THE ORTHOPAEDIC FORUM

Epidemiology and Prevention of Cast Saw Injuries

Results of a Quality Improvement Program at a Single Institution

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Background: An investigation was conducted to establish the hospital-wide prevalence of cast saw injuries and to identify variables that put patients at increased risk, with the goal of reducing the injury rate.

Methods: Information was collected from January 2010 through December 2012 on all patients who had a cast removed or cut at our institution. Locations included the operating suites, emergency department, ambulatory clinics, and hospital floors. A cast cutting log was used to capture the total number of casts cut. An adverse event form was used to document each injury. A continuous quality improvement approach was used throughout the study period to implement incremental improvements to our program. Changes included an education and certification program on cast saw use for all providers, a protocol for a plastic surgery consultation, and a cast saw blade inspection protocol with maintenance logs.

Results: Twenty-nine injuries occurred in 23,615 cast cuttings over the three years, for an overall rate of 1.23 (95% confidence interval [CI], 0.86 to 1.76) per 1000. A minor decrease in cast saw injuries was recorded over the course of the study (eleven of 8043 [1.37 per 1000] in 2010, ten of 7885 [1.27 per 1000] in 2011, and eight of 7687 [1.04 per 1000] in 2012), but the decrease was not significant ($p = 0.87$). The emergency department had the highest rate of cast saw injuries ($p < 0.0001$), with a significantly greater rate during the night compared with the day (eleven of 1293 [8.51 per 1000] compared with fifteen of 19,419 [0.77 per 1000], respectively; $p < 0.0001$). The injuries were all minor. Key risk factors for a cast saw injury included provider inexperience, patient sedation, and poor cast saw blade condition.

Conclusions: The rate of cast saw injuries in a busy pediatric orthopaedic department was small, but a considerably increased risk existed for those patients cared for in the emergency department by orthopaedic residents. Improving education and training in cast saw use has the potential to decrease the prevalence of cast saw injuries over time.

Peer Review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

Oscillating saws are commonly used to remove casts. These saws are engineered to cut through hard cast material but not through cast padding or skin[1]. Despite this design, cast saws still pose an injury risk to patients. Potential complications of cast saw use include (1) abrasions or lacerations resulting from the blade coming in contact with the skin when the cast padding is insufficient, and (2) burns resulting from heat created by the friction between the saw blade and cast material[1-9].

Few studies on cast saw injuries have been published, and to our knowledge none have focused exclusively on a pediatric population. In 1998, Ansari et al. reported a cast saw injury rate of 0.72% (7.2 per 1000) during the removal of 3875 consecutive plaster casts in an adult fracture clinic setting[2]. The primary risk factors for injury were undertrained care providers and dull saw blades. Undertrained users often employ a poor cast saw technique, which Shuler and Grisafi define as "dragging" the cast saw blade as opposed to the recommended "in and out" motion[3]. In current orthopaedic practice, cast applications and removals are routinely performed by orthopaedic residents in training, midlevel providers, and orthopaedic technicians. Correspondingly, time dedicated to orthopaedic resident education on these basic orthopaedic skills has decreased; in some cases, less than one hour of formal training is allotted for cast application and removal[1]. Previous studies on cast saw injuries have used limb or cadaver models to evaluate burn etiology from casting materials, saw blade temperatures, and skin temperatures[2-12]. Although these studies provide evidence-based insight into the best technical practice, a lack of clinically observed injury data for pediatric patients exists.

In addition to patient safety risks, there are considerable medicolegal implications of cast saw injuries. Over a ten-year period, insurers paid in excess of $100,000 per claim for 33% of medical malpractice claims related to complications in closed fracture management[1]. Similar amounts were paid for 25% of claims for problems arising during traction and immobilization. Although there are no specific data on cast saw injuries, the literature does cite instances of patients demanding compensation for cast saw injuries[2]. These medicolegal and patient safety risks—coupled with the lack of observational clinical data—highlight the need for increased attention and response to cast saw injuries.

During the fall of 2009, our institution experienced a sudden spike in minor, but likely preventable, cast saw injuries. We did not have previous comparative data on these injuries at our institution; subjectively, however, we were concerned that there was a true increase, previous underreporting of cast saw injuries, or both. Given the preventable nature of most incidents, the Department of Orthopaedic Surgery set an aggressive goal of making cast saw injuries a "never event." While performing a root cause analysis, we discovered that our orthopaedic surgery residents, and to a lesser degree our midlevel providers, were less accustomed to handling a cast saw than previous generations of trainees had been. The purpose of the present study was to determine the prevalence of cast saw injuries across our department, identify variables that place patients at increased risk, and characterize the effect of systematic, targeted prevention strategies. Two hypotheses were explored. The primary hypothesis was that the majority of cast saw injuries occurred in the emergency department, at night, and in the hands of inexperienced trainees. The secondary hypothesis was that a decrease in the total number and rate of cast saw injuries would occur with the introduction of an educational program designed to improve overall cast removal safety.

Materials and Methods

Surveillance and Prevalence

Data collection was initiated in January 2010 to record the number of casts cut and any associated adverse events. A cast was considered "cut" if it was removed or bivalved with an oscillating saw at our institution. All casts cut outside our institution were excluded from this study. Beginning in June 2010, documentation was refined to include the specific location of the cast cutting procedure (ambulatory clinics, operating room [OR] suites, emergency department, or inpatient care units). A cast cutting log recording the number of cut casts in each category and the total number was created for daily documentation, and designated team members compiled these totals monthly into a spreadsheet for analysis.

An adverse event reporting system and protocol were established to record the number of cast saw injuries and document specific environmental and physical risk factors pertinent to the event. The attending physician who first assessed the injury would complete the adverse event reporting form, which included location (emergency department, operating room, inpatient units, main clinic, or satellite clinic), level of patient consciousness at the time of cast cutting (awake, conscious sedation, or general anesthesia), type of cast saw operator (resident, fellow, midlevel provider, attending physician, or orthopaedic technician), casting and padding materials, and cast dimensions (number, length, width, and depth) for each cast saw injury. The attending physician would also be responsible for deciding whether the lesion was a result of a cast saw injury, an unrelated abrasion, or a pressure lesion resulting from swelling associated with a bivalved cast. Supplementary details pertaining to the event were collected from the hospital patient safety event reporting system (SERS). This information was used for root cause analysis and process improvement.

Statistical Methods

Injury rates were calculated as the number of injuries per 1000 casts cut. Since we did not have an exact breakdown of the total number of casts cut, we made a series of conservative assumptions for the purpose of calculating and comparing rates for casts cut during the day or night and by residents or orthopaedic technicians. All of the casts cut in the cast rooms of the ambulatory clinics; 70% of the casts cut in the main operating room; 60% of the casts cut in the emergency department; and 50% of the casts cut on the hospital floor, at the sports medicine clinic, and in the satellite operating rooms ("other" locations) were summed together to estimate the number cut during the daytime, and the remaining cast cuts were taken as the total nighttime estimate. We assumed that all of the casts cut in the emergency department, 25% of the casts cut in the main operating room, and 50% of the casts cut at the "other" locations were cut by residents, whereas all of the casts cut in the ambulatory clinic, 75% of the casts cut in the main operating room, and 50% of the casts cut at the "other" locations were cut by orthopaedic technicians. Confidence intervals (CIs) were calculated with use of the Wilson method, which has good statistical properties even for the rate of rare events such as those in the present data[13]. Comparisons of rates were made with the Fisher exact test. The number of injuries inflicted by more compared with less experienced residents (January through June compared with July through December rotations) and according to year (2010, 2011, or 2012) were compared with use of an exact chi-square goodness-of-fit test assuming a null hypothesis of equal numbers of injuries across time periods. All p values are two-sided.

Process Improvement

Our investigation used a continuous quality improvement approach employing principles from the Toyota Production System[14-16]. Specifically, we adopted a "kaizen" process of continuous and incremental improvement that leverages

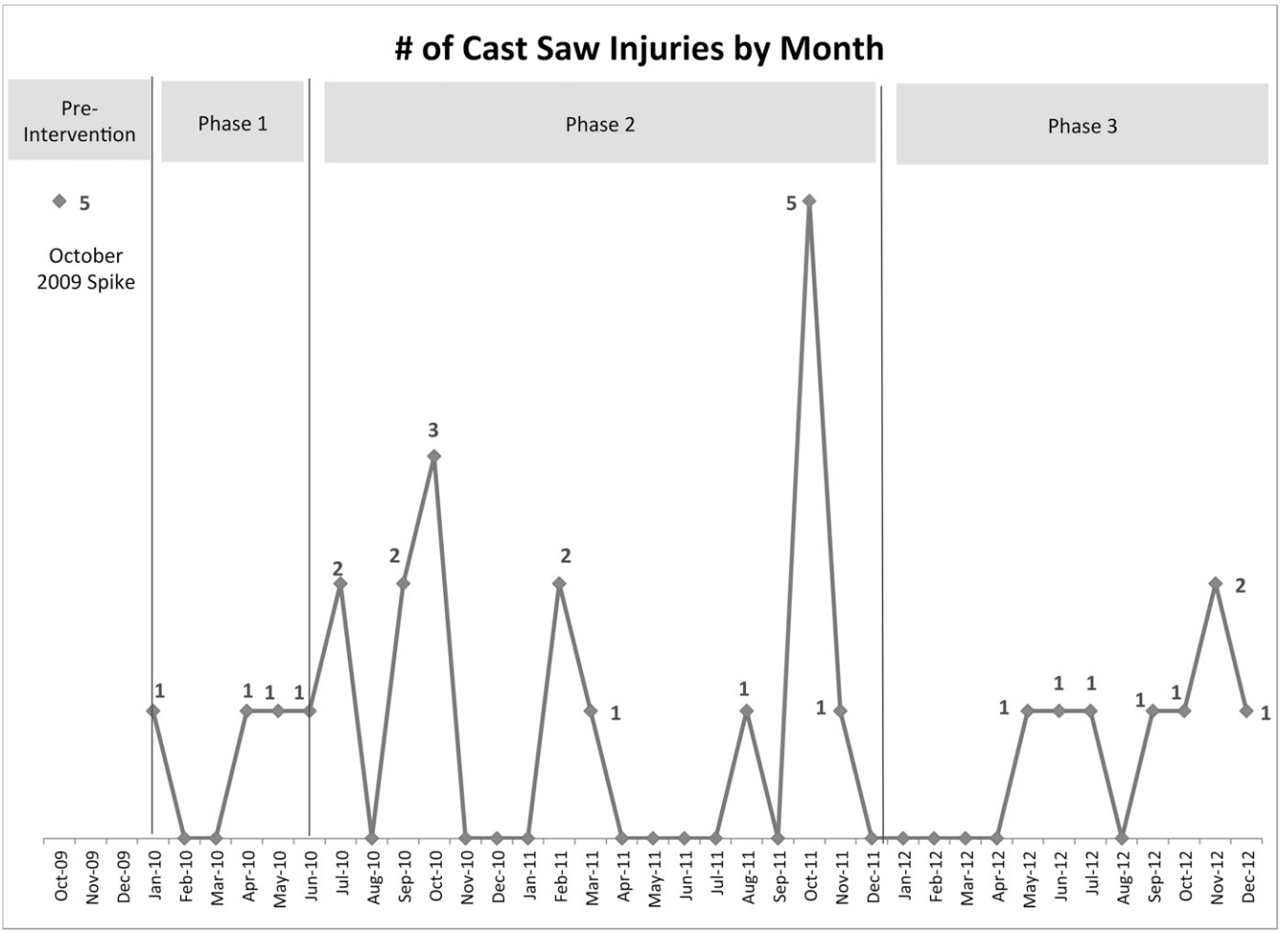

Fig. 1

Number of cast saw injuries by month, 2010 through 2012. The number of injuries per month is represented by the line. The pre-intervention period depicts the spike in injuries observed during October 2009.

the skills of front-line staff to create more value and less risk for our patients in the process of care[14]. This approach allowed us to make real-time improvements to our care processes with the goal of obtaining an injury-free result with each cast removal or bivalving. Targeted improvements over the time span were made in three distinct phases (Fig. 1).

Phase 1

Surveillance system and data collection activities were initiated in Phase 1 (January through June 2010). Cast cutting and adverse event data were categorized as occurring on the main campus or at a satellite location. Weekly cast saw blade checks by cast technicians were implemented in the emergency department on the basis of our second hypothesis.

Resident training included a one-hour lecture and a half-hour hands-on training session in the cast room that focused on cast application and removal. A new certification requirement was introduced for all midlevel providers and orthopaedic technicians. Trainees were required to demonstrate safe cast saw use and equipment maintenance skills before their competency checklist was signed by the lead orthopaedic technician and the clinical chief of the department.

Phase 2

During Phase 2 (July 2010 through December 2011), the surveillance program was refined to allow for more granular collection of data according to location. Injury rates were calculated for each location. Biweekly equipment checks began in the emergency department, as the analysis during Phase 1 indicated that suboptimal equipment in that department was a contributing factor to cast saw injuries. The mandatory reporting of all cast saw injuries to the hospital SERS was strictly enforced. A formal protocol was established requiring the attending physician assessing the cast saw injury to offer a plastic surgery consultation to the patient or patient's family if the lesion was moderate to severe in nature. Each incident was reviewed at six months after the injury date to assess follow-up care and the final outcome. Resident training continued in the same manner as in Phase 1.

Phase 3

Phase 3 began in January 2012 and continued through the end of the period reported in this paper (December 2012). In Phase 3, the surveillance program was expanded to include two new satellite offices. Interim results continued to indicate increased event rates occurring at night in the emergency department at the hands of residents. As a result, the frequency of equipment checks was increased to daily and an emergency department log documenting blade rotations and changes was introduced. Cast training was also increased, as the analyses during Phases 1 and 2 indicated that patients undergoing conscious sedation in the emergency department for fracture reduction were at highest risk for a cast saw injury. The Phase-2 cast saw training (a one-hour didactic and practical teaching session) was expanded to a full day of hands-on certification

TABLE I Injury Rates, June 2010 through December 2012

	Injuries	Casts Removed	Rate Per 1000*	95% CI
Location				
Cast room (ambulatory clinics)	7	17,059	0.41	0.20, 0.85
Emergency department	15	785	19.11	11.61, 31.29
Main campus OR	3	2274	1.32	0.45, 3.87
Other†	1	594	1.68	0.30, 9.47
Time of day‡				
Day	15	19,419	0.77	0.47, 1.27
Night	11	1293	8.51	4.76, 15.17
Provider type‡				
Resident	16	1651	9.69	5.97, 15.69
Orthopaedic technician	10	19,061	0.52	0.29, 0.97

*P < 0.0001 for location (p = 0.09 excluding the emergency department), p < 0.0001 for time of day, and p < 0.0001 for provider type.†Hospital floor, sports medicine clinic, or satellite OR. ‡See Materials and Methods for an explanation of how the number of cast removals was estimated.

in the cast room. The cast room training included a competency checklist signed off on by the lead orthopaedic technician and the clinical chief.

A review policy was also introduced for any party deemed responsible for a cast saw injury. If a serious injury or multiple injuries resulted from the same health-care provider, he or she was required to repeat all of the educational training components and obtain recertification. If subsequent episodes occurred, the care provider was put on probation from cast saw use and was required to spend a week in the cast room under direct supervision by the lead orthopaedic technician for cast saw recertification before returning to unsupervised cast saw use.

Source of Funding

No external funding was received for this study.

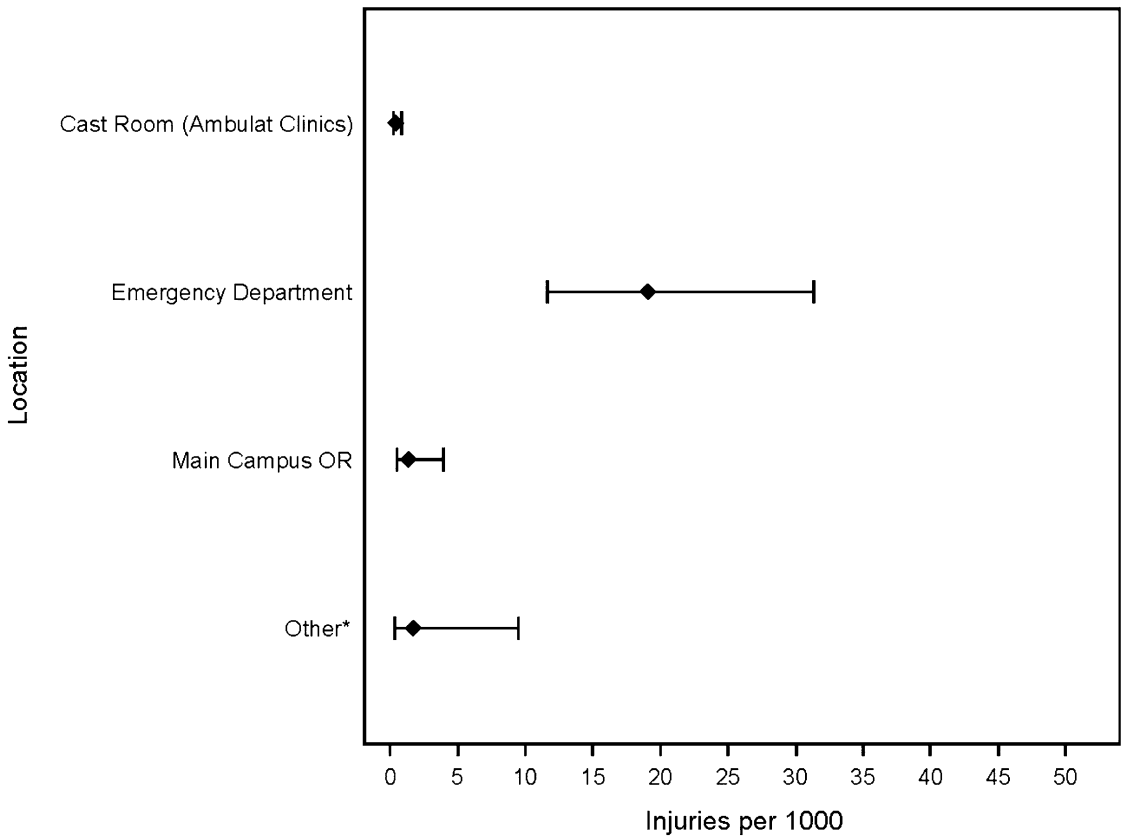

Fig. 2

Injury rates with 95% confidence intervals according to location, June 2010 through December 2012. *Other locations were the hospital floor, sports medicine clinic, and satellite ORs.

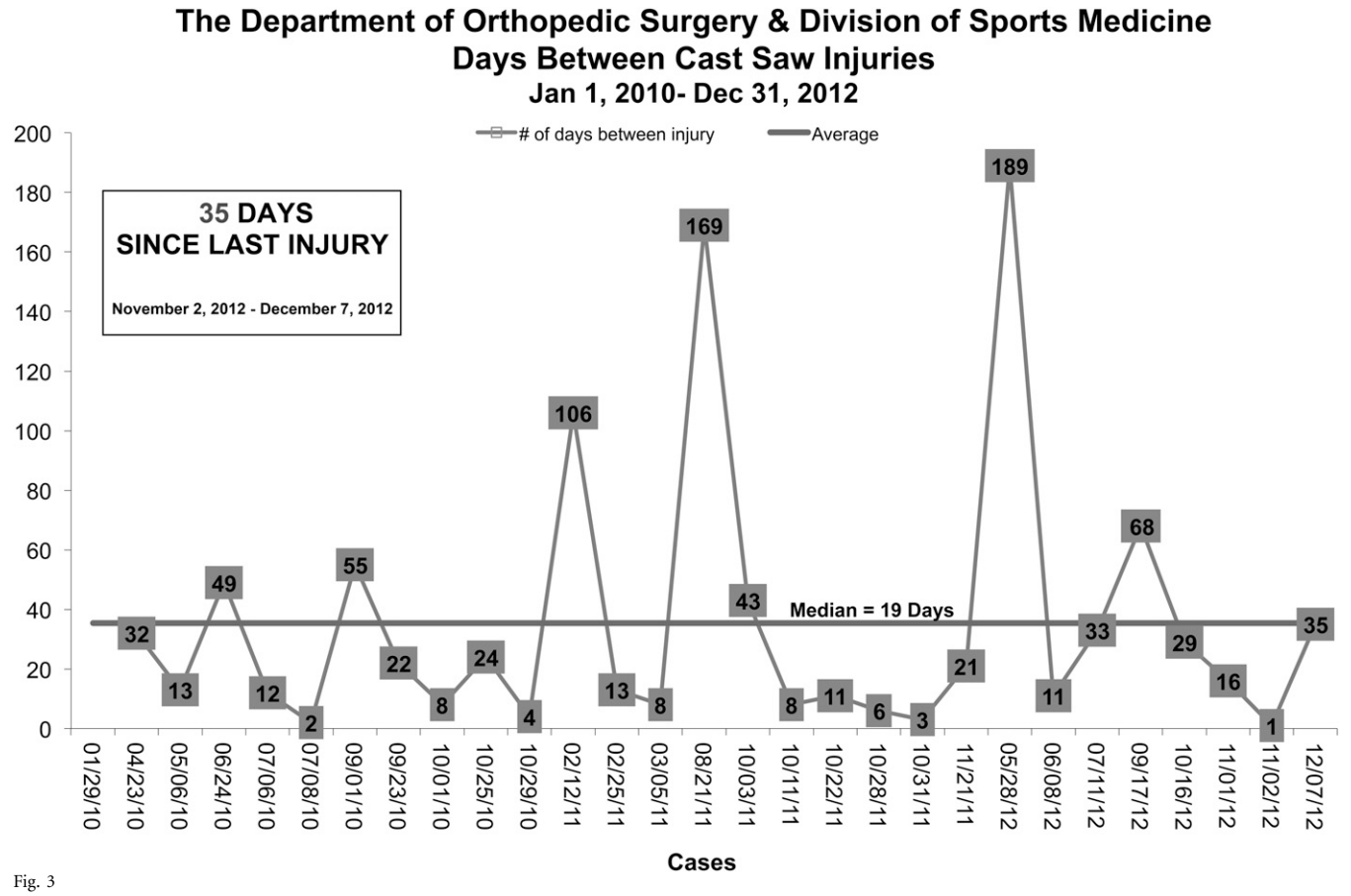

Fig. 3

Days between cast saw injuries, 2010 through 2012.

Results

Over the three-year study period (2010 through 2012), there were twenty-nine cast-saw injuries in 23,615 casts cut, for an overall rate of 1.23 (95% CI, 0.86 to 1.76) per 1000. A minor decrease in cast saw injuries was recorded over the course of the study (eleven of 8043 [1.37 per 1000] in 2010, ten of 7885 [1.27 per 1000] in 2011, and eight of 7687 [1.04 per 1000] in 2012), but the decrease was not significant ($p = 0.87$).

Table I and Figure 2 illustrate injury rates according to location, provider, and time of day for the 20,712 casts cut during June 2010 through December 2012. (Exact location data were not obtained during Phase 1, January through June 2010.) The variation in rates across locations was highly significant, primarily because of the high injury rate in the emergency department ($p < 0.0001$). In addition, there appeared to be a diurnal pattern in cast saw injuries, with a significantly greater rate during the night compared with the day (eleven of 1293 [8.51 per 1000] compared with fifteen of 19,419 [0.77 per 1000], respectively; $p < 0.0001$). The cast saw injuries in the emergency department all occurred at the hands of a resident and occurred mostly at night (eleven of fifteen).

All orthopaedic residents who rotate through our department are in their third year of training and spend six consecutive months at our hospital. Cast saw injuries were dichotomized according to resident experience, with residents who started in July classified as "inexperienced" and those who started in January as "experienced." Thirteen (72%) of the eighteen injuries that occurred at the hands of residents were among the less experienced group ($p = 0.10$).

The longest consecutive span of time without a cast saw injury during 2010 was fifty-five days, whereas the longest span from November 21, 2011, until May 28, 2012, was 189 incident-free days (Fig. 3). In addition, there appeared to be a nonsignificant trend toward decreasing injuries attributed to residents over time (eight of eleven, eight of ten, and two of eight during 2010, 2011, and 2012, respectively; $p = 0.06$).

Beginning in Phase 2, plastic surgery consultations were offered at the discretion of the attending physician assessing the wound. Interestingly, in all circumstances, families declined the plastic surgery referral. No cast saw injuries required further surgical treatment since the onset of the program. Furthermore, there has been no medicolegal action taken against the orthopaedic department for cast saw injuries during this period.

The highest-risk location for cast saw injury was the emergency department, with a rate of 19.11 (95% CI, 11.61 to 31.29) per 1000. Analysis of the adverse events forms demonstrated that the majority of cast saw injuries occurred in

TABLE II Characteristics of the Adverse Events According to Year

	2010	2011	2012	Total
No. of events	11	10	8	29
Location				
Cast room (ambulatory clinic)	3	2	3	8
Emergency department	6	7	2	15
Main campus OR	2	1	2	5
Satellite OR	0	0	0	0
Other*	0	0	1	1
Provider type				
Resident	8	8	2	18
Orthopaedic technician	3	2	6	11
Patient neurologic status				
Unconscious, under anesthesia	3	1	2	6
Unconscious, sedated	5	6	1	12
Cooperative, awake	2	3	2	7
Uncooperative, needed coaxing	1	0	2	3
Uncooperative, needed restraint	0	0	1	1
Time of day				
Day	6	5	6	17
Night	5	5	2	12

*Hospital floor, sports medicine clinic, or satellite OR.

unconscious or uncooperative patients (twenty-two of twenty-nine, 76%) and at the hands of residents (eighteen of twenty-nine, 62%) (Table II). Of note, one resident in training was placed on probation and underwent formal reeducation early in the program after several different episodes of cast saw injury.

Discussion

Cast saw injuries are a known complication associated with cast removal in pediatric patients. The present study demonstrated that the incidence rate across our orthopaedic department was very low at 1.23 per 1000 (compared with a previously reported rate of 7.23 per 1000[2]). All injuries during our study period were superficial, not requiring additional treatment or surgery. However, the rate of cast saw injury in our emergency department, 19.11 per 1000, was significantly higher than that in other hospital locations. Furthermore, 73% of the injuries in the emergency department (eleven of fifteen) occurred at night, all at the hands of residents, satisfying our primary hypothesis.

Previous literature on risk factors associated with cast saw injuries mirrors the findings of this study. Young patients sustaining a traumatic injury with swelling, deformity, and potential neurologic and vascular issues are a high-risk group for sustaining a cast saw burn[2,7,9]. Ansari et al. attributed elevated injury rates to inexperienced users and blunt saw blades[2]. Shuler and Grisafi also reported that variables affecting heat during cast removal are clinician-dependent, and therefore extra attention should be paid to technique and equipment[3]. The results of the present study indirectly support those findings, as the greatest rate of injury occurred in the emergency department, exclusively at the hands of residents.

Our secondary hypothesis was that an educational initiative would be an effective method for reducing cast saw injury rates. Unfortunately, we were unable to demonstrate a significant decrease in the number of cast saw injuries as our educational model improved and our trainees received more formal training prior to cast saw use. Although there was a modest positive trend toward a reduction in injuries at the hands of residents in the emergency department during the study period, this result could have occurred from chance alone and further longitudinal study is necessary to demonstrate significant improvements resulting from our quality improvement initiative. Since our baseline injury rate was markedly below that reported by Ansari et al., it is also possible that starting our program resulted in an immediate improvement from a previous, unknown higher rate of injury because cast saw users were aware that their performance was now being monitored (the Hawthorne effect)[17,18] and that improvements since then have been harder to achieve.

Root cause analysis demonstrated that infrequent saw blade maintenance in the emergency department could represent a major area for quality improvement. However, the definition of a dull cast saw blade is subjective as dullness is a difficult measure to quantify. When assessing heat generation during cast application and removal, Killian et al. found that an average of three to five uses of a cast saw blade increases the average temperature by 20° to 40°C because of an increase in dullness with each use[4]. During Phase 1 of the present study,

equipment maintenance in the emergency department was provided sporadically by orthopaedic technicians from the ambulatory clinic and was not formally documented. During Phase 2, we implemented a biweekly saw blade assessment by one of the orthopaedic technicians. According to the adverse event reports collected during Phase 2, the last known cast saw blade rotation or change was "four plus days ago" for eight of the thirteen incidents that occurred in the emergency department. As part of our Phase-3 improvements, we increased emergency department cast saw maintenance to a daily occurrence. Perhaps as a result of this intervention, only two cast saw injuries occurred in the emergency department at the hands of residents during Phase 3; however, further longitudinal study and improved definition of cast saw blade conditions are necessary to support this assertion.

In addition to cast saw blade maintenance and resident education, inexperience in general seems to be a major risk factor for cast saw injuries. A much higher rate of cast saw injuries occurred in the emergency department, where residents have less experience than our regular orthopaedic cast technicians. When we dichotomized injuries at the hands of residents according to experience, we observed an almost threefold greater number of injuries at the hands of residents at the beginning of their third year (thirteen injuries) compared with the more experienced cohort beginning in January (five injuries), although the difference did not reach significance ($p = 0.10$). These clusters of events highlight the need for adequate and timely cast saw training from the beginning of any rotation or service, with heightened awareness in those with less overall experience.

There are several limitations to this study. Although data collection was rigorous, reporting was voluntary and we may therefore have missed some encounters. When documentation of cast saw use is tied directly to the electronic medical record, such as in the ambulatory clinics and operating rooms, the data are more reliable. As part of the continuous improvement process, we identified locations and time periods with underreported numbers and sought to capture that data more effectively. Since adjusting our methods, we have captured the number of casts cut in the emergency department and operating room more accurately. Over time, this improved accuracy of the denominator will result in a bias toward a decreased injury rate. The preliminary results of the study are encouraging, but further longitudinal study is necessary to demonstrate a sustained improvement associated with our quality improvement initiative. Finally, our finding that the nighttime injury rate was higher than the daytime rate relies on estimates of the proportion of casts cut during the day at each location other than the ambulatory clinic (which is open only during the day). In order to test the sensitivity of the finding to our estimates of these proportions, we made the alternative assumption that all cast cutting at locations other than the ambulatory clinic was done at night. By thus overestimating and underestimating the denominators for nighttime and daytime cuts, respectively, this analysis would be biased toward lowering nighttime rates and increasing daytime rates. Even in this biased analysis, the nighttime injury rate was elevated by more than threefold (eleven of 3653 [3.01 per 1000] compared with fifteen of 17,059 [0.88 per 1000], $p = 0.003$).

The results of this study offer insights into prevention strategies and quality improvement. We assert that recognition of at-risk personnel and locations is the primary step in reducing cast saw injuries. This is particularly true given the relative de-emphasis of closed fracture care experience of orthopaedic residents. Since we improved standards for such education—including didactic education, hands-on clinical training, and basic competency certification—we feel that we are providing our trainees with better resources to safety handle cast saws. Similarly, requiring daily inspection and care of the cast saw blades by the orthopaedic technicians and teaching all users how to rotate and change overused blades has the potential to significantly decrease our cast saw injury rate over time. Periods of increased injury frequency appear to correspond with gaps in resident and fellow training. Thus, timely training regarding cast use and blade maintenance is the key to reaching the future goal of complete elimination of cast saw injuries. Other options to decrease cast saw injuries could include applying only splints in the emergency department or having a cast saw technician on call at night in that department; however, neither alternative is plausible in our current system.

This study demonstrated that the rate of cast saw injuries in a busy pediatric orthopaedic department was small but that a considerably increased risk existed for those patients cared for in the emergency department by orthopaedic residents. Although a dedicated quality improvement initiative can increase the education and skill of cast saw users, the resulting decrease in the rate of cast saw injuries was not statistically significant. Effective quality improvement strategies include implementing daily cast saw blade maintenance, providing didactic and hands-on curricula for new rotating residents and midlevel providers, and identifying patients who are at high risk for injury prior to cast removal. By training orthopaedic residents in the proper and safe use of cast saws, we can continue to decrease the rate of cast saw injuries and perhaps make these injuries a never event in the future. ■

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