fixation and splint immobilization was 23.6 ± 4.0 days and was not influenced by fracture stage or patient age. After pin removal, 3 patients showed a change in Baumann's angle greater than 12° and no patients lost intersection of the anterior humeral line with the capitular ossification center. One patient needed early surgical revision for displacement before pin removal and no patient needed delayed humeral osteotomy.

Conclusion

Pin and splint removal 3 weeks after surgical treatment of supracondylar humeral fractures did not increase the risk of secondary displacement, irrespective of fracture stage. Early removal may also reduce complications associated with prolonged immobilization, such as pin tract infection and joint stiffness.

Level of evidence:

III (retrospective cohort study)

Introduction

Supracondylar fractures of the distal humerus (SCH) are among the most common pediatric fractures, representing approximately 15% of all childhood fractures and 48–78% of elbow fractures (1–3). Management ranges from cast immobilization for stable, nondisplaced fractures to closed reduction and pin fixation for unstable but reducible injuries. Open reduction with pinning is generally reserved for fractures associated with soft-tissue entrapment, vascular injury, or failed closed reduction (4, 5). Common constructs include two lateral retrograde pins, crossed fixation with one medial and one or two lateral pins, or three lateral pins. After fixation, the elbow is immobilized in a splint to enhance stability. Pins may be left exposed to outpatient removal with appropriate analgesia or buried, requiring a second procedure under general anesthesia (6).

Although adequately treated supracondylar fractures generally have good to excellent functional outcomes (3), complications may still occur and can adversely affect long-term elbow function. The most reported treatment-related complications include secondary displacement (2.9% to 13.4%), pin migration, pin-tract infection, postoperative stiffness, and malunion with recurvatum, cubitus varus or valgus with tardy ulnar nerve palsy (3, 4, 7–13).

However, there is still no consensus on the optimal timing of pin removal (2, 14–16). Ideally, pins should be removed neither too early, as this may compromise fracture stability, nor too late, as this may unnecessarily prolongs immobilization, limit joint motion, and increase the risk of stiffness and pin-tract infection (17).

Clinicians often remain hesitant to remove pins and splints early, particularly after displaced or unstable fractures or technically demanding procedures. Moreover, evidence is limited regarding early osteosynthesis material removal, the radiographic criteria used to assess secondary displacement, and their correlation with clinical outcomes.

The primary objective of this study was to evaluate the incidence of secondary displacement before and after early pin removal according to fracture stage. Secondary objectives were to characterize the timing of displacement, define literature-based radiographic criteria for significant displacement, and assess the association between radiographic findings and clinical outcomes. We hypothesized that early pin and splint removal (≤ 4 weeks) would not increase the risk of secondary displacement, regardless of fracture stage, compared to data from the literature.

Methods

Study design and setting

This retrospective cohort study was conducted at a tertiary university hospital from 2015 to 2024 and reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study was approved by the institutional ethics committee (CCER no: 2017 – 01617) and all the subjects or their legal representant provided written informed consent for the use of their data in research.

Population

Patients who underwent pin fixation for displaced supracondylar humeral fractures were identified from institutional electronic medical records using diagnostic and procedural codes. The following inclusion and exclusion criteria were applied:

Eligibility criteria

(1) Children younger than 16 years with a supracondylar fracture of the distal humerus; (2) Surgical treatment and follow-up completed at our institution; (3) At least 3 months of clinical and radiographic follow-up; and (4) Full adherence to postoperative treatment principles during follow-up.

Exclusion criteria

(1) Previous fracture or surgery involving the ipsilateral elbow; (2) Pathological fracture; (3) Bilateral supracondylar fractures; (4) Floating elbow injury pattern; (5) Surgery performed at another hospital; (6) Follow-up shorter than 3 months; (7) Incomplete medical records or radiographic data; (8) Radiographs of insufficient quality because of excessive artefacts; (9) Non-adherence to postoperative treatment principles during follow-up.

Sources and methods for participants selection

All eligible patients meeting inclusion criteria during the study period were identified through retrospective chart review. Patients were followed longitudinally with standardized assessments at baseline and follow-up visits (minimum three-months interval)..

Surgical Technique and Follow-up protocol

Surgical Technique and Follow-up protocol
All patients were treated by board-certified, fellowship-trained pediatric orthopaedic surgeons. Fixation primarily involved two divergent lateral pins; a third lateral or medial crossing pin was added only when residual instability persisted after initial lateral fixation. Patients were seen for pin and splint removal 3 weeks after surgery, with additional routine follow-up at 6 weeks, 3 months, and thereafter as clinically indicated. Follow-up was discontinued once satisfactory clinical recovery was achieved. Physiotherapy was not routinely prescribed, except in cases of neurological impairment or persistent limited mobility 12 weeks after surgery.

Variables and data sources

Medical records were reviewed to extract data on patient demographics (age and sex), injury characteristics (Rigault-Lagrange fracture type and neurovascular status at injury), surgical details (pin

number, fixation construct, and any additional fracture treatment), and postoperative outcomes (time to pin and splint removal and complications).

Fracture classification and radiographic assessment

Fractures were classified according to the Rigault-Lagrange system (18). Reduction quality and post-removal displacement were evaluated on radiographs obtained immediately after surgery, before pin removal at 3 weeks, and after pin removal. On lateral views, the position of the anterior humeral line (AHL) relative to the capitellar ossification center was recorded (19).

On anteroposterior views, the epiphyseal-diaphyseal angle (Baumann's angle) was measured, normal values ranging from 64° to 81°, with a mean of 72°–75°.

Primary and secondary outcomes

Based on prior literature, a change greater than 12° between two radiographs was considered significant and served as the primary outcome (20, 21) for the coronal plane. On the sagittal plane, significant displacement was defined by AHL passing anterior to the capitellar ossification center, with no intersection (22, 23). Secondary outcomes included systematically recorded complications, such as pin tract infection (24), symptomatic malunion requiring reoperation, and nerve injuries involving the radial, ulnar, or median nerve.

Sample size calculation

Before the study, a power analysis was performed for secondary fracture displacement, based on an expected rate below 5% from previous studies (10, 25, 26). The final cohort of 211 patients exceeded the required sample size of 203, which provided 80% power with a ± 3.0% margin at the 95% confidence level.

Statistical analysis

Analyses were performed using R software (version 4.4.1, R Foundation for Statistical Computing, Vienna, Austria) and the RStudio interface (version 2024.09.0, Posit software, PBC). The level of significance was set at p-values < 0.05. The normality of the data distribution was assessed using the Shapiro-Wilk test. Comparisons between groups based on fracture stages were made using the unpaired Student's T-test.

Descriptive statistics were calculated for all variables. Continuous variables with non-normal distributions were reported as median [interquartile range] or mean ± standard deviation [range], as appropriate. Between-group comparisons were performed using unpaired Mann-Whitney U tests for continuous outcomes and Fisher's exact test for categorical outcomes, reported as n (%).

Results

Population flow and recruitment

The cohort included 211 patients with supracondylar distal humeral fractures (108 males and 103 females), all with at least 3 months of follow-up. The mean age was 6.5 ± 2.3 years (range, 1.0–12.9). The right side was affected in 42% of cases. The patient selection flowchart is shown in Fig. 1.

Fracture and surgical treatment characteristics

Table 1 summarizes patient epidemiological characteristics and fracture stages: 87 patients had Rigault-Lagrange stage 2 fractures, 54 had stage 3 fractures, and 70 had stage 4 fractures. Most of the patients underwent closed reduction and percutaneous pinning (206/211, 98%). Fixation consisted of two lateral pins in 161 cases, three lateral pins in 30 cases, and crossed pins (two lateral and one medial) in the remaining 20 cases (Table 2). Pins and splint were removed after a mean of 23.6 ± 4.0 days after surgery.

Table 1
Epidemiological data of the 211 included patients

Outcomes	**Values**
Mean age ± SD (years)	6.5 (2.3) [range: 1.0 to 12.9]
Male sex, n (%)	108/211 (51.2%)
Season	
Spring n (%)	63/211 (29.9%)
Summer n (%)	59/211 (28.0%)
Autumn n (%)	65/211 (30.8%)
Winter n (%)	24/211 (11.4%)
Rigault-Lagrange stage	
Type II, n (%)	87/211 (41.2%)
Type III, n (%)	54/211 (25.6%)
Type IV, n (%)	70/211 (33.2%)
Data are presented as mean (standard deviation) [range] for continuous variables and n (%) for categorical variables.	

Table 2
Operative parameters and complications

Outcomes	Values
Pin construct type	
2-lateral pins	161/211 (76.3%)
3-lateral pins	30/211 (14.2%)
Crossed pins	20/211 (9.5%)
Displacement during follow-up	11/211 (5.2%)
Surgical revision for secondary displacement	1 (0.4%)
Corrective osteotomy (n)	0 (0.0%)
Pin track infections	4/211 (1.9%)
Data are presented as n (%) for categorical variables.	

Secondary displacement

Secondary radiological displacement was observed in 11 patients with a total of 13 displacements; 10 displacements occurred before pin removal and 3 after removal (2 patients had displacements before and after on the coronal plane). Displacement occurred in the sagittal plane in 2 cases and in the coronal plane in 11 cases. Secondary displacement did not appear to be associated with fracture severity (Table 3).

Table 3
Secondary fracture displacement data.

Outcomes	Before pin removal *	After pin removal *
Displacement per fracture stage		
Type II, n (%)	3/87 (3.4%)	0/87 (0%)
Type III, n (%)	3/54 (5.5%)	0/54 (0%)
Type IV, n (%)	4/70 (5.7%)	3/70 (4.3%)
Displacement per construct type		
2-lateral pins	9/161 (5.6%)	1/161 (0.6%)
3-lateral pins	1/30 (3.3%)	2/30 (6.7%)
Crossed pins	0/20 (0%)	0/20 (0%)
Direction of displacement		
Frontal plane, n (%)	8/13 (61.5%)	3/13 (23.1%)
Sagittal plane, n (%)	2/13(15.4%)	0/13 (0.0%)
Number of displacements (n = 13)	10/13 (76.9%)	3/13 (23.1%)

***** *Secondary radiological displacement was observed in 11 patients with a total of 13 displacements (2 patients had displacements before and after on the coronal plane).; 10 displacements occurred before pin removal and 3 after removal.*

Timing and severity of displacement

Analysis of displacement timing and severity showed that early displacement was associated with greater displacement severity. Among patients with secondary displacement, 10/13 (76.9%) had two lateral pin fixation. The remaining one (1/13) had three lateral pin constructs and one (1/13) presented with monocortical pin fixation..

Other complications

Four children developed infectious complications. Two had pin tract infections associated with septic arthritis of the elbow and required pin removal, surgical debridement, arthrotomy with irrigation, and antibiotic therapy. The other two were treated with pin removal and antibiotics alone. All infections were resolved without long-term sequelae. Neurological deficits were observed in 14 patients: 8 had anterior interosseous nerve palsy (57%), 2 had ulnar nerve injury (14%), and the remaining patients had radial nerve palsy. All patients have full functional and clinical recovery between 6 and 12 months postoperatively and none of them needed secondary surgery for release, transposition, or graft.

Clinical outcomes

One patient needed early surgical revision one week postoperatively, treated with secondary closed reduction and pinning. This patient presented with major coronal plane displacement and had uneventful outcomes at 3 months postoperatively. None of the included patients required delayed corrective osteotomy for distal humeral realignment. Functional outcomes were considered satisfactory during follow-up, including in patients with posterior displacement and recurvatum of up to 20°. The two patients with displacement on the sagittal plane, were 4 and 5 years old respectively and showed satisfactory remodeling during follow-up. In the coronal plane, changes in Baumann's angle were not associated with clinically significant varus or valgus deformity or impaired elbow function.

Discussion

The timing of pin removal and postoperative immobilization after displaced supracondylar fractures varies widely between centers, with no clear evidence-based consensus. In clinical practice, decisions are often guided by institutional protocols or surgeon preference. The key issue is determining when fracture healing in young children is sufficient to allow safe removal of both pins and immobilization without increasing the risk of secondary displacement.

In children, supracondylar humeral fractures usually heal rapidly. Although no precise healing threshold has been defined, 3 weeks is generally considered sufficient for fracture consolidation. Clinically, surgeons treating delayed presentations or revising early loss of reduction often observe substantial healing by approximately 10 days, which can make reduction more difficult (27, 28). Few studies have assessed outcomes by fracture stage or examined the risk of displacement after early pin and splint removal. Our study addresses this gap by evaluating whether the duration of pin fixation and immobilization can be safely shortened.

Our study showed a low rate of secondary fracture displacement after pin removal at 3 weeks, with an overall incidence of 5.2%. Similarly, low rates have been reported in previous studies, although pins were removed later. Aubret et al. observed no secondary displacement after K-wire removal at a mean of 29.8 days; the two early displacements in their series occurred before pin removal and were attributed to inadequate initial reduction or fixation (29). Pennock et al. reported a 4.2% loss-of-reduction rate (26), whereas Yaokreh et al. found a 3.4% rate of secondary displacement after K-wire removal at 6 weeks (30). Together, these findings highlight the need to define the optimal timing for pin and splint removal. Professional societies have also addressed this question. In a 2022 survey of 184 members of the European Paediatric Orthopaedic Society, reported that most respondents removed pins 3 to 4 weeks after surgery, although the rationale for this timing was not specified (31). The survey also did not report immobilization duration or whether additional immobilization was used after pin removal. Jones et al. similarly found that a mean immobilization period of 28.8 days after surgery for displaced supracondylar fractures achieved good outcomes without increasing complications compared with longer immobilization, supporting 4 weeks of splinting as a safe and reasonable approach (2). By contrast, Sheikdon et al. showed that immobilization extended to 6 weeks was significantly associated with

poorer functional outcomes, particularly reduced elbow range of motion and carrying angle, with effects persisting up to 6 months postoperatively (17).

Our results also suggest that the risk of displacement did not differ significantly between fracture stages, indicating that pin and splint removal at 3 weeks may be safe even for more displaced or unstable fractures. Similarly, Pennock et al. reported that age, sex, fracture type, comminution, and fracture location were not associated with loss of reduction after pin removal (26). This finding is clinically relevant because it challenges the common assumption that more severe fractures require longer immobilization.

Secondary displacement may occur at two distinct time points: before pin and splint removal or after. In our cohort, 76.9% of displacements occurred before pin removal and 23.1% afterward. Early displacement, defined as loss of reduction between immediate postoperative radiographs and radiographs obtained at pin removal, is most likely related to technical factors during fixation. Reported risk factors for early instability include failure to secure both fragments with at least two bicortical pins, inadequate pin separation at the fracture site (> 2 mm), fracture comminution, and flexion-type fracture pattern (10, 25). In a series of 279 fractures, pins fixation failure occurred in 2.9% of cases and required revision surgery between postoperative days 7 and 10 in 1.6% (10). Delayed displacement may occur after pins removal during longer-term follow-up, but available evidence suggests that this risk is very low when stability has been maintained until pins removal (32).

Secondary radiographic displacement, whether early or delayed, does not always result in clinically meaningful functional impairment. In our cohort, one patient required early surgical revision, but no one had delayed corrective humeral osteotomy, suggesting that radiographic criteria may not fully reflect functional outcomes and should be further evaluated. This discrepancy may be partly explained by differences between sagittal and coronal measurements and their clinical relevance. In the sagittal plane, an AHL positioned anterior to the capitellum has been associated with reduced elbow flexion and poorer outcomes (23). An AHL crossing the middle or posterior third of the capitellum is generally considered optimal, whereas crossing the anterior third may remain acceptable in children younger than 5 years because of remodeling potential (23, 33). In the coronal plane, alignment is usually acceptable when Baumann's angle remains between 64° and 81°, even if it changes by more than 12° from the postoperative value. Clinically significant coronal malalignment is more likely when Baumann's angle is outside this range, differs by more than 10° from the contralateral side, and is accompanied by visible clinical deformity (21).

Because supracondylar humeral fractures occur in young children with substantial remaining growth, some remodeling of established malunion can be expected. Previous studies have shown restoration of the AHL to the middle or posterior third of the capitellum, with subsequent improvement in elbow flexion during follow-up (23). Patient age and residual remodeling potential should therefore be considered. Gamble et al. reported complete remodeling of sagittal displacement in 60% of children and partial remodeling in a further 30%. Remodeling may be complete in children younger than 5 years, but

spontaneous correction decreases with age and becomes minimal after 8 years (33). Early removal of percutaneous pins may also reduce pin tract infections. In our cohort, the infection rate was 1.9%, lower than rates reported in previous studies. For example, a pooled analysis of 18 studies including 2,655 patients found an overall pin tract infection rate of 5.1% (34–51). This low infection rate may therefore support earlier pin removal, particularly when pins are left percutaneous.

This study has several limitations inherent to its retrospective design. Data were collected retrospectively from records of variable quality, and cases with incomplete data were excluded. We could not assess several potential confounders, including treatment adherence, physical activity, bone quality, or contralateral elbow measurements. Measurement variability may be partly attributable to limitations in reproducing the X-ray acquisition and obtaining strictly identical radiographic views. The cohort was drawn from a single center, and no control group with prolonged immobilization (> 4 weeks) was available. Finally, the limited number of secondary displacements precluded subgroup analyses and robust identification of risk factors.

Future studies should further test this hypothesis. Identifying early and delayed risk factors for secondary displacement could support the development of a risk score to individualize immobilization duration. A multicenter randomized controlled trial comparing early removal at 3 weeks with delayed removal could evaluate secondary displacement, complications, validated functional outcomes, and costs. Automated radiographic measurements using artificial intelligence may also reduce measurement variability and help build predictive models based on age, initial displacement, and fracture stage.

Conclusion

SCH fractures frequently affect children. Surgery with closed reduction, pinning, and splinting is standard and generally yields good functional results. Postoperative protocols differ by region, hospitals and surgeons, but this study shows that removing pins and splints at three weeks does not increase the risk of secondary fracture displacement, regardless of the fracture stage. In this context, early pins removal may mitigate the risk of complications associated with prolonged immobilization, including pin tract infections and joint stiffness. These findings support the implementation of standardized postoperative management protocols and provide clearer guidance for clinicians worldwide.

Abbreviations

SCH Supracondylar fractures of the distal humerus

AHL Anterior Humeral Line

Declarations

Conflict of Interest Statement

The Author(s) declare(s) that there is no conflict of interest.

Ethics Statement

This study was approved by the Institutional Research Ethics Committee (CCER 2017 – 01617) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants or their legal guardians.

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This research received no external funding.

Author Contribution

A.T.: Conceptualization; Methodology; Writing – original draft; Writing – review & editing. V.S.: Investigation; Data curation; Writing – review & editing. J.M.: Investigation; Data curation; Writing – review & editing. A.R.: Validation; Writing – review & editing. R.D.: Validation; Writing – review & editing. G.D.M.: Validation; Writing – review & editing. O.V.: Validation; Writing – review & editing. D.C.: Validation; Writing – review & editing. A.T.-F.: Conceptualization; Methodology; Formal analysis; Data curation; Validation; Writing – review & editing. C.S.: Conceptualization; Supervision; Data curation; Validation; Writing – review & editing.

Data Availability

Data of the current study are not publicly available. They are, however, available upon request.

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Figures

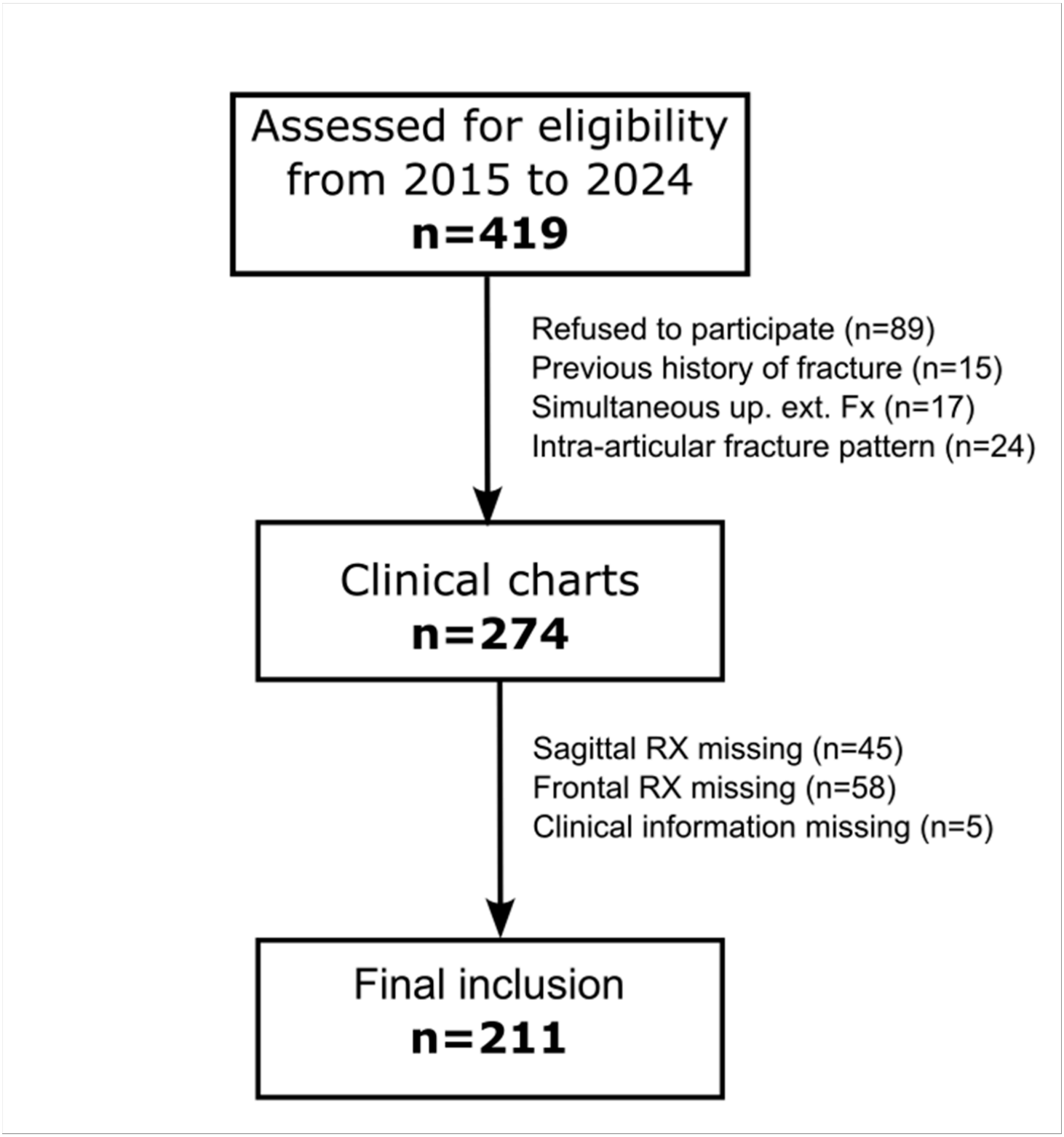


Figure 1

Flow chart of the included patients.