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Improving Lower Extremity Casting Quality by Providing an Experienced Assistant in Pediatric Tibia Fractures Managed by Trainees

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Abstract

Background: The value of employing an orthopedic technician or advanced practice provider (OT/APP) to assist trainees during on-call hours has not been assessed. As the third most common pediatric long bone fracture, most tibial fractures can be managed with closed reduction and casting. *Purpose:* We sought to determine whether clinical outcomes could be positively affected for traumatic childhood tibia fractures by using an experienced OT/APP to aid orthopedic surgery residents with closed reduction and casting. *Methods:* We performed a retrospective chart review of tibial shaft fractures that occurred between 2010 and January 2017. Fractures undergoing manipulation and closed reduction by orthopedic surgery residents (post-graduate year 2 to 4) in the emergency department were included and differentiated into 2 cohorts: (1) residents who performed the procedure alone and (2) residents who were assisted by an OT/APP. Comparisons in cast quality and treatment success were made using univariate statistics followed by a multivariate Classification and Regression Tree (CART) analysis. *Results:* Of the 73 patients who met our criteria, 38 received treatment by a resident alone and 35 by a resident assisted by an OT/APP. Evidence to support our hypothesis was found with the resident-alone group "over" padding the casts posteriorly. Univariate analysis demonstrated that the rate of subsequent surgical intervention was more than double in the resident-alone group (31% vs 14%), yet OT/APP castings underwent more wedging at follow-up (17% vs 0%). CART analysis revealed initial fracture severity and lack of OT/APP assistance as predictors of surgical intervention with terminal nodes, in increasing order of risk of requiring surgical intervention: lower translation on sagittal and anteroposterior (AP), lower sagittal translation with greater AP translation, greater sagittal translation with OT/APP assistance, and greater sagittal translation without assistance. The initiation of a cast application-training program in 2015 decreased the need for surgical treatment in the resident-only group (pre-program 38.5% vs post-program 17%), although this was not statistically significant. *Conclusion:* When residents were assisted by OT/APP with initial tibia closed reduction and casting, subsequent loss of reduction was more likely to be managed with cast wedging; when this assistance was not available, there was a higher rate of fractures needing surgical intervention due, in part, to poor casting technique. The reduction in the rate of surgical intervention after an internal training program was implemented suggests that trainees may improve their casting ability without added help of an experienced assistant. Future study should be performed on distal radius fractures to determine if the presented findings are valid across casting types.

Keywords
tibia fracture, value, pediatric, cast application, trainee

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Introduction

Closed reduction and casting is a common treatment in the management of pediatric fractures and is considered the mainstay of treatment for diaphyseal tibial fractures [5,9]. Complications may occur at any step in the management process for these fractures, including during fracture reduction, the immobilization/molding/casting process, or at cast removal. There are many factors that could play a role in fracture re-displacement, such as poor cast molding, shifts in swelling, or inadequate fracture reduction; furthermore, the inexperience of orthopedic surgery residents should also be considered [10]. Experienced assistance in the form of an orthopedic technician (OT) or an advanced practice provider (APP; such as a physician assistant or nurse practitioner) may help trainees succeed in the casting process.

Prior studies have looked into cast quality and its effect on outcomes. One such study was a quality improvement initiative to reduce cast complications such as cast-saw injury, pressure ulcers, rashes, and burns [2]. Cast quality when casts are applied by residents and attending surgeons has also been compared by examining fracture reduction maintenance in distal radius fractures [1]. A comparison of fracture reductions performed by either APPs or residents has also been studied [6]. While these studies assessed aspects of cast quality based on the cast applicant, there have been no studies focusing on whether the cast applicant directly affects fracture healing or further intervention, nor has there been direct evidence to compare when an experienced cast applicant assists someone who is less experienced in the process. Thus, the value of employing an OT or APP to assist trainees is unknown.

The purpose of this study was to compare differences in cast quality and treatment success for pediatric tibial shaft fractures when casted by residents with or without experienced assistance. We specifically assessed tibia shaft fractures, which are the third most common long bone fracture in children [12]. Our hypothesis was that cast quality would be better in children when treatment by a trainee is initiated with the assistance of an OT/APP. The primary aim was to determine if casting by a resident alone would result in greater need for subsequent surgical intervention to improve poor or lost fracture alignment. The secondary aim was to identify if the overall cast quality improved for the resident-alone cohort after the initiation of the mandatory summer "boot camp" training program.

Methods

Upon institutional review board (IRB) approval, we performed a retrospective chart and radiographic review of all pediatric patients with diaphyseal tibia shaft fractures between 2010 and January 2017. Patients were eligible for inclusion if (1) their fracture was isolated to the diaphysis of the tibia with no physeal involvement, (2) their fracture was treated initially by closed reduction, and (3) they initially presented to our institution's emergency department. Patients were excluded from the study if they had underlying syndromes or metabolic bone disease; if the fracture was a toddler fracture, buckle fracture, or re-fracture; if they were initially splinted at an outside facility; or if radiographs were incomplete for evaluation.

Charts were reviewed for relevant demographic and clinical information. Patients were followed with serial clinic visits and radiographs until final healing was obtained. The initial injury date was determined from the patients' charts and the cause of injury was grouped into high or low energy mechanisms (eg, motor vehicle accidents vs mechanical falls or sports injuries, respectively). Method of treatment was recorded (manipulation, sedation, and casting). Date of cast application, who applied the cast (resident alone or resident with an OT/APP), and type of cast (univalved vs bivalved, and weight bearing status) were noted from medical records. All casts were above-knee design and made with fiberglass. In addition, even residents who applied a cast "alone" had assistance in holding the patient's leg from emergency department staff who otherwise were not experienced cast appliers.

Radiographs were evaluated and measurements made with tools from McKesson PACS (Picture Archiving and Communications System, San Francisco, CA). A simplified version of the Arbeitsgemeinschaft für Osteosynthesefragen classification system [11] was used to categorize fractures on injury film. Tibial comminution was defined by the presence of 3 or more fracture fragments. In addition, fractures were classified by their orientation (short oblique, long oblique, spiral, or transverse). To differentiate long oblique and spiral fractures, if the fracture was at an angle $> 70°$, it was considered a spiral fracture. Presence of a fibula fracture was documented. Injury film was also used to determine if the physes were open or closed, as well as the initial anteroposterior (AP) and sagittal alignment (both using the Cobb angle tool), and the percent translation in both the AP and sagittal views.

Radiographs taken immediately after casting and/or within 2 weeks after the cast was applied were used to measure initial cast quality but not the maintenance of reduction. Measurements were taken at the following locations on the radiographs: front of cast, back of cast, and cast mold at the fracture site (both on the right and left side in both AP and sagittal views; Fig. 1). Two measurements were taken at each site: total measurement (fiberglass to skin) and fiberglass only (to assess thickness of casting material). These measures were based on the measurements used to critique forearm casts, such as cast index, padding index, Canterbury index, gap index, and 3-point index [3,4,7]. The Achilles mold, which is independent of the fracture mold,

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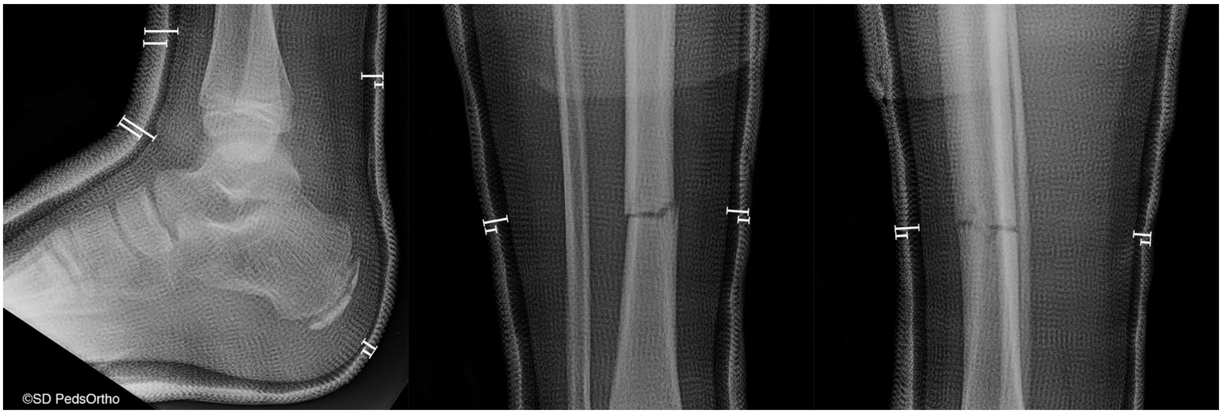

Fig. 1. Sagittal and anteroposterior views demonstrating the measurements taken on the radiographs which include front of cast, back of cast, and cast mold at the fracture site.

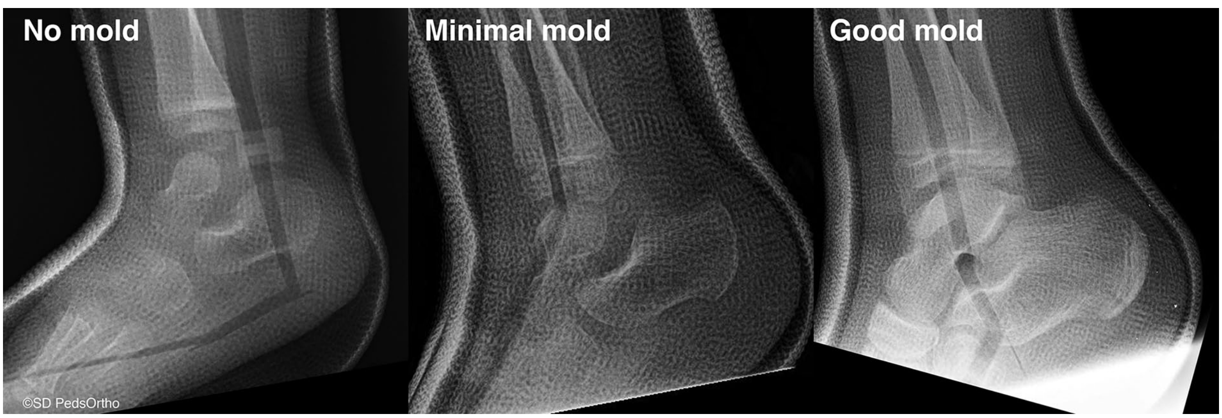

Fig. 2. Imaging showing the 3 categories of the Achilles mold: no mold present, a minimal mold, and a good mold.

was noted and grouped into 3 categories: no mold present, a minimal mold, and a good mold (Fig. 2). These were defined as straight (no mold), slight contour (minimal mold), and well contoured matching the normal anatomy (good mold). This mold is believed to be important in maintaining the position of the cast on the child's leg and protecting the heel from pressure ulcer injury.

The final radiographs were the first images taken without a cast, with appropriate healing defined as cortical bridging with 3 or more cortices; this indicated that surgical intervention was avoided (our primary outcome measure). This final follow-up radiograph was assessed for the AP and sagittal alignment and percent translation in both orthogonal views. Later follow-up images were not measured to specifically limit the effect of bone remodeling on our outcome measures in this pediatric population.

In addition, we noted any changes made to the cast, including the date, reason for the change, and type of cast change (ie, wedging, windowing, cast repair). Treatment outcome data included any further interventions, the date of additional interventions, what treatment was performed (a re-reduction, cast wedging, an open reduction with internal fixation), any loss of reduction (LOR), and LOR date. LOR was defined by the real-time assessment of the treating provider and was recorded if indicated in the patient's chart. Finally, date of the final cast removal and date of last clinic visit were recorded.

In 2015, during the study period, the local residency program began an annual cast-training program. It is part of a "boot camp" course that all residents attend during the first week of the academic year. Its aim is to enhance residents' ability to apply a well-fitted cast with appropriate molds, to reduce the risk of casting failure. To determine the effect of this program on treatment outcomes, we evaluated casts applied before residents took this training separately from those applied after the training.

Table 1. Descriptive and pretreatment comparisons between the groups (means and standard deviations presented unless percentiles stated).

	Resident only (n = 38)	Orthopedic technician/ advanced practice provider (n = 35)	P
Age (years)	10 ± 4	9.5 ± 4	.6
Weight (kg)	37 ± 16	36 ± 18	.7
Body mass index	19 ± 4	17 ± 4	.3
Time from injury to cast (days)	0.2 ± 0.5	1 ± 2	.16
Sex (M/F %)	58/42%	74/26%	.14
Fibula Intact (Y/N %)	42/58%	37/63%	.67
Physis (open/closed %)	92/8%	91/9%	.9
AP alignment (degrees)	5 ± 6	5 ± 5	.77
Sagittal alignment (degrees)	5 ± 5	5.5 ± 6	.71
AP translation (displacement %)	20 ± 13%	26 ± 28%	.19
Sagittal translation (displacement %)	17 ± 21%	19 ± 21%	.6

AP anteroposterior.

Statistical Methods

Baseline, treatment, and outcome data were compared between the 2 casting cohorts (resident alone and resident with OT/APP assistance). Continuous variables were compared using analysis of variance (ANOVA). All continuous variables were assessed for normality and homogeneity of variance; χ^2 test/Fisher exact was used to evaluate differences in categorical variables. Classification and Regression Tree (CART) analysis was used to identify predictors of cast failure (requiring surgical intervention). A secondary analysis of patients treated before the yearly cast-training program began (pre-summer of 2015) and post-summer of 2015 was performed to determine if the rate of surgery in the resident-only group had been positively affected. Analyses were performed with SPSS v. 24 (IBM Corp., Armonk, NY), and α was set at $P \leq .05$ to declare significance.

Results

Out of the 593 charts reviewed, 73 children met inclusion criteria for the study, with the majority excluded because they had toddler fractures, their charts lacked documentation on who placed the cast, or radiographs were missing. Thirty-eight (57.9% male patients) were casted by a resident alone and 35 (74.3% male patients) were casted by a resident with the assistance of an OT/APP. The mean patient age was 10.0 ± 4.1 years for the resident-alone cohort and 9.5 ± 4.3 years for the resident with OT/APP cohort ($P = .60$). Demographic data revealed no differences between cohorts with respect to weight, body mass index, delay between injury and casting (in days), AP and sagittal alignment angles pre-casting, and percent displacement (AP and sagittal view) pre-casting (Table 1).

Table 2. Fracture type comparisons between the 2 groups.

	Resident only (n = 38)	Orthopedic technician/ advanced practice provider (n = 35)
Comminuted	5	4
Long oblique	5	7
Short oblique	2	8
Spiral	20	13
Transvers	6	3

Fracture type was similar across the cohorts ($P = .17$; Table 2). There was an even distribution of those with and without fibula fractures between the 2 cohorts ($P = .67$); 37.1% of those with an assistant had an intact fibula, compared with 42.1% of those without an assistant had an intact fibula.

All casts were either univalved or bivalved at the time of cast application with *no differences noted between groups*; 31 casted without OT/APP assistance were univalved and 29 casted with assistance were univalved ($P = .99$). Only 3 children were explicitly instructed that they were allowed to bear weight on the affected leg after the valved cast was repaired, and no difference is noted between groups ($P = .60$).

In terms of cast quality, the resident-alone cohort added significantly more padding to the back of the cast and had thicker layers of fiberglass ($P \leq .05$, Table 3). Our measurements had an intraclass coefficient for front of cast measures of .961 and .924, and back of cast measures of .876 and .767, which indicates good-to-excellent reliability. The Achilles mold assessment had a κ of .697, which indicates substantial agreement. None of the other measures of cast quality or post-treatment radiographic measures met

Table 3. Cast quality and post-treatment comparisons between the 2 groups, in millimeters, at the time of initial cast placement; means and standard deviations presented unless percentiles stated.

	Resident only (n = 38)	Orthopedic technician/ advanced practice provider (n = 35)	*P*
Front of cast lateral view	12 ± 2	11 ± 2	.059
Front of cast lateral view (fiberglass only)	7 ± 2	6 ± 2	.057
Back of cast lateral view	6 ± 2	5 ± 1	.034
Back of cast lateral view (fiberglass only)	3 ± 1	2 ± 1	.032
AP mold at fracture site; left	8 ± 2	8 ± 2	.82
AP mold at fracture site (fiberglass only); left	4 ± 1	4 ± 2	.8
AP mold at fracture site; right	8 ± 2	7 ± 2	.41
AP mold at fracture site (fiberglass only); right	5 ± 2	5 ± 2	.81
Sagittal mold at fracture site; left	8 ± 2	8 ± 3	.9
Sagittal mold at fracture site (fiberglass only); left	5 ± 2	5 ± 2	.69
Sagittal mold at fracture site; right	8 ± 2	8 ± 2	.97
Sagittal mold at fracture site (fiberglass only); right	5 ± 2	5 ± 4	.37
AP alignment (Cobb)	2 ± 2	3 ± 2	.064
Sagittal alignment (Cobb)	3 ± 3	4 ± 3	.15
AP translation (displacement %)	17 ± 14%	21 ± 22%	.33
Sagittal translation (displacement %)	10 ± 12%	12 ± 12%	.34
Achilles mold (yes %)	63%	66%	.87
Cast required wedging in follow-up (yes %)	0%	17%	.01
Unplanned cast change (yes %)	0%	3%	.48
Surgical intervention (yes %)	32%	14%	.081

AP anteroposterior.

statistical significance, although the measures of cast thickness were nearly significant anteriorly. Before the cast application boot camp was implemented, there was a significant clinically meaningful difference in the rate of patients requiring subsequent surgery: 38.5% of the patients casted by residents alone needed surgery after the conservative treatment failed versus 14.8% of those whose resident received assistance from OT/APP ($P = .05$). Interestingly, more casts performed by the OT/APP assistance cohort ultimately underwent wedging to salvage the attempt at conservative management than in the resident-alone cohort (Table 3, $P \leq .05$).

Per CART multivariate analysis, the initial fracture severity and lack of OT/APP assistance were predictors of surgical intervention. Children who had >20% sagittal translation and were casted without OT/APP assistance required surgery 69% of the time. With the same amount of displacement but with OT/APP assisted cast placement, surgery was required only 29% of the time. Regardless of OT/APP assistance, if they had ≤20% sagittal translation and ≤29% AP translation, then they had the best success and only a 2.9% rate of requiring surgery, the lowest in our study. If they had ≤20% sagittal translation and >29% AP translation, then risk increased and surgery was required at a rate of 27%.

With regard to our secondary aim, an analysis of the cast-training "boot camp" program, 53 children were in the pre-summer 2015 cohort and 20 were in the post-summer 2015 cohort. Pre-summer 2015, 38.5% of patients in the resident-alone group required surgical intervention versus 15% in the OT/APP assistance cohort ($P = .05$). Post-summer 2015, the rate of patients requiring later surgical intervention in the resident-alone cohort decreased to 17%, which was not significantly different from the 13% that occurred in the OT/APP assistance cohort in the same time period ($P = .8$).

Discussion

Over time, trainees no doubt gain the experience necessary to become adept at cast application during their residency training. However, training programs may differ in the time, number of lectures, or number of casting events they require to gain competency. All on-call residents at our institution are post-graduate year 2, 3, or 4. They have undergone formal training on fracture reduction and cast application and are supervised regularly to ensure patient safety. All fractures treated at our institution are also reviewed at the end of each week to ensure appropriate management, as the residents are evaluated on the quality of casts applied and given constructive feedback to improve cast quality and fracture management. The safety, value, and quality of care should be considered in balance with the ability to train our next generation of orthopedic surgeons. Past study on this topic is sparse, with no evidence to document the usefulness of helping trainees during cast application by pairing them with an OT/APP. Our study attempted to give some insight into the ability to provide value to the patient and education for our residents.

Our study identified a few notable differences when comparing cast application between residents alone and those who were assisted by an OT/APP for closed management of tibia fractures in children. A notable difference was that residents who applied a cast without assistance used more padding on the back of casts. While we do not believe this causes the fracture to lose reduction, it may indicate that the trainees lacked the knowledge that is gained by experience. Still, the true question within our hypothesis was whether or not the outcomes of these children would be improved by using an OT/APP to assist the resident. We contend that this was the case, despite the higher rate of cast wedging in the assisted cohort. This higher rate of cast wedging may have 2 different explanations: (1) the cast originally applied was good enough to salvage, and it merely needed wedging to restore alignment of the fracture, or (2) the resident and the experienced OT/APP failed to apply a good cast, and wedging was necessary at a subsequent clinic visit with an attending surgeon.

We know that cast wedging is an effective tool to treat angulated tibia shaft fractures [8]. While this was a divergence from the original treatment plan of closed reduction and casting, it still helped to reduce the number of children who ultimately needed surgical intervention due to further LOR. Each case of cast wedging in this study had documented reduction at the index casting and confirmed LOR at the clinic visit during which the additional procedure was performed. Different attending surgeons were involved in the decision to wedge and salvage the cast; these same attending surgeons were involved in other cases of subsequent surgical intervention, suggesting that there was no bias regarding wedging or surgery from a specific surgeon. Although our specific radiographic measurements did not highlight further differences in the ability to discern a good from a bad cast between the 2 study groups, perhaps the gestalt of a good cast weighed on the attending surgeons' decisions to wedge the cast and salvage the closed reduction instead of rendering the initial treatment a failure and proceeding with surgical intervention. This is possible, given that a previous study found that casts applied by an experienced OT/APP were better than those applied by a trainee [6].

Another difference between the 2 cohorts was in the subsequent need for surgery after failed closed reduction and casting. In the resident-only cohort, 38.5% of children needed surgical intervention versus 14.8% from the OT/APP assistance cohort. While this difference just meets criteria for statistical significance ($P = .05$), it is also likely clinically meaningful, as our results nearly mirror a prior study done by Ho and Wilson on both-bone diaphyseal forearm fractures, which demonstrated patients treated by orthopedic residents had a higher rate of LOR compared with APPs alone (33% vs 18%; $P = .052$) [6]. The data appear consistent, even across hospital systems and orthopedic surgery residency programs.

From the CART multivariate analysis (in which cutoff numbers are created), the top predictor for conservative treatment failure and the need for surgical intervention is the percent translation in the sagittal view—with a statistically derived cut off at 20% translation. Other factors that influenced the rate of subsequent surgical intervention included the amount of the fracture translation in the AP view (cut off at 29%) and the presence or absence of an OT/APP. The cohort of children with the highest rate of required subsequent surgery (69%) was a greater sagittal translation with no OT/APP assisting. Unlike the similarity mentioned above with the Ho and Wilson study [6], this current study seemed to show that patients treated by orthopedic residents had more operative intervention to restore fracture alignment. In their study, it was noted that patients treated by residents alone had slightly more major interventions without statistical significance (11% vs 8%; $P = .56$) [4]. This difference between the 2 studies may be due to the types of fractures studied; we assessed tibial shaft fractures, whereas they studied both-bones diaphyseal forearm fractures. Or it may be related to differences in the trainees' knowledge on casting at the time of study.

The difference between less and more experience is subtle, but even the addition of the boot camp for residents appears to significantly decrease the risk for subsequent surgical management. The cast-training program is led by a fellowship-trained, board-certified pediatric orthopedic surgeon and teaches residents proper casting techniques before starting the year, including basics on padding, overlap of material, and 3-point molding. The summer education program, although brief, did change the rate of successful management of casted tibia fractures in the resident-alone cohort, shifting the need for subsequent surgical intervention from 38.5% pre-training program to 16.7% post-training program. This difference shifted the outcome (when compared with the OT/APP assisted cohort outcome) from being significantly worse and requiring more surgery to remedy the treatment failure to being equal to those receiving OT/APP assistance, $P = .05$ and $P = .80$, respectively.

Because the cohort sizes varied related to boot camp exposure, an attempt to determine the effect size was undertaken, and these were slightly different (0.27 in the pre-summer 2015 cohort and 0.06 in the post-summer 2015 cohort). It is also worth noting that our pediatric orthopedic training facility incorporates a weekly morning conference to review all the cases treated for the week (the majority being closed reduction and casting in the emergency department by trainees), wherein critique and praise are offered for the quality of the cast application and mold. While real-time education is presumably helpful to residents, it cannot by accounted for within this study.

There are several limitations to this study, the most significant being the retrospective design that limits other patient-derived outcome measures. One can argue that our short-term follow-up is also a limitation; however, the purposeful short duration was in our methodology to reduce the assessment of pediatric bone healing (remodeling) and instead focus the study on differences in management between our variable cohorts and their casts' ability to maintain the reduction provided. Finally, we had multiple educational sessions regarding agreement on how the radiographic measurements were to be made; we did not have more than 1 observer. Therefore, while we minimized inter-observer variability, we could have some intra-observer variability.

To our knowledge, there is no previous publication looking at cast quality and the effect on treatment outcome as it relates to the value of employing an OT/APP to assist trainees during on-call hours. In conclusion, it appears that the quality of casting was improved when an OT/APP was able to assist the junior residents (post-graduate years 2–4). Further studies into other fracture types are likely warranted to confirm these findings, particularly in the upper extremity. Our results reveal that having extra assistance with the cast application, plus a focused training program for the residents in proper casting technique, may help to reduce failure of initial closed management of tibia fractures in children. In addition, future studies could focus on performing a cost-benefit analysis to evaluate how incurring additional costs to employ an experienced assistant are balanced with improved patient care. Moreover, the development of other teaching modalities, such as real-time teaching videos for trainees, may be of equal benefit, and future prospective study will focus on this method of training residents. Until that time, it appears reasonable to employ either an OT to assist or an APP to help educate junior residents during on-call hours or guarantee that the residents undergo a casting and molding class to augment their training when they rotate onto a pediatric orthopedic service.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Brandi M. Woo, BS; Tracey P. Bastrom, MA; and M. Morgan Dennis, BS, declare they have no conflicts of interest. Andrew T. Pennock reports relationships with Stryker Corporation; Sportstek Medical, Inc.; Orthopediatrics Corp.; Smith & Nephew, Inc.; American Orthopedic Society for Sports Medicine; Imagen; and the Pediatric Orthopedic Society of North America, outside the submitted work. Vidyadhar V. Upasani, MD, reports relationships with Medical Device Business Services; NuVasive, Inc.; OrthoPediatrics Corp.; DePuy Synthes Sales Inc.; Brainlab, Inc.; BroadWater; EOS Imaging; Globus Medical; Imagen; nView; Pediatric Orthopedic Society of North America; Scoliosis Research Society; *Spine*; and Wolters Kluwer Health/Lippincott Williams & Wilkins, outside the submitted work. Eric W. Edmonds reports relationships with Arthrex, Inc.; OrthoPediatrics Corp.; Sportstek Medical, Inc.; DePuy Synthes Sales Inc.; AAOS; and the Pediatric Orthopedic Society of North America, outside the submitted work.

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Human/Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

Informed Consent

Informed consent was waived from all patients included in this study.

Level of Evidence

Level III, Therapeutic case-control study.

Required Author Forms

Disclosure forms provided by the authors are available with the online version of this article as supplemental material.

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