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Perceptions of Fracture Location

Breanna Dominguez

Wright State University - Main Campus, dominguez.11@wright.edu

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Abstract

OBJECTIVE: Aseptic non-union is a significant complication in approximately 5% of long bone fractures. Bone stimulation devices are used before surgical intervention and can have favorable results if accurately placed. The objective of this study is to determine accuracy of clinician fracture localization based solely on viewing radiographs.

METHODS: A transverse diaphyseal fracture was induced in a cadaveric radius and tibia using a bone saw and osteotome; fractures were not apparent from incision or soft tissue. The sample included 20 physicians and 16 pre-clinical medical students. Participants used reference anteroposterior (AP) and lateral radiographs to determine fracture location and placed a radiopaque marker on cadaver, no palpation was allowed. Repeat AP radiographs of each participant’s placed marker were obtained.

RESULTS: On the radius 70% of physicians and 69% of medical students placed the marker within 1.7 cm. On the tibia, 80% of physicians and 75% of medical students placed the marker within therapeutic limits. Outside of the 1.7 cm, physician average distance was closer to the fracture than the medical student average. Overall, neither physicians nor medical students were significantly more inaccurate for the radius vs. tibia.
Key words: radiographic identification, fracture localization, bone stimulator therapy, non-union fractures

Introduction/Literature Review

Aseptic non-union is a significant complication of approximately 5% of long bone fractures. Specifically, midshaft forearm and leg fractures are prone to non-union with rates as high as 14% in combined tibia and fibula fractures. The definition of a non-union varies among surgeons, but is generally diagnosed when radiographic evidence shows no bony healing at greater than six months from the time of injury. Prior to invasive surgical intervention, bone stimulators are used to stimulate osteogenesis and healing in the affected bone(s). Compared to surgical intervention, the use of bone stimulator devices can save patients an average of $6,000 USD in medical costs. The EXOGEN bone stimulator utilizes low-intensity, pulsed ultrasound (LIPUS) to stimulate fibroblasts and mechano-receptors and thus promote new bone growth and healing. These devices can have favorable results but have a limited therapeutic radius of 1.7 cm through 20 cm of soft tissue. This narrow effective range means that accurate placement is essential to obtain therapeutic results. In order for a patient, even a complaint one, to benefit from bone stimulator use, the physician must first advise accurate placement.

The objective of this study was to determine if physicians are able to accurately localize fractures solely by viewing radiographs. Accurate physician placement is paramount, as patients rely on physician guidance for instructions before initiating therapy.

Hypothesis/Specific Aims/Research Questions

When presented with a fracture model, subjects with less medical training will be less accurate in identifying fracture location.
Methods

Participants were recruited from medical students, orthopaedic residents, and orthopaedic attendings. Pre-clinical medical students (M1 and M2) were recruited via email invitation to both classes. All other participants were recruited from specifically orthopaedic surgery staff, physicians. Participants were surveyed for years in practice, level of training, and level of education before viewing the radiographs. The final sample included 20 Physicians (6 attendings, 14 residents) and 16 pre-clinical medical students without clinical experience.

Two cadaver specimens were obtained, one upper extremity and one lower extremity. In the forearm, an extended incision was made on the radial side from the level of the styloid process of the radius to the level of the capitulum (Figure 1). In the leg, an incision was made from the level of lateral malleolus to the level of lateral condyle of the tibia (Figure 2). These long incisions were made so the site of fracture could not be guessed solely from incision length and location. The radius and tibia were then manipulated using a bone saw and osteotome to induce a single, transverse diaphyseal fracture. Care was taken to ensure fracture locations were not apparent from soft tissue damage, particularly for the tibia (Figure 3). Deep and superficial sutures were used to close the incisions. Anteroposterior (AP) and lateral radiographs were obtained for participant reference (Figure 4).

Both cadaver limbs were measured at three different levels to show that the specimens were not obese and soft tissue mass was not impacting results. Proximal, fracture, and distal circumference were measured.

Participants were individually brought into the x-ray suite and shown the reference radiographs of each fracture and asked to place a 15 mm diameter radiopaque marker on the cadaver limbs where they perceived the fracture location (Figure 5). The marker left no indication of previous
participants’ placement on the soft tissue. Participants were allowed to go back and forth between the radiographs with no time limit. Participants were not allowed to palpate to prevent fracture displacement or soft-tissue disturbances. Repeat radiographs for each participant’s marker placement were then obtained.

Marker-to-fracture-line distance was measured using PACS software along the longitudinal bone axis perpendicular to the transverse fracture line (Figure 6). The absolute distance proximally or distally from the fracture line was calculated. Medial and lateral inaccuracy were not included in measure as the fracture line was transverse and inaccuracy would be mitigated in clinical practice by palpation.

Statistical analysis was performed using SAS 9.4 (SAS Institute, Cary, NC), with significance set to $\alpha=0.05$. Differences between physicians and pre-clinical medical students in placement accuracy rates were compared using chi-square tests. Within participants placing the marker outside of the therapeutic radius, differences between physicians and pre-clinical medical students in distance from the fracture were analyzed using Wilcoxon-Mann-Whitney tests. Wilcoxon signed rank tests were used to determine whether there were differences in marker placement accuracy between the radius and tibia within each participant group (physicians, medical students).

**Results**

On the radius cadaver model, 70% of physicians and 69% of medical students accurately placed the marker within the 1.7 cm therapeutic range ($\chi^2=0.01$, $P=0.94$; see Figure 7). The 30% of physicians who inaccurately placed the radius marker did so at a mean (±SD) distance of 2.1±0.5 cm, whereas the 31% of medical students with inaccurate placement had a mean distance of 3.6±0.9 cm ($Z=2.28$, $P=0.02$; see Figure 8). On the tibia cadaver model, 80% of physicians and
75% of medical students accurately placed the marker within the 1.7 cm therapeutic range ($\chi^2=0.13, P=0.72$; see Figure 7). The 20% of physicians who inaccurately placed the tibia marker did so at a mean (±SD) distance of 2.6±0.5 cm, whereas the 25% of medical students with inaccurate placement had a mean distance of 3.5±0.5 cm ($Z=-0.14, P=0.89$; see Figure 8). Mean marker placement distances from the fracture were similar for the radius and tibia models within physicians (1.2±0.8 vs. 1.1±0.9 cm, respectively; $T_S=21.0, P=0.45$; see Figure 9). Within preclinical medical students, mean marker placement distance from the fracture was slightly higher for the radius (1.7±1.4 cm) than for the tibia (1.3±1.6 cm; $T_S=22.5, P=0.26$; see Figure 9).

Discussion

Up to 5% of long bone fractures are complicated by aseptic non-union\(^1\). Prior to invasive corrective surgery, these fractures can be treated with bone stimulation. Bone stimulation devices use ultrasound waves to stimulate osteogenesis and promote healing of the non-union\(^3,5\). Bone stimulation has been shown to be as effective as corrective surgery without associated complications and risks\(^7\). These devices have a narrow therapeutic range of 3.4 cm\(^3\). As such, even with compliant patients, accurate direction from physicians is required for any therapeutic results to be achieved.

In order for a physician to accurately advise a patient on placement, they must be able to accurately identify the fracture location. In this study, the fractures were induced via osteotomy with large, longitudinal incisions and participants were not able to palpate. A possible limitation of this study is that practicing orthopedists would likely have been the ones to perform the surgery on the fracture and would be able to palpate in office. The utility of masking fracture location via long incisions and prohibiting palpation lies in the fact that non-unions are not an immediate complication of fracture, but rather a more long-term complication\(^2\). A recent study sought to
quantify ‘non-union’ fractures and despite there being no consensus, the majority of participants classified it based on at least a 4-month period without evidence of healing\(^2\). As such, physicians would not have recently operated on the fractures and would likely not remember exact location. Palpation of the bone would yield good medial/lateral localization but not proximal/distal localization with the required accuracy.

While the majority of physicians were able to accurately localize within therapeutic range, there were still up to 30\% that would not have achieved therapeutic placement. In these patients, bone stimulation therapy would yield no healing benefits. It has been shown that increasing time between surgery and starting bone stimulation therapy decreases the likelihood that the fracture will heal with therapy, this was especially true of upper extremity fractures\(^8\). Initiating bone stimulation therapy with a marker outside of the therapeutic range, as seen in 30\% of physicians in this study, would effectively prolong the time between surgery and beginning effective stimulation and potentially decrease the likelihood the fracture will heal.

While the general trend seen was increased accuracy with transition from beginning a medical career to reaching attending status, there was no increase in accuracy for more years in the same training level. For example, an attending with 6 years in practice was within therapeutic range (0.02 cm from fracture site) compared to a non-therapeutic localization (2.9 cm from the fracture site) by a physician practicing for 28 years. The same trend was seen across all medical training groups. Levels of training (first year medical student or resident vs. final year medical student or resident) within the groups did not result in a more accurate placement. This may be a result of small sample size that we were able to obtain or the amount of time taken to place the marker by physicians with more training. Further studies that take placement time into account may mitigate the differences within training levels and may be a future direction to take this study.
Conclusion

Overall, this study shows that about 70% of physicians are able to accurately advise patients for bone stimulator placement. In order to ensure the most consistent patient outcomes, secondary measures should be taken to verify fracture location before initiating therapy for the patient. Using ultrasound to verify fracture location when initiating bone stimulator therapy would mitigate the inaccuracy of physician placement. Alternatively, an in-office radiograph with a radiopaque marker would be another quick and effective way to verify accuracy of placement. Verifying placement with ultrasound or radiograph before sending the patient home to begin therapy would reduce the number of inaccurately identified fractures and promote more therapeutic bone stimulation results.

The participants were not given a time limit nor were they timed at how long they spent before placing the marker. It appeared that some attendings did not take much time localizing before placing the marker but the clinical staff did. The amount of time taken, or not taken, before placing the marker may have affected the ability to localize in these groups. Additionally, both of these groups were the smallest participants groups, with only six participants in both groups. As mentioned before, both of these factors could have contributed to the higher level of accuracy seen with the office staff and the lower level seen with the attendings on the radius.

The biggest limitation of this study was the small sample size we were able to obtain for attendings and non-clinical staff. At an institution with relatively few orthopaedic surgery attendings this was bound to be a limitation of the study. Adding EM residents and attendings was considered to increase our sample size; however, this was ruled against because it would have added another variable to the study. Repeating this study at a larger institution, or across several institutions, could give a more accurate sense of the actual difference between levels of medical
training and fracture localization accuracy. Additionally, a study where fracture location is verified with ultrasound or radiograph and then marked with a henna dot and then daily patient compliance is tracked would be a way to measure optimum therapeutic effects.

The implication that physicians may not be accurately advising on bone stimulator placements means there is room for improvement. Using additional verification methods could lead to decreased healing time and improved patient outcomes. This study is a good introduction to investigating accuracy of bone stimulator placement. It can provide good guidance for further investigation of bone stimulators and their clinical use.
References


3. Activating bone healing at every stage EXOGEN ® Ultrasound Bone Healing System.


Figures

Figure 1: cadaveric forearm imaging set up and longitudinal incision

Figure 2: cadaveric leg imaging setup

Figure 3: final participant imaging setup

Figure 4: baseline radiograph of fracture models for participant reference
Figure 5: Example participant localization indicated by the radiopaque circles.

Figure 6: PACS sample measurement.

Figure 7: Percent of physicians (gray bars) and medical students (white bars) with accurate marker placement on the radius and tibia. Percentages did not differ significantly between groups for either bone (radius: $P=0.94$; tibia: $P=0.72$).
Figure 8: Distributions of marker-to-fracture distances (cm) within participants who placed the marker outside the therapeutic radius. Physicians (gray boxes) had significantly shorter inaccurate distances than medical students (white boxes) for the radius (P=0.02), but not for the tibia (P=0.89).

Figure 9: Distributions of marker-to-fracture distances among all physicians (gray boxes) and medical students (white boxes), comparing radial and tibial placements. Placement accuracy in terms of distance did not differ significantly between bones for either physicians (P=0.45) or the medical students (P=0.26).