

Incidence of secondary interventions after early spica casting for diaphyseal femur fractures in young children

Éliane Rioux Trottier, MD
Leah Hatcher, BEng
Jessica Feng, BSc
Mark Camp, MD, MSc
Maryse Bouchard, MD, MSc

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Correspondence to:

M. Bouchard
Division of Orthopedics
The Hospital for Sick Children
555 University Ave
Toronto ON M5G 1X8
maryse.bouchard@sickkids.ca

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Background: Children aged 6 months to 5 years with diaphyseal femur fractures are typically treated with spica casting, as recommended by the American Association of Orthopaedic Surgeons clinical practice guideline. We aimed to determine the incidence of secondary interventions after early spica casting for femur fractures in children aged 6 years or less.

Methods: This was a retrospective cohort study of patients aged 6 years or less with diaphyseal femur fractures treated with early spica casting at a single Canadian tertiary care, level 1 trauma pediatric centre between January 2005 and May 2015.

Results: A total of 246 patients were included (190 boys [77.2%] and 56 girls [22.8%] with a mean age of 2.28 yr [standard deviation (SD) 1.35 yr]). Nine patients (3.7%) required early secondary interventions (cast wedging in 8 and flexible intramedullary nail fixation in 1). At last follow-up, 51 patients (20.7%) had clinically measurable limb length discrepancy (LLD) (mean 9.4 mm [SD 3–25 mm]), and 1 patient (0.4%) had mild clinical valgus deformity. Older, heavier patients with initial fracture shortening of 20 mm or more had a higher likelihood of developing a clinically measurable LLD. No patient required surgical intervention after fracture union to correct acquired LLD or angular deformity.

Conclusion: Early spica casting for diaphyseal femoral fractures in children aged 6 years or younger had a low rate of complications and return to the operating room. Although 21% of patients had a clinically measurable LLD at last follow-up, no patient required secondary intervention after fracture union to correct acquired LLD or angular deformity. These findings have relevance for the Canadian health care system, especially during the COVID-19 pandemic.

Contexte : Habituellement, les enfants de 6 mois à 5 ans ayant subi une fracture diaphysaire du fémur sont traités au moyen d'un spica plâtré, comme le recommande le guide de pratique clinique de l'American Association of Orthopaedic Surgeons. Notre objectif était de déterminer la fréquence des interventions secondaires suivant une immobilisation précoce au moyen d'un spica plâtré pour les fractures du fémur chez les enfants âgés de 6 ans ou moins.

Méthodes : Il s'agissait d'une étude de cohorte rétrospective de patients âgés de 6 ans ou moins présentant une fracture diaphysaire du fémur et traités par immobilisation précoce au moyen d'un spica plâtré dans un centre pédiatrique de soins tertiaires et de traumatologie de niveau 1 situé au Canada entre janvier 2005 et mai 2015.

Résultats : L'étude a porté sur 246 patients en tout (190 garçons [77,2%] et 56 filles [22,8%] dont l'âge moyen était de 2,28 ans [écart type (ET) 1,35 an]). Neuf patients (3,7%) ont eu besoin d'une intervention secondaire précoce (correction du plâtre dans 8 cas et fixation par clou centromédullaire souple dans 1 cas). Lors du dernier suivi, 51 patients (20,7%) présentaient une inégalité de longueur des membres (ILM) cliniquement mesurable (moyenne de 9,4 mm [ET 3–25 mm]), et 1 patient (0,4%) présentait une légère déformation valgus clinique. Les patients plus âgés et plus lourds dont le raccourcissement initial de la fracture était d'au moins 20 mm étaient plus susceptibles de développer une ILM cliniquement mesurable. Aucun patient n'a eu besoin d'une intervention chirurgicale après l'union osseuse pour corriger une ILM acquise ou une difformité angulaire.

Conclusion : L'immobilisation précoce au moyen d'un spica plâtré dans les cas de fracture diaphysaire du fémur chez les enfants de 6 ans ou moins est associée à un faible taux de complication et de retour en salle d'opération. Bien que 21% des patients présentaient une ILM cliniquement mesurable lors du dernier suivi, aucun n'a eu besoin d'une intervention secondaire après l'union osseuse pour corriger une ILM acquise ou une difformité angulaire. Ces résultats sont pertinents pour le système de santé canadien, particulièrement dans le contexte de la pandémie de COVID-19.

The 2009 American Academy of Orthopaedic Surgeons clinical practice guideline on pediatric diaphyseal femur fractures recommends early spica cast application (within 3 d of injury¹), or traction followed by late spica cast application, for patients aged 6 months to 5 years with less than 2 cm of shortening.² The guideline does not recommend for or against early spica cast application for fractures with 2 cm or more of shortening. Late casting combines a period of time in traction to allow callus to form before cast application to minimize the risk of subsequent fracture displacement, which would necessitate a prolonged hospital stay in addition to cast application in the operating room. Prior studies, however, have not shown late spica casting to reduce the rate of displacement compared to early casting.^{3,4}

In a recent retrospective study, Younis and colleagues³ evaluated the clinical and radiologic outcomes of early (within 48 h of injury) versus late spica cast application in patients aged 7–66 months and found a similar radiographic outcome between the 2 groups; however, patient-reported outcomes based on the Pediatric Outcome Questionnaire were better with early cast application. Wright and colleagues⁵ reported that 11% of 56 children aged 4–10 years with femoral fractures treated with early spica cast application required additional treatment (cast adjustment or surgery), and Younis and colleagues³ reported that 3 of 20 patients who underwent early spica casting and 1 of 24 patients with late spica casting required cast wedging.

Caring for a child with a spica cast can be taxing on families. Independent mobility is hindered and toileting is challenging. Epps and colleagues⁶ reviewed the cases of 45 patients treated with early single-leg spica cast application and found that half were able to attend school or day-care, 95% were able to crawl, 90% were able to pull to stand, 81% could cruise, and 62% could walk independently with assistive devices. Flynn and colleagues⁷ reported that single-leg spica, as opposed to the more cumbersome double-leg spica, was safe for treatment of femoral shaft fracture in children. Late casting, with a prolonged hospital stay and time in traction, may add to the family's burden and increase financial costs to the parents and health care system.

In settings where operating room availability for fracture management is scarce, optimizing use of resources such as operating room time and inpatient beds is important, and, therefore, early spica casting may be desirable. The primary objective of this study was to determine the incidence of early and late secondary interventions after early spica cast treatment for diaphyseal femur fracture in patients aged 6 years or younger. Early interventions included cast wedging, cast change and surgery before fracture union. Late interventions, defined as those occurring after fracture union, included osteotomy, hemiepiphyodesis, and limb length equalization proced-

ures such as epiphysiodesis, shortening osteotomy and distraction osteosynthesis. The secondary objectives were to determine the rate of complications from early spica casting and to identify risk factors predictive of secondary intervention. These questions are critical, as unnecessary demands on health care resources for reintervention are particularly taxing to public health care systems such as Canada's. This is especially important during the COVID-19 pandemic, when access to beds and operating rooms has become increasingly scarce.

METHODS

This was a retrospective cohort study of patients aged 6 years or younger with diaphyseal femur fracture treated with early spica casting at a single tertiary care level 1 trauma pediatric centre between January 2005 and May 2015. Ethics board approval was obtained.

The inclusion criteria were age 1 day to 6 years at the time of injury and diaphyseal femur fracture treated with early (≤ 3 d after injury) spica casting. Exclusion criteria included open fracture, nondiaphyseal femur fracture, pathologic fracture (including fractures associated with metabolic bone disease), trauma suspected to be nonaccidental, multitrauma (femur and other visceral or orthopedic injury), fracture treated by techniques other than early spica casting, spica application more than 3 days after injury, incomplete medical records, and missing pre- or postintervention radiographs, or both.

At our institution, most patients aged 6 months to 5 years with diaphyseal femur fractures are treated with early spica cast application, unless precluded by their medical condition. Patients are initially assessed in the emergency department by an orthopedic surgery trainee. Patients in the age group of this study are placed in longitudinal skin traction with a weight equivalent to 10% of their body weight. The patient is taken to the operating room as soon as there is availability for spica cast application by an orthopedic fellow and resident, with staff surgeon support as needed (as fellows are considered junior faculty, the presence of a staff surgeon is not mandatory). Owing to lack of a dedicated trauma room, the wait from emergency department to operating room can vary from hours to days. During daytime hours on weekdays, an orthopedic technician is usually present to assist with cast application in the operating room. Fluoroscopy is used to ensure adequate reduction in the cast. Patients are discharged when their condition is stable, they are comfortable taking medication orally, they are voiding and eating well, and ward nurses have provided cast and patient care teaching.

The patient is seen 1 week after reduction and casting for radiographic and clinical assessment in our fracture clinic, run by a nurse practitioner and orthopedic surgery

trainees (fellows and residents); a supervising staff surgeon is available for consultation. Subsequent follow-up is at the discretion of the fracture clinic clinician based on the patient's age and the reduction and stability of the fracture. Cast wedging is considered in clinic to correct angular deformity if needed. The immobilization time is usually determined according to the formula child's age (in years) + 2 weeks.

Long-term follow-up is left to the discretion of the treating clinician in the clinic. We usually do not routinely recommend any treatment for limb length discrepancy (LLD) of less than 20 mm, as there are no proven clinical or functional consequences of such a small magnitude, and this amount is often considered idiopathic.⁸ A study among military recruits showed that 32% had a naturally occurring LLD of 5–15 mm, and 4% had an LLD of more than 15 mm; none required or sought treatment.⁹

Fracture shortening was measured by a single pediatric orthopedic fellow (É.R.T.) using our picture archiving and communication system by tracing perpendicular lines at the level of the proximal fragment and the distal fragment and measuring the distance between the 2 lines. Fracture angulation was measured with the Cobb angle tool in the picture archiving and communication system. Malunion was defined as any clinically obvious sagittal or coronal plane deformity within the thigh or overall limb alignment.

We obtained the clinically measurable LLD data from the patient's chart. If the clinician at the time of review assessed and documented an LLD, the data were included in the study. Different clinicians may have different ways to measure LLD, the most common being having older patients stand on blocks, or assessing pelvic obliquity. For younger patients, the Galeazzi test may have been used.

Statistical analysis

We analyzed the data using R 3.6.3 statistical software (R Foundation for Statistical Computing). Descriptive statistics of patient characteristics and incidence outcomes for the entire population are reported as means and standard deviations (SDs) for continuous variables, and as counts and proportions for categorical variables. We performed univariate logistic regression to assess whether the categorical outcomes were associated with patient age, weight, energy of mechanism of injury (high or low), time between injury and surgery, presence of orthopedic technician, initial shortening and angulation in spica, fracture pattern and spica type. Odds ratios (ORs) corresponding to the effect of the patient characteristics were reported. We used linear regression to assess whether there was an effect of patient characteristics on the fracture shortening between spica application and first and last follow-up. We performed subgroup analysis comparing patients

with less than 20 mm of shortening on initial radiographs to those with 20 mm or more of shortening. Coefficients and *p* values corresponding to the effect of the patient characteristics are reported. A *p* value < 0.05 was considered to be statistically significant.

RESULTS

A total of 417 patients were treated with a spica cast for femur fracture at our institution between January 2005 and May 2015. We excluded 171 patients (age > 6 yr [3 cases], spica application > 3 d after injury [10], nondiaphyseal fracture [34], nonaccidental injury [11], pathologic/fragility fracture [53], multitrauma [7], and incomplete medical or radiographic chart [53]). The demographic characteristics of the remaining 246 patients (190 boys [77.2%] and 56 girls [22.8%] with a mean age of 2.28 [SD 1.35] yr) are summarized in Table 1.

Of the 246 patients, 224 had adequate initial radiographs to obtain measurements. The mean amount of shortening was 14.9 mm (SD 10.0 mm), the mean coronal angulation was 10.8° (SD 9.5°) (*n* = 238), and the mean sagittal angulation was 10.8° (SD 10.5°) (*n* = 232) (Table 1). Spiral fracture was the most common pattern (152 patients [61.8%]). The mean delay between injury and casting was 0.98 (SD 0.56) days. The majority of patients (169 of 240 [70.4%]) received a single-leg spica cast. An orthopedic technician assisted in 147 of 245 cases (60.0%). The average time in cast was 36.68 (SD 8.44) days. The mean duration of follow-up was 7.48 (SD 10.46) months (range 0.66–91.36 mo).

Seven patients (2.8%) required cast wedging in the operating room at the time of spica cast application (Table 2). The need for concurrent cast wedging was significantly associated with increased age (OR 1.65, 95% confidence interval [CI] 1.05–2.59) but not with weight, fracture pattern characteristics, delay to surgery or presence of an orthopedic technician in the operating room. One patient had loss of distal pulse during cast application, which necessitated removal of the cast, repeat closed reduction and reapplication of spica. This patient had uneventful peri- and postoperative courses.

Secondary interventions

Eight patients (3.2%) required cast wedging postoperatively (Table 2). One patient (0.4%) had cast wedging done on the ward on postoperative day 1 as radiographs obtained immediately after surgery showed unacceptable varus deformity. In 7 cases (2.8%), cast wedging was done at follow-up clinic visits to correct unacceptable angulations. The need for postoperative cast wedging was significantly associated with increased age (OR 0.6, 95% CI 0.39–0.95), low-energy mechanism (OR 0.08, 95% CI 0.02–0.34) and oblique

Table 1. Characteristics of children aged 6 years or younger who had early spica cast treatment for diaphyseal femur fracture, and of fractures, treatment and follow-up

Characteristic	No. (%) of patients* n = 246
Patients	
Sex	
Female	56 (22.8)
Male	190 (77.2)
Age, mean ± SD (range), yr	2.28 ± 1.35 (0.00–6.00)
Weight, mean ± SD (range), kg (n = 245)	14.58 ± 3.35 (6.30–24.00)
Fractures	
Energy of mechanism	
High	213 (86.6)
Low	33 (13.4)
Laterality	
Left	116 (47.2)
Right	130 (52.8)
Pattern	
Spiral	152 (61.8)
Oblique	63 (25.6)
Transverse	27 (11.0)
Comminuted	4 (1.6)
Initial shortening, mean ± SD (range), mm (n = 224)	14.9 ± 10.0 (0.00–43.60)
Initial coronal angulation, mean ± SD (range), ° (n = 238)	10.8 ± 9.5 (0.00–57.00)
Initial sagittal angulation, mean ± SD (range), ° (n = 232)	10.8 ± 10.5 (0.10–61.00)
Treatment	
Delay between injury and spica application, mean ± SD (range), d	0.98 ± 0.56 (0.00–3.00)
Type of spica (n = 240)	
Single leg	169 (70.4)
One and a half legs	66 (27.5)
Two legs	5 (2.1)
Orthopedic technician present (n = 245)	147 (60.0)
Total hospital stay duration, mean ± SD (range), d	1.60 ± 0.98 (0.00–6.00)
Duration of postoperative hospital stay, mean ± SD (range), d	0.94 ± 0.86 (0.00–5.00)
Follow-up	
Time in spica, mean ± SD (range), d	36.68 ± 8.44 (10.00–79.00)
Duration of follow-up, mean ± SD (range), mo	7.48 ± 10.46 (0.66–91.36)
No. of follow-up visits, mean ± SD (range)	3.31 ± 1.28 (1.00–9.00)
Radiographic shortening at last follow-up, mean ± SD (range), mm (n = 58)	5.5 ± 5.6 (0.00–19.40)
Radiographic coronal angulation at last follow-up, mean ± SD (range), ° (n = 215)	4.2 ± 4.6 (0.00–34.40)
Radiographic sagittal angulation at last follow-up, mean ± SD (range), ° (n = 199)	9.0 ± 8.2 (0.10–55.90)
SD = standard deviation. *Except where noted otherwise.	

fracture pattern (OR 1.68, 95% CI 0.24–33.13). Only 1 patient (0.4%) needed further operative treatment, for malunion.

One patient, aged 6 years, required a cast change on postoperative day 3 for discomfort and a mild pressure sore, which did not require any treatment. This patient

Table 2. Secondary interventions and complications

Intervention or complication	No. (%) of patients
Associated procedure	
Cast wedging during index procedure	7 (2.8)
Loss of pulse after cast application necessitating immediate cast change	1 (0.4)
Secondary intervention	
Early	
Cast wedging	8 (3.2)
Cast change and flexible intramedullary nailing	1 (0.4)
Late	
Removal of flexible intramedullary nails	1 (0.4)
Complications	
Skin issues	10 (4.1)
Cast breakage	1 (0.4)
Clinically measurable LLD	51 (20.7)
Clinically noticeable angular deformity	1 (0.4)
LLD = limb length discrepancy.	

subsequently had a loss of reduction (25 mm of shortening) identified at the first follow-up visit, and management was revised to flexible intramedullary nailing. The fracture healed uneventfully, and the nails were removed 1.5 years after fixation, without resulting angular deformity or clinically measurable LLD.

Complications

Ten patients (4.1%) developed skin complications such as blisters, abrasions, rash or irritation. Skin complications were associated only with low-energy mechanism (OR 0.16, 95% CI 0.05–0.6). One patient's spica cast broke, and management was transitioned to a long leg cast on postoperative day 45 for 1 more week. The patient had a clinically measurable LLD of 10 mm at last follow-up, at 4.2 months. Two patients (0.8%) experienced refracture 4 and 5 years after the index event. Minor complications were associated with a low-energy mechanism (OR 9.86, 95% CI 3.63–27.34).

Incidence of limb length discrepancy

Fifty-one patients (20.7%) had a clinically measurable LLD at last follow-up. The mean amount of LLD was 9.4 mm (range 3–25 mm), with only 3 patients (1.2%) having an LLD of 20 mm or more. Factors associated with a clinically measurable LLD were increased age (OR 1.69, 95% CI 1.35–2.15), increased weight (OR 1.23, 95% CI 1.12–1.37), greater initial fracture shortening (OR 1.05, 95% CI 1.02–1.09) and greater coronal angulation on initial radiograph (OR 1.04, 95% CI 1.01–1.08). Only 1 patient (0.4%), with clinically noticeable valgus deformity, had any residual clinical coronal or sagittal plane deformity.

Table 3. Characteristics of patients, fractures, treatment and follow-up, secondary interventions and complications, by amount of initial fracture shortening (< 20 mm v. ≥ 20 mm) (n = 224)

Characteristic	Amount of initial fracture shortening; no. (%) of cases*		p value
	< 20 mm n = 157	≥ 20 mm n = 67	
Patients			
Sex			0.6
Female	39 (24.8)	14 (20.9)	
Male	118 (75.2)	53 (79.1)	
Age, mean ± SD, yr	1.90 ± 1.18	3.07 ± 1.33	0.006
Weight, mean ± SD, kg	13.57 ± 3.05	16.54 ± 3.14	< 0.001
Fractures			
Fracture pattern			0.3
Spiral	93 (59.2)	44 (65.7)	
Oblique	41 (26.1)	18 (26.9)	
Transverse	22 (14.0)	4 (6.0)	
Comminuted	1 (0.6)	1 (1.5)	
Initial shortening, mean ± SD, mm	9.9 ± 6.8	26.4 ± 5.9	—
Initial coronal angulation, mean ± SD, °	10.6 ± 10.1	11.6 ± 8.3	0.5
Initial angulation sagittal, mean ± SD, °	10.6 ± 11	9.8 ± 8.7	0.6
Treatment			
Delay between injury and spica application, mean ± SD, d	0.99 ± 0.58	0.97 ± 0.52	—
Type of spica			0.6
Single leg	112 (71.3)	45 (67.2)	
One and a half legs	37 (23.6)	21 (31.3)	
Two legs	4 (2.5)	1 (1.5)	
Unknown	4 (2.5)	0 (0.0)	
Orthopedic technician present			0.07
Yes	99 (63.1)	33 (49.2)	
No	57 (36.3)	34 (50.7)	
Missing	1 (0.6)	0 (0.0)	
Length of total hospital stay, mean ± SD, d	1.59 ± 0.93	1.64 ± 1.08	0.7
Follow-up			
Time with spica, mean ± SD, d	35.45 ± 7.66	39.24 ± 9.6	0.002
Duration of follow-up, mean ± SD, mo	6.74 ± 9.73	8.88 ± 11.61	0.2
No. of follow-up visits, mean ± SD	3.18 ± 1.24	3.63 ± 1.35	0.02
Radiographic shortening at last follow-up, mean ± SD, mm	4.0 ± 4.9	10.2 ± 5.8	< 0.001
Radiographic coronal angulation at last follow-up, mean ± SD, °	3.9 ± 4.7	4.8 ± 4.5	0.2
Radiographic sagittal angulation at last follow-up, mean ± SD, °	9.7 ± 9.3	7.3 ± 5.1	0.07
Secondary interventions and complications			
Concurrent intervention			0.8
Cast wedging	5 (3.2)	2 (3.0)	
Cast change	1 (0.6)	0 (0.0)	
Early secondary intervention			—
Cast wedging	2 (1.3)	3 (4.5)	
Cast change and flexible intramedullary nailing	0 (0.0)	1 (1.5)	
Early complications			0.4
Skin issues	7 (4.5)	2 (3.0)	
Cast breakage	0 (0.0)	1 (1.5)	
Clinically measurable LLD	26 (16.6)	20 (29.8)	0.04
Clinically measurable valgus deformity	0 (0.0)	1 (1.5)	0.7
LLD = limb length discrepancy; SD = standard deviation. *Except where noted otherwise.			

No patient required surgical intervention after fracture union to correct acquired LLD or angular deformity.

Fracture shortening

Of the 224 patients with adequate initial radiographs to obtain measurements, 157 (70.1%) had less than 20 mm of fracture shortening, and 67 (29.9%) had 20 mm or more of fracture shortening (Table 3). Subgroup analysis showed that, compared to patients with less than 20 mm of shortening, those with 20 mm or more of shortening were older (mean 3.07 yr [SD 1.33 yr] v. 1.90 yr [SD 1.18 yr], $p = 0.006$), heavier (mean 16.54 kg [SD 3.14 kg] v. 13.57 kg [SD 3.05 kg], $p < 0.001$) and immobilized longer (mean 39.24 d [SD 9.60 d] v. 35.45 d [SD 7.66 d], $p = 0.002$), and had more follow-up visits (mean 3.63 [SD 1.35] v. 3.18 [SD 1.24], $p = 0.02$). They also had more radiographic shortening at last follow-up (mean 10.2 mm [SD 5.8 mm] v. 4.0 mm [SD 4.9 mm], $p < 0.001$) and a higher incidence of clinically measurable LLD (3 mm–25 mm) (20 [29.8%] v. 26 [16.6%], $p = 0.04$). Although there was a higher rate of total early complications in the group with 20 mm or more of shortening (7 [10.4%] v. 9 [5.7%], $p < 0.001$), there was no significant between-group difference when cast wedging alone was compared (3 [4.5%] v. 2 [1.3%], $p = 0.3$). No patient in either group required late intervention.

DISCUSSION

In our cohort, there was a low rate of early secondary intervention after early (≤ 3 d) spica cast application for diaphyseal femur fractures, with only 3.2% of patients requiring cast wedging and only 1 patient (0.4%) returning to the operating room for cast change owing to skin irritation. This patient's fracture was observed to be shortened by 25 mm at the first follow-up visit, and management was therefore revised to intramedullary nails 11 days after initial spica cast application. This rate of early secondary intervention is lower than that reported by Wright and colleagues,⁵ who found that 11% of patients aged 4–10 years required another treatment, including readmission for cast change, or change of treatment to external fixator or intramedullary nailing. It is also lower than that reported by Younis and colleagues,³ who found that 15% of patients treated with early spica casting required cast wedging, and 15% required cast change.

In the present study, less than 3% of patients required cast wedging during the index procedure. These patients were older. Given that older children have less fracture remodelling potential than younger children,¹⁰ it can be presumed that the surgeon was less willing to accept deformity after reduction and would be more likely to wedge the cast to improve alignment at

initial cast application. To our knowledge, no other group has published on the rate of concomitant cast wedging with spica cast application.

Minor complications were noted in 4.5% of patients, with the majority being skin issues such as rash, blisters and irritation; 1 patient's cast broke. This rate of minor complications is similar to the rate of 5% reported by Younis and colleagues.³ Skin complications are not uncommon with spica casting: in a recent systematic review, the rate of skin irritation was 8.2%.¹⁰ Unexpectedly, minor complications were associated with low-energy mechanisms; the reason for this is unclear. Secondary data analysis did not reveal any explanatory factors such as younger age or type of spica cast (single-leg v. bilateral).

Despite an incidence of clinically measurable acquired LLD of 20.7% at last follow-up, to our knowledge, no patient had required late surgical intervention to correct an LLD or angular deformity at the time of writing. Factors associated with clinically measurable LLD were increased age, increased weight, greater initial fracture shortening, coronal angulation and initial fracture shortening of 20 mm or more.

Patients with 20 mm or more of initial fracture shortening were older and heavier than those with less than 20 mm of shortening, spent more time in the cast and required more follow-up clinic visits. The rates of early (cast wedging in clinic) and late secondary interventions did not differ between the 2 groups. However, there was a higher incidence of clinically measurable LLD at final follow-up among patients with initial fracture shortening of 20 mm or more (29.8% v. 16.6%). Only 3 patients in this group had clinically measurable LLD of 20 mm or more at last follow-up; however, they were followed for only 1.24–2.66 months, and their fracture may have remodelled more with more time. To our knowledge, there are no studies comparing outcomes of treatment based on initial shortening of diaphyseal femur fractures in children aged 6 years or younger.

In a prospective cohort study of 101 patients with femur fractures treated with spica casting, 90 patients (89.1%) had shortening of less than 20 mm at final follow-up.¹¹ Two patients had clinical shortening of more than 20 mm, and 4 patients had shortening of more than 20 mm on scanogram assessment. However, the authors did not report on the mean amount of shortening. Energy of the injury, initial fracture shortening and body habitus did not correlate with final shortening, but age was significantly correlated. These findings differ from ours: we found weight and initial shortening to be significantly associated with development of a clinically measurable LLD. It may be more difficult to apply and mould a cast appropriately in larger children, and greater initial shortening may imply greater energy of injury and soft tissue injury, rendering maintenance of reduction and length more difficult.

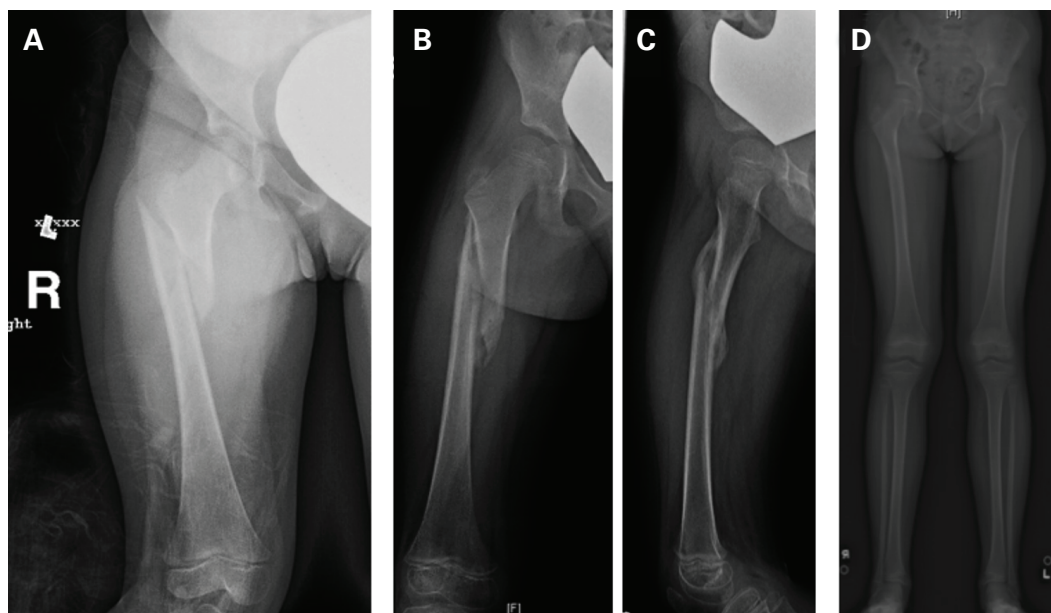


Fig. 1. Radiographs showing fracture remodelling in a 3-year-old girl with initial fracture shortening of 28 mm (A, anteroposterior view). Anteroposterior (B) and lateral (C) views at time of spica removal (postoperative day 47). (D) Anteroposterior radiograph at final follow-up (3 yr and 3 mo postoperatively) showing clinically measurable limb length discrepancy of 3 mm.

Since early spica cast application is routine practice in our centre, we did not have a comparative late spica group. In a systematic review, Wright⁴ compared the rates of LLD and malunion between early spica cast application, traction with delayed spica cast application and internal fixation, and found that LLD greater than 20 mm was most common in the internal fixation group (25%), followed by delayed spica casting (10%) and early spica (3%). This is similar to the rate in our patients, 1.2%. The rate of malunion (varus or valgus deformity $> 10^\circ$) was highest with delayed spica (16%), followed by early spica (9%); there were no cases of malunion in the internal fixation group.⁴ The malunion rate in our cohort was lower, at 0.4%.

Limitations

A strength of our study is the large cohort. It also has limitations. Owing to its retrospective nature, data missing from the medical records led to the exclusion of a substantial proportion of patients. The duration of clinical follow-up was too short to show conclusively whether any of our patients might have returned as teenagers for consideration of a limb-equalization procedure. However, since our institution is the only pediatric specialty centre in our catchment area, we can reasonably assume that the majority of patients needing interventions for notable LLDs would have returned or been re-referred to our institution. In addition, since femur fractures in children aged 6 years or younger can remodel up to 2 years after injury,¹⁰ the short follow-up period may not have allowed full remodelling, therefore inflating the ultimate

rate of reported LLD and angular deformities. For example, Figure 1 illustrates the radiographic course of a 3-year-old girl with initial shortening of more than 20 mm who had 3 mm of clinically measurable LLD at last follow-up, 3 years and 3 months after her fracture. The mean follow-up time in the study by Younis and colleagues³ was 22.8 (range 9–56) months, and in that of Wright and colleagues,⁵ 2 years. Other investigators did not specify the length of follow-up.^{4,6,7}

At our institution, the fracture clinic is led by nurse practitioners and orthopedic surgery trainees (fellows and residents), with supervision by an orthopedic staff surgeon as needed. Our institution has guidelines to help guide the acute care and follow-up of patients with trauma, but the ultimate decision is left to clinician judgment. This could lead to judgment bias depending on the trainee's level of experience. The radiographs are not calibrated or standardized, which may lead to measurement errors, particularly for LLD. To minimize variance in measuring technique, all measurements were made by a single pediatric orthopedic fellow. Finally, given the retrospective nature of the study, we were unable to collect questionnaires on satisfaction and quality of life to assess the caregiver burden of spica casting. However, such information has been published previously.^{3,6}

CONCLUSION

Early spica casting for diaphyseal femoral fractures in children aged 6 years or younger had a low rate of complications. Although 21% of patients had a clinically measurable LLD at last follow-up, to our knowledge, no patient required

secondary intervention after fracture union to correct acquired LLD or angular deformity. Older, heavier patients with initial fracture shortening of 20 mm or more had a higher likelihood of developing clinically measurable LLD. These findings have relevance for Canadian health care systems, especially during the COVID-19 pandemic.

Affiliations: From the Division of Orthopaedic Surgery, Department of Surgery, University of Toronto, Toronto, Ont. (Rioux Trottier, Camp, Bouchard); and the Division of Orthopaedics, The Hospital for Sick Children, Toronto, Ont. (Rioux Trottier, Hatcher, Feng, Camp, Bouchard).

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