Cost and Complications of Percutaneous Fixation of Hand Fractures in a Procedure Room Versus the Operating Room

HAND
2018, Vol. 13(4) 428–434
© The Author(s) 2017
Reprints and permissions:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1558944717715105
hand.sagepub.com

Mark T. Garon¹, Patrick Massey¹, Andreas Chen¹,
Trevor Carroll¹, Bradley G. Nelson¹, and Anne M. Hollister¹

Abstract

Background: The purpose of this study was to compare closed reduction and percutaneous pinning of metacarpal and phalanx fractures performed in the operating room (OR) versus the procedure room of the emergency department with primary outcomes being infection rate, radiographic union, and monetary cost. **Methods:** From January 2006 to December 2010, all closed reduction and percutaneous pinnings of metacarpal and phalanx fractures (CPT codes: 26608; 26727) by a single board-certified hand surgeon (A.M.H.) were retrospectively reviewed. Patients were placed into 2 groups: Group 1 was patients treated in the OR, and group 2 was patients in an emergency department procedure room. Infection, malunion, and nonunion rates were compared using a chi-square test. Charges were compared using a t-test, and cost of supplies and labor was evaluated. **Results:** A total of 189 patients met final inclusion criteria for this study: 130 in group 1 and 59 in group 2. There was no statistically significant difference in infection rates ($P = .13$), nonunion ($P = .40$), malunion rates ($P = .89$), and hardware failure with revision ($P = .94$) between the 2 groups. The procedure room patients had an average hospital charge of \$1358.55 compared with \$3691.85 for OR-treated patients ($P = .001$). The total cost of supplies and nonphysician labor was \$432.31 per OR case and \$179.59 per procedure room case. **Conclusions:** Metacarpal and phalanx fractures of the hand amenable to closed reduction and percutaneous pinning can be treated in the procedure room with no increase in risk of infection, malunion, or nonunion rates. In addition, these surgeries can be performed in a procedure room with lower cost and less charges to patients than in the operating room.

Keywords: hand, percutaneous, metacarpal, fracture, pinning, phalanx, phalangeal

Introduction

Displaced metacarpal and proximal phalanx fractures are amenable to a variety of treatments, usually based on fracture characteristics. Closed reduction and percutaneous pinning (CRPP) is a useful tool in the armamentarium of any hand surgeon treating metacarpal and phalangeal fractures. This technique is usually performed in the operating room (OR) setting. The OR allows for a controlled and sterile environment in which the procedure may be performed under general or regional anesthesia. These benefits do not come without disadvantages such as increasing utilization of resources. These include OR time, staff, and materials as well as increasing the time to definitive treatment and total cost to the patient.

In almost all emergency departments, there is a room designated for procedures. At the level I trauma center where this study was performed, there is an orthopedic surgery procedure room within the emergency department.

This procedure room is complete with fluoroscopy, surgical instruments, patient monitors, and a pressurized nitrogen air supply. Traditionally at our trauma center, metacarpal and phalangeal fractures amenable to CRPP have been performed under sterile conditions with a regional block in the procedure room.

To fully understand the differences between closed reduction and percutaneous pinning in the procedure room versus the OR, the concepts of cost and charge must be better elucidated. Cost does not equal charge in terms of medical billing. Cost refers to the expenditures of a hospital to

¹Louisiana State University Health Sciences Center, Shreveport, USA

Corresponding Author:

Patrick Massey, Department of Orthopaedic Surgery, Louisiana State University Health Sciences Center, 1501 Kings Highway, P.O. Box 33932, Shreveport, LA 71130-3932, USA.
Email: pmasse@lsuhsc.edu

obtain resources, whereas charge refers to the amount the hospital or physician bills for a procedure.^{10,12} To expand on these definitions, patient cost refers to both the monetary and nonmonetary costs of the patient to receive the desired treatment. Two of the most important nonmonetary costs to the patient include time and psychological costs. It is difficult to assess hospital costs and the nonmonetary patient costs. However, there are 2 numbers that patients, surgeons, and hospitals are routinely aware of: hospital charge or patient monetary cost and physician reimbursement. Many surgeons are paid on a fee schedule for each procedure, which does not change if the procedure is done in the OR versus the emergency room (ER) when the same Current Procedural Terminology (CPT) code is used. However, if the procedure is done in the clinic-based setting or procedure room, the OR fee for the hospital is not included in the patient's monetary cost. In theory, this would lead to a reduction in total patient cost. All of these factors must be assessed when determining treatment options, but the most important factors are patient safety, treatment efficacy, and total patient cost.

The purpose of this study was to compare closed reduction and percutaneous pinning of metacarpal and phalanx fractures performed in the OR versus the procedure room of the emergency department with primary outcomes being infection rate, radiographic union, and monetary cost.

The hypothesis was percutaneous pinned metacarpal and phalanx fractures treated in the procedure room would have equivalent infection rates and union rates with lower patient cost than fractures treated in the OR.

Materials and Methods

Prior to evaluating patients, a power analysis was performed to obtain the number of patients needed in each group for a power of $1 - \beta = .80$. Using the formulas described by Chow et al, it was determined that $n = 13$ for each group was required for sufficient power.³ To obtain patients for this retrospective review, our institution's billing database was searched by the CPT code for closed reduction and percutaneous pinning of metacarpal and phalanx fractures (CPT codes: 26608; 26727) by a single board-certified hand surgeon (A.M.H.) from January 2006 to December 2010. Patients were only included if they had an isolated fracture (no other hand injuries requiring surgery) and were above the age of 18. The CPT code for phalanx fractures included proximal and middle phalanx fractures. Distal phalanx fractures were not included in this study and have a separate CPT code. Patients were excluded if they had an open fracture or follow-up was less than 4 weeks. Patients were divided into 2 groups: Group 1 was patients pinned in the OR, and group 2 was patients pinned in the procedure room. Charts and radiographs were then reviewed for analysis.

Description of Procedure

Patients who presented to a level I emergency department with nonemergent hand fractures amenable to CRPP were given the option to have the procedure performed in the procedure room at the initial visit or have the procedure performed in the OR on a separate hospital visit. Patients who would not tolerate regional anesthesia such as children, unstable trauma patients, and psychotic patients, were not given this option and were scheduled for the OR. Preoperative evaluation and lab work were performed while the patient was in the emergency department regardless of the setting of the surgery. Prior to the patient choosing the procedure location, risks and benefits of the surgery as well as the setting were discussed with the patient. Informed written consent forms for the procedure were completed at this time.

For those patients who chose to have the procedure performed in the OR, lab work was reviewed and the patient was discharged from the emergency department after being placed in an appropriate splint and/or buddy tape and asked to return for day surgery. OR procedures were either performed under regional anesthesia or general anesthesia as determined by the anesthesia staff. The procedure was performed under sterile conditions on a radiolucent arm board with fluoroscopy and preoperative antibiotics as determined by hospital policy.

For those patients who chose to have closed reduction with percutaneous pinning performed in the procedure room, a wrist block was performed after consents and lab work were reviewed. The standard wrist block was performed under sterile conditions using betadine 10% solution or chlorhexidine 4% scrub based on patient allergies. The block was done using an equal mixture of 1% lidocaine and 0.25% Marcaine. While the wrist block was taking effect, the procedure room was setup using the image intensifier as a sterile operative field. An adjustable table was used as a sterile field and a rolling stool was used for seating; radiation protection was utilized by the patient and surgeon. All unsterile surfaces are draped with a folded sheet to create a sterile field. After the block has taken effect, the patient is rolled to the procedure room and given preoperative antibiotics as determined by our hospital policy for the OR. This typically utilized cefazolin or clindamycin for penicillin-allergic patients. After cleaning the hand with soap and water to remove all soil, oil, or other debris from the hand, the upper extremity was prepped from the finger tips to the midforearm again using either betadine 10% solution or chlorhexidine 4% scrub, again identical to the procedures performed in the OR. Once the extremity has been prepped, the hand was laid across the sterile field on the top of the image intensifier. Sterile towels are used to cover the remainder of the unsterile arm. The surgeon then obtained sterile gloves and a mask, a timeout is performed

Figure 1. Lateral radiographs of a right index middle phalanx fracture closed reduced and percutaneously pinned in the procedure room: (a) preoperatively, (b) early, and (c) late postoperatively.

Table 1. Malunion Tolerances.

Bone location	Tolerances of deformity
Thumb metacarpal	25° in coronal and sagittal planes, 1-mm articular displacement; Base: 2-mm step-off, incongruent joint
Index finger metacarpal	Head: 1-mm articular step-off; Neck: 15°; Shaft: 5-mm shortening, 10° coronal, 10° sagittal; Base: 2-mm step-off, incongruent joint
Long finger metacarpal	Head: 1-mm articular step-off; Neck: 15°; Shaft: 5-mm shortening, 10° coronal, 10° sagittal; Base: 2-mm step-off, incongruent joint
Ring finger metacarpal	Head: 1-mm articular step-off; Neck: 40°; Shaft: 5-mm shortening, 10° coronal, 20° sagittal; Base: 2-mm step-off, incongruent joint
Small finger metacarpal	Head: 1-mm articular step-off; Neck: 60°; Shaft: 5-mm shortening, 10° coronal, 30° sagittal; Base: 2-mm step-off, incongruent joint
Phalanx	>10° in any plane, 1-mm articular step-off

with the nurse, and the procedure commenced using a pneumatic drill and appropriate sized Kirschner wires (Figure 1).

Post-procedure protocol for both procedure room and OR-treated fractures was to cut pins below the skin, apply nonadherent dressings with the appropriate splint and/or buddy tape combination, and follow up within 1 week for wound check and radiographs. Subsequent visits were based on attending preference.

A patient was considered to have an infection if purulent drainage or increased swelling with pain and erythema was noted in the clinic note. Radiographs were also reviewed by a board-certified hand surgeon (A.M.H.) to assess malunion, based on published tolerances of metacarpal and phalanx fractures (Table 1).⁹ The reviewer was blinded to which group each patient was in prior to evaluating the radiographs. Nonunion was identified if no callus or union was present at the final follow-up. Hardware failure was determined if the patient had to return to the OR for early revision for loss of fixation. To assess hospital

charge, billing information was collected from invoices, comparing charges and supplies used. Once all charts and radiographs were reviewed, the data were compiled and analyzed.

Statistics

As there was no previous study comparing the rate of complications for percutaneous pinned fractures in the OR versus ER procedure room, estimations were used based on other studies. Using complication rates of other studies comparing OR versus procedure room surgeries, a number needed was calculated for a power of $1 - \beta = .80$. The formula used was $n_A = \kappa n_B$ and $n_B = ((p_A(1 - p_A)) / \kappa + p_B(1 - p_B)) \times ((Z_{1-\alpha/2} + Z_{1-\beta}) / (p_A - p_B))^2$.³ Using previous studies, an estimation was made for an infection rate of 0.4 for group A and an infection rate of 0.0036 for group B.¹¹ This yielded a calculation of 13 patients needed in each group to produce a power of at least .80.

Figure 2. Flow chart for patient selection (inclusion and exclusion criteria).

Note. Patients were included if they underwent percutaneous pinning of a metacarpal or proximal phalanx or middle phalanx in an outpatient OR setting or in the ER. Patients were excluded if the fracture was open or follow-up was less than 4 weeks. OR = operating room; ER = emergency room.

Chi-square analysis was performed to compare the prevalence of infection, malunion, and nonunion of the OR group versus the procedure room group. The Student 2-sample *t*-test was used to compare the cost of hospital charges, time until pin removal, and age of group 1 versus group 2.

Results

Two hundred seventy-six adult patients were found to have undergone CRPP of metacarpal, proximal phalanx, or middle phalanx fractures during the study period. After excluding 69 patients with open fractures and 18 patients lost to follow-up, 189 patients met final inclusion criteria (see Figure 2). There were 59 patients treated in the OR (group 1) and 130 patients treated in the procedure room (group 2) for final analysis.

There were 150 male (79%) and 39 female (21%) patients. The average time from injury to pin fixation was 6.9 and 0.3 days in the OR versus procedure room groups, respectively. The average time from pin placement to pin removal was 43.9 and 45.8 days in the OR versus procedure room group, respectively ($P = .76$). There was a statistically significant higher number of right-sided fractures in group

Table 2. Demographic Data of Included Patients.

	Group 1: OR	Group 2: ER	P value
Total patients	59	130	
Age, y	33.5	31.2	.25
Time from injury to fixation, d ^a	6.9	0.3	.00
Time to pin removal, d	42.8	45.8	.76
Sex			.27
Male	44	106	
Female	15	24	
Injured side ^b			.0003
Left	34	39	
Right	25	91	

Note. OR = operating room; ER = emergency room.

^aThere was a longer time from injury to fixation for the OR group.

^bThere was a statistically higher prevalence of right-sided injuries in group 2 (procedure room group) compared with the OR group (group 1) ($P = .0003$).

Table 3. Distribution of Fracture by Group.

	Group 1: OR (n = 59)	Group 2: ER (n = 130)
Distribution of fractures by digit ^a		
Thumb	10	17
Index	8	16
Long	9	13
Ring	16	35
Small	16	49
Distribution of fracture by location ^b		
Metacarpal base	29	42
Metacarpal shaft	8	27
Metacarpal neck	7	12
Metacarpal head	0	1
Proximal phalanx	11	38
Middle phalanx	4	10

Note. OR = operating room; ER = emergency room.

^aThere was a statistically significant difference in distribution of fracture location ($P = .001$) in group 1 versus group 2.

^bThere was also a significant difference in digit distribution ($P = .006$).

2 (procedure room) versus group 1 (OR) ($P = .0003$). The demographic data can be seen in Table 2. The majority of fractures were located in the small finger and the metacarpal base. There was a statistically significant difference in fracture location ($P = .001$) and digit distribution ($P = .006$) in group 1 versus group 2 (see Table 3).

There were 59 fractures that underwent closed reduction with percutaneous pinning in the OR, resulting in 1 (2%) nonunion, 5 (9%) malunions, 2 (3%) hardware infections that required pin removal only, and 1 (2%) failure of hardware with

Figure 3. Complication rate (%) of percutaneous fractures fixed in the operating room (group 1) versus the procedure room (group 2).

Note. There was no difference in the complication rate when comparing the operating room (group 1) versus the procedure room (group 2) with respect to nonunion, malunion, infection, and failure of hardware ($P = .13, .40, .89$, and $.94$, respectively).

revision. In the procedure room treatment arm, 130 fractures underwent closed reduction with percutaneous pinning resulting in 0 nonunions, 7 (5%) malunions, 5 (4%) hardware infections treated with pin removal, and 2 (2%) failure of hardware with revision. There was no statistically significant difference in infection rates ($P = .13$), nonunion ($P = .40$), malunion rates ($P = .89$), and hardware failure with revision ($P = .94$) between the 2 groups (Figure 3). Performing CRPP in the procedure room had an average patient hospital charge of \$1358.55 compared with \$3691.85 for OR-treated patients ($P = .001$). The total cost of supplies and nonphysician labor was \$432.31 per OR case and \$179.59 per procedure room case. The cost of supplies was \$288.16 per OR case and \$153.44 per procedure room case. Nonphysician labor also had higher costs with \$144.15 per OR case and \$26.15 per procedure room case. A total breakdown of resources used and costs can be seen in Table 4.

Discussion

At this time in history, the cost of health care is at the forefront of the minds of patients, doctors, hospitals, and politicians. Discovering new strategies to decrease patient costs is essential to sustain our current health care system. Traditionally, percutaneous treatment of metacarpal fractures has been performed in the OR to allow for a controlled and sterile environment. Although many physicians may reject the idea of performing invasive treatment outside the OR, the reality is that many invasive procedures are done under sterile conditions outside the OR already. At many level I trauma centers, invasive orthopedic procedures are routinely performed in the emergency department such as tibial

Table 4. Cost Analysis of Supplies and Nonphysician Labor of Percutaneous Pinning of the Hand in the Operating Room Versus the Procedure Room.

Supplies or labor	Operating room	Procedure room
Cefazolin 2 g/50 mL	\$6.98	\$6.98
Bupivacaine 0.25% (50 mL)	\$3.27	\$3.27
Lidocaine 1% (50 mL)	\$0.00	\$3.79
10-mL syringes (×3)	\$0.00	\$0.41
21-gauge needles (×3)	\$0.00	\$0.19
18-gauge fill needles (×3)	\$0.00	\$0.22
Electrolyte-A-SOLP	\$10.75	\$0.00
Lactated Ringer's 1000 mL	\$7.17	\$0.00
Sodium chloride 0.9%, 500 mL	\$7.67	\$0.00
Mepivacaine 15 mg/mL (1.5%)	\$1.14	\$0.00
Ropivacaine 5 mg/mL (0.5%)	\$13.20	\$0.00
18-in tourniquet	\$21.43	\$0.00
Sterile sheets for body (×2)	\$4.94	\$0.00
Extremity drape 89 × 128 in	\$10.80	\$0.00
Sterile blue towels (×4)	\$0.00	\$2.28
DVT Garment Standard Calf	\$6.99	\$0.00
Surgeon Protexis sterile gloves	\$3.90	\$3.90
Gown for surgeon and scrub tech	\$6.84	\$0.00
Mask for surgeon	\$0.30	\$0.00
Sterile gloves for scrub tech	\$3.90	\$0.00
Mask for scrub tech	\$0.30	\$0.00
Scrub brush	\$2.18	\$1.09
Betadine bottle	\$0.00	\$3.99
Skin scrub tray	\$10.33	\$0.00
Kirschner wires (2)	\$13.33	\$13.33
4-in cast padding	\$1.75	\$1.75
4 × 4 gauze sterile (×4)	\$0.15	\$0.15
Dermabond	\$18.05	\$0.00
4-in elastic bandage	\$0.50	\$0.50
Plaster	\$6.59	\$6.59
Orthopedic carpal tunnel pack	\$20.70	\$0.00
Drill sterile processing	\$105.00	\$105.00
Certified nurse anesthetist	\$83.00	\$0.00
Registered nurse	\$26.15	\$26.15
Scrub technician	\$20.00	\$0.00
Fluoroscopy technician	\$15.00	\$0.00
Total supply cost	\$288.16	\$153.44
Total labor cost	\$144.15	\$26.15
Total cost	\$432.31	\$179.59

or femoral traction pins, application of external fixation, and even Gardner-Wells tongs for unstable cervical spine fractures. Thus placement of orthopedic implants in the procedure room setting is not a novel idea.

Our study has effectively analyzed hospital charge, malunion rates, and infection rates of percutaneous treatment of metacarpal and phalanx fractures in the OR and the procedure room. This study showed that there was no increase in infection rates for the procedure room compared with the

OR. In 1995, a similar study by Starker and Eaton showed no deep pin tract infections, osteomyelitis, or pyarthrosis in 68 patients with 71 fractures treated in the procedure room.¹⁹ To our knowledge, there are no other studies assessing the infection rate of percutaneous treated hand fractures in a procedure room; however, many other studies of Kirschner wire infection rates have been performed. In a study done by Rafique et al, 10 of 55 exposed pins and 2 of 45 buried Kirschner wires became infected during the treatment of metacarpal and phalangeal fractures.¹⁵ In a second study done by Hargreaves et al, 10 of 50 exposed Kirschner wires and 2 of 49 buried Kirschner wires became infected.⁶ This treatment group included 1 open fracture in each group, and open reduction was used in 9 patients total. A third study of 137 patients with hand/wrist fractures and dislocations showed 10 infections with exposed Kirschner wires.¹ A study by Hsu et al reported a wire infection rate of 6.0% out of 408 pins used for hand and wrist injuries.⁸ Finally, a study by Henry reported a pin infection rate of 7.0% with regard to metacarpal and phalangeal injuries.⁷ Infection rates range from 0% to 34% with most studies falling below 10%. The current study infection rate for procedure room-treated hand fractures (4%) is not significantly different from our OR-treated group (3%), and it is comparable with multiple studies on pin tract infections.^{1,4-8,10,13,15-19}

This study showed no increase in malunion or nonunion rates in the procedure room treatment group versus the OR group. Botte et al reported a nonunion rate of 4% with smooth Kirschner wire fixation for all types of metacarpal and phalangeal fractures.¹ Studies by Botte et al, Henry, and Hsu et al reported nonunion rates of 4%, which again is comparable with the results presented from the procedure room.^{1,7,8}

In addition to an equivalent complication rate, procedure room pinning led to a reduction in overall cost. The hospital charge of taking a patient to the OR cannot be overstated. Our results showed that OR treatment labor and supply costs were \$252.72 more expensive than the procedure room treatment. This increase in cost was attributed to both a \$134.72 increase in supplies costs and \$118.00 increase in nonphysician labor cost. According to the U.S. Department of Health and Human Services, the national physician fee for percutaneous treatment of a metacarpal fracture (CPT code: 26608) and for proximal phalanx (CPT code: 26727) is the same regardless of the surgical setting. Thus, the increase in total patient cost cannot be attributed to the physician fee. Payments were not reported in this study, due to the paucity of payments and variability in received payments as this was performed at a charity hospital.

In a study done by Shippert in 2005, 100 hospitals were surveyed for how much they charge for 1 minute of OR time.¹⁸ The results showed a hospital charge of \$62 (range: \$21.80-\$133.12) per minute for the hospital OR fee and \$4 (range: \$2.20-\$6.10) per minute for the anesthesia fee. Both of these fees are eliminated when treatment is undertaken in the proce-

dure room or clinic. Similarly, Chatterjee et al reported that performing both a single-port endoscopic and open carpal tunnel release in the clinic was both more efficient and less expensive (half the cost for endoscopic and a fourth of the cost for open) than performing the same procedure in the OR.² Other specialties have also started researching hospital charges of the OR; Prickett et al reported a charge comparison of \$2737.17 for office-based procedures versus \$7329.69 for OR-based procedures ($P < .001$) in a rhinology practice.¹⁵ In the current study, there was increased patient cost with OR treatment, as well as increased resources used which are outlined in Table 4. In an era where time and resources are limited, procedure room treatment significantly decreased patient cost.

As this study is a retrospective cohort, selection bias is one weakness of the study. The patients treated in the OR had a delay in fixation of 6.9 days as compared with 0.3 days in the procedure room group. This delay was possibly related to scheduling and may have negatively affected the outcomes in the OR group. To eliminate this bias, it would be helpful to confirm this study with a randomized control trial. Another potential weakness of the study was that 18 patients (8.7%) were lost to follow-up. This group of patients that had minimal to no follow-up reflects one of the many issues with health care in an urban trauma center and patient noncompliance. With a large population of noncompliant patients, it is conceivable that infection rates, malunion rates, and nonunion rates will all be elevated. Although the results do not reflect a statistical increase in malunion or nonunion in our OR treatment arm, there was a trend toward higher malunion in the OR group. This may be due to many of our intra-articular, comminuted, and more complex fracture patterns were more likely taken to the OR for treatment. This may have led to an increase in malunions as more "complex" fractures were more often treated in the OR. Finally, a shortcoming of this study is the relatively smaller sample size of patients taken to the OR and the asymmetric group sizes. Future studies should be performed with larger sample sizes and randomization to groups.

While most of the CRPP occurred in the ER at the time of presentation, this model may not be feasible in every type of practice. Expecting a solo hand practitioner to be available 24 hours a day and 365 days a year is not reasonable. Procedure room CRPP may be beneficial at trauma centers where a procedure room is already available and OR time is sparse. Our techniques described here could be modified to the office setting in which the procedures are performed after the ER physician has referred the patient to the hand clinic. All new consults from the ER could be seen first thing in the morning, or after the regularly scheduled clinic was complete and treatment could be performed in the office procedure room. Ultimately, it is a joint decision between the patient and the treating physician as to what works better for patient care and office efficiency.

In conclusion, metacarpal and phalanx fractures of the hand amenable to CRPP can be treated in the procedure room with no increase in risk of infection, malunion, or nonunion

rates. In addition, these surgeries can be performed in a procedure room with lower cost and less charges to patients than in the OR.

Acknowledgment

The authors thank Clifton Frilot II, PhD, MBA, PE, for evaluating the statistics and providing the power analysis.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and 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 2008. Informed consent was obtained from all patients for the procedures performed in this study. As this was a retrospective case series, informed consent for the study was not required by the institutional review board.

Statement of Informed Consent

The institutional review board (IRB) at our institution has evaluated this project and approved it. No identifiable information about the patients was included, and informed consent was not required under these guidelines per our institution's IRB.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Botte MJ, Davis JL, Rose BA, et al. Complications of smooth pin fixation of fractures and dislocations in the hand and wrist. *Clin Orthop Relat Res*. 1992;(276):194-201. <http://www.ncbi.nlm.nih.gov/pubmed/1537152>. Accessed June 2, 2017.
2. Chatterjee A, McCarthy JE, Montagne SA, et al. A cost, profit, and efficiency analysis of performing carpal tunnel surgery in the operating room versus the clinic setting in the United States. *Ann Plast Surg*. 2011;66(3):245-248. doi:10.1097/SAP.0b013e3181db7784.
3. Chow S, Shao J, Wang H. *Sample Size Calculations in Clinical Research*. 2nd ed. Boca Raton, FL: Chapman & Hall/CRC Biostatistics Series; 2008.
4. Diaz-Garcia RJ, Oda T, Shauver MJ, et al. A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. *J Hand Surg Am*. 2011;36(5):824-835. doi:10.1016/j.jhsa.2011.02.005.
5. Grewal R, Perey B, Wilmlink M, et al. A randomized prospective study on the treatment of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating versus mini open reduction, percutaneous fixation, and external fixation. *J Hand Surg Am*. 2005;30(4):764-772. doi:10.1016/j.jhsa.2005.04.019.
6. Hargreaves DG, Drew SJ, Eckersley R. Kirschner wire pin tract infection rates: a randomized controlled trial between percutaneous and buried wires. *J Hand Surg Am*. 2004;29(4):374-376. doi:10.1016/j.jhsb.2004.03.003.
7. Henry MH. Fractures of the proximal phalanx and metacarpals in the hand: preferred methods of stabilization. *J Am Acad Orthop Surg*. 2008;16(10):586-595.
8. Hsu LP, Schwartz EG, Kalainov DM, et al. Complications of K-wire fixation in procedures involving the hand and wrist. *J Hand Surg Am*. 2011;36(4):610-616. doi:10.1016/j.jhsa.2011.01.023.
9. Kollitz KM, Hammert WC, Vedder NB, et al. Metacarpal fractures: treatment and complications. *Hand*. 2014;9(1):16-23.
10. Lakshmanan P, Dixit V, Reed MR, et al. Infection rate of percutaneous Kirschner wire fixation for distal radius fractures. *J Orthop Surg (Hong Kong)*. 2010;18(1):85-86.
11. LeBlanc MR, Lalonde DH, Thoma A, et al. Is main operating room sterility really necessary in carpal tunnel surgery? A multicenter prospective study of minor procedure room field sterility surgery. *Hand*. 2011;6(1):60-63.
12. Macario A. What does one minute of operating room time cost? *J Clin Anesth*. 2010;22(4):233-236. doi:10.1016/j.jclinane.2010.02.003.
13. McFadyen I, Field J, McCann P, et al. Should unstable extra-articular distal radial fractures be treated with fixed-angle volar-locked plates or percutaneous Kirschner wires? A prospective randomised controlled trial. *Injury*. 2011;42(2):162-166. doi:10.1016/j.injury.2010.07.236.
14. Prickett KK, Wise SK, DelGaudio JM. Cost analysis of office-based and operating room procedures in rhinology. *Int Forum Allergy Rhinol*. 2012;2(3):207-211. doi:10.1002/alr.21020.
15. Rafique A, Ghani S, Sadiq M, et al. Kirschner wire pin tract infection rates between percutaneous and buried wires in treating metacarpal and phalangeal fractures. *J Coll Physicians Surg Pak*. 2006;16(8):518-520. doi:8.2006/JCPSP.518520.
16. Sharma H, Taylor GR, Clarke NMP. A review of K-wire related complications in the emergency management of paediatric upper extremity trauma. *Ann R Coll Surg Engl*. 2007;89(3):252-258. doi:10.1308/003588407X155482.
17. Shippert R. A study of time-dependent operating room fees and how to save \$100,000 by using time-saving products. *Am J Cosmet Surg*. 2005;22(1):25-34.
18. Stahl S, Schwartz O. Complications of K-wire fixation of fractures and dislocations in the hand and wrist. *Arch Orthop Trauma Surg*. 2001;121(9):527-530. doi:10.1007/s004020100279.
19. Starker I, Eaton RG. Kirschner wire placement in the emergency room. Is there a risk? *J Hand Surg Br*. 1995;20(4):535-538. <http://www.ncbi.nlm.nih.gov/pubmed/7595001>. Accessed June 2, 2017.