

Intraoperative Hypothermia During Surgical Fixation of Hip Fractures

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abstract

Hip fractures are common orthopedic injuries and are associated with significant morbidity/mortality. Intraoperative normothermia is recommended by national guidelines to minimize additional morbidity/mortality, but limited evidence exists regarding hypothermia's effect on orthopedic patients. The purpose of this study was to determine the incidence of intraoperative hypothermia in patients with operatively treated hip fractures and evaluate its effect on complications and outcomes. Retrospective chart review was performed on clinical records from 1541 consecutive patients who sustained a hip fracture and underwent operative fixation at the authors' institution between January 2005 and October 2013. A total of 1525 patients were included for analysis, excluding those with injuries requiring additional surgical intervention. Patient demographic data, surgery-specific data, postoperative complications, length of stay, and 30-day readmission were recorded. Patients with a mean intraoperative temperature less than 36°C were identified as hypothermic. Statistical analysis with univariate and multivariate logistic regression modeling evaluated associations with hypothermia and effect on complications/outcomes. The incidence of intraoperative hypothermia in operatively treated hip fractures was 17.0%. Hypothermia was associated with an increase in the rate of deep surgical-site infection (odds ratio, 3.30; 95% confidence interval, 1.19-9.14; $P=.022$). Lower body mass index and increasing age demonstrated increased association with hypothermia ($P=.004$ and $P=.005$, respectively). To the authors' knowledge, this is the first and largest study analyzing the effect of intraoperative hypothermia in orthopedic patients. In patients with hip fractures, the study's findings confirm evidence found in other surgical specialties that hypothermia may be associated with an increased risk of deep surgical-site infection and that lower body mass index and increasing age are risk factors for intraoperative hypothermia. [*Orthopedics*. 201x; xx(x):exx-exx.]

Hip fractures are common orthopedic injuries, and the incidence is projected to increase substantially in the near future.^{1,2} Not only are hip fractures common, they are also associated with poor prognosis and 1-year mortality rates ranging from 20% to 30%.^{3,4} Beyond mortality, survival after hip fracture significantly decreases patient independence and quality of life and increases the burden on the health care system.^{5,6}

There has been an enhanced focus on reducing surgical complications, demonstrated by guidelines published by the World Health Organization (WHO), the Agency for Healthcare Research and Quality (AHRQ), and the Surgical Care Improvement Project (SCIP).⁷⁻⁹ Poor

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clinical outcomes and significant financial burden associated with potentially avoidable complications have been the drivers of these measures.¹⁰⁻¹² Patients who sustain hip fractures have significant morbidity and mortality prior to considering other perioperative complications. For this reason, hip fractures have been the focus of adherence to guidelines aimed at reducing complications. All of the aforementioned guidelines recommend maintenance of normothermia (defined as body temperature greater than 36°C) in the immediate perioperative period.⁷⁻⁹

Whereas most recommendations in these guidelines are supported by an abundance of evidence, the rationale for the recommendation of normothermia is based on evidence outside the field of orthopedics and has been generally applied to all surgical patients.¹³ Evidence indicates that perioperative hypothermia may (1) impair wound healing and increase the risk of surgical-site infection, (2) increase intraoperative blood loss and need for transfusion, and (3) increase cardiovascular morbidity.¹⁴⁻²⁶ Interestingly, the effect perioperative normothermia plays in outcomes associated with orthopedic surgical procedures, and specifically hip fractures, has limited overall evidence.^{27,28} The purpose of the current study was to determine the incidence of mean intraoperative hypothermia during surgical fixation of hip fractures at the authors' institution and to evaluate the effect of hypothermia on complications and outcomes in the immediate postoperative period.

MATERIALS AND METHODS

Under institutional review board approval, a retrospective chart review was performed on records from 1541 consecutive patients who underwent operative treatment of a hip fracture at the authors' institution between January 2005 and October 2013. In the initial query, patients who had less than 6 weeks of follow-up, death within 6 weeks of presentation, or incomplete perioperative data were ex-

cluded. Data were collected from 2 academically affiliated hospitals, one a large, urban tertiary care center and the other a suburban community hospital in a large metropolitan area. After excluding patients who had multiple injuries requiring additional surgical intervention, a total of 1525 patients were included in the analysis. A total of 974 (63.8%) patients had an intertrochanteric (IT) fracture and 551 (36.2%) patients had a femoral neck (FN) fracture.

Three independent reviewers (A.M.P., T.R.J., J.S.) collected data and performed extensive chart reviews of the included patients. The following data were recorded: patient demographic data, including age, sex, race, diagnosis, and surgical procedure and side; basic clinical data, including preoperative hemoglobin, medical comorbidities, and American Society of Anesthesiologists (ASA) classification; and surgery-specific data, including operative time, use of intraoperative active rewarming device, perioperative temperature measurements, estimated intraoperative blood loss (EBL), intraoperative intravenous fluid (IVF) administration, length of hospital stay (LOS), requirement for postoperative transfusion, and 30-day readmission rates. Temperature measurements were obtained from the anesthesia record. Prior to November 2012, anesthesia records were hand recorded and uploaded to patients' electronic medical record. After November 2012, the authors' institution transitioned to an electronic record that included electronic anesthesia records. Hypothermic patients were defined as those who demonstrated a mean intraoperative temperature less than 36°C.

Postoperative complications recorded included superficial (SSSI) and deep surgical-site infection (DSSI), nonsurgical-site infection (NSSI), symptomatic deep venous thrombosis (DVT), pulmonary embolism (PE), myocardial infarction (MI), and stroke. Superficial infection was defined as infection superficial to the fascia. Patients were identified as

having DSSI if the infection was deep to the fascia and if they required reoperation including deep irrigation and debridement and/or removal of components for infection. Nonsurgical-site infection was defined as systemic infection anatomically distant to the surgical site requiring antibiotic treatment. Patients wore intermittent pneumatic compression devices during their hospital stay and received chemical VTE prophylaxis postoperatively. All patients received a dose of prophylactic antibiotics 60 minutes prior to surgical incision, and dosing continued 24 hours postoperatively.

Hip fractures at the authors' institution are treated according to the following basic algorithm. Stable IT fractures (Orthopedic Trauma Association [OTA] classification 31-A1) are treated with a sliding hip screw, and unstable IT fractures (OTA 31-A2 or 31-A3) are treated with a cephalomedullary nail. Nondisplaced, valgus-impacted FN fractures (OTA 31-B1) are treated with closed reduction and percutaneous pinning, whereas displaced FN fractures (OTA 31-B2 and B3) are treated with hip hemiarthroplasty. In relatively young patients with active lifestyles, total hip arthroplasty (THA) is considered for displaced FN fractures.

The authors' institution uses warmed-air convection active rewarmers (Bair Hugger; 3M, St Paul, Minnesota) for intraoperative temperature management. The use of active rewarming during operative cases is determined by the anesthesiologist using the following algorithm: patients undergoing general anesthesia have an active rewarming device used, whereas those patients with regional anesthesia only get active rewarming if intraoperative hypothermia is documented or if the operative time is expected to be greater than 60 minutes. Pre- and postoperative temperature measurements are taken via skin probe thermometers (LCD Sensostrip; DeRoyal, Powell, Tennessee) by the nursing staff. Intraoperative temperature measurements are taken at the discre-

tion of the anesthesiologist/certified registered nurse anesthetist and are measured either by skin probe, axillary temperature reading, or an esophageal temperature sensor (Covidien, Boulder, Colorado).

Statistical analysis was performed on a cohort including all hip fractures (IT and FN fractures) as either mean intraoperative normothermia or mean intraoperative hypothermia (<36°C). All continuous data are described as mean±SD, and categorical data are described as count and column percentage. Univariate tests were performed using independent 2-group *t* test and chi-square test. A multivariable logistic regression model was built using clinically relevant variables to identify possible independent predictors of hypothermia. Statistical significance was set at a *P* value less than .05, and all analyses were performed using SAS version 9.4 software (SAS Institute Inc, Cary, North Carolina).

RESULTS

A total of 1525 patients with hip fractures were analyzed (63.8% IT fractures, 36.2% FN fractures). Of those patients sustaining FN fractures, 398 (72.2%) were treated with hemiarthroplasty, 85 (15.4%) with closed reduction and percutaneous pinning (CRPP), 50 (9.1%) with sliding hip screw (SHS), 13 (2.4%) with cephalomedullary nailing (CMN), 4 (0.7%) with THA, and 1 with a Girdlestone femoral head resection arthroplasty procedure. For IT fractures, 802 (82.3%) were treated with CMN, 162 (16.6%) with SHS, and 10 (1.0%) with recon intramedullary nailing (IMN). Overall incidence of intraoperative hypothermia was 17.0% in patients who had surgical treatment of a hip fracture.

Demographic data revealed that hypothermic patients were on average older than normothermic patients (*P*=.005). In addition, lower body mass index (BMI) demonstrated a significant association with intraoperative hypothermia (*P*=.004) (Table 1). Sex, race, surgical side, and

Table 1

Demographic and Comorbidity Data for Hip Fracture Patients				
Characteristic	All Patients (N=1525)	Normothermic Patients (n=1265)	Hypothermic Patients (n=260)	<i>P</i>
Age, mean±SD, y	77.6±14.2 (n=1522)	77.2±14.6 (n=1263)	79.6±11.9 (n=259)	.005 ^a
Sex				
Male	36% (n=549)	37% (n=463)	33% (n=86)	.296
Female	64% (n=974)	63% (n=801)	67% (n=173)	
Side				
Right	49% (n=746)	48% (n=605)	55% (n=142)	.111
Left	51% (n=777)	52% (n=660)	45% (n=118)	
Race				
White	58% (n=884)	58% (n=733)	58% (n=151)	.758
Black	32% (n=488)	32% (n=402)	33% (n=86)	
Other	10% (n=153)	10% (n=130)	9% (n=23)	
BMI, mean±SD, kg/m ²	24.1±6.1 (n=1370)	24.3±6.2 (n=1135)	23.2±5.3 (n=235)	.004 ^a
Tobacco use				
Nonsmoker	70% (n=1066)	70% (n=887)	69% (n=179)	.068
Smoker	27% (n=410)	27% (n=342)	26% (n=68)	
Former smoker	0% (n=1)	0% (n=0)	0% (n=1)	
Unknown	3% (n=48)	3% (n=36)	5% (n=12)	
CAD, No.				
No	1153 (76%)	945 (75%)	208 (82%)	.016 ^a
Yes	364 (24%)	318 (25%)	46 (18%)	
Arrhythmia, No.				
No	1166 (77%)	953 (75%)	213 (84%)	.004 ^a
Yes	352 (23%)	311 (25%)	41 (16%)	
Hypertension, No.				
No	402 (26%)	338 (27%)	64 (25%)	.606
Yes	1115 (74%)	925 (73%)	190 (75%)	
DM, No.				
No	1176 (78%)	978 (77%)	198 (78%)	.857
Yes	341 (22%)	285 (23%)	56 (22%)	
CKD, No.				
No	1189 (78%)	993 (79%)	196 (77%)	.519
Yes	328 (22%)	269 (21%)	59 (23%)	

Abbreviations: BMI, body mass index; CAD, coronary artery disease; CKD, chronic kidney disease; DM, diabetes mellitus.
^a*P*<.05 is statistically significant.

tobacco use demonstrated no association with mean intraoperative hypothermia. Analysis of comorbid conditions and their

effect on hypothermia in these hip fracture patients revealed that both coronary artery disease (CAD) and arrhythmia were sig-

Table 2

Perioperative Data and Association With Hypothermia

Characteristic	All Patients (N=1525)	Normothermic Patients (n=1265)	Hypothermic Patients (n=260)	P ^a
Preoperative hemoglobin, mean±SD, g/dL	11.4±1.9 (n=1505)	11.4±1.9 (n=1251)	11.4±2.0 (n=254)	.621
ASA classification				
1	1% (n=17)	1% (n=16)	0% (n=1)	
2	12% (n=176)	11% (n=142)	14% (n=34)	
3	66% (n=984)	65% (n=814)	69% (n=170)	.299
4	21% (n=309)	22% (n=269)	16% (n=40)	
5	0% (n=4)	0% (n=3)	0% (n=1)	
Rewarmer used				
No	27% (n=405)	26% (n=330)	30% (n=75)	.220
Yes	73% (n=1109)	74% (n=933)	70% (n=176)	
Operative time, mean±SD, min	153.4±46.3 (n=1520)	154.3±46.6 (n=1263)	149.4±44.5 (n=257)	.122
EBL, mean±SD, mL	203.9±175.7 (n=1511)	207.2±176.8 (n=1262)	187.1±169.2 (n=249)	.099
IVF, mean±SD, mL	1422.9±801.9 (n=1498)	1425.7±797.9 (n=1252)	1408.6±823.3 (n=246)	.761

Abbreviations: ASA, American Society of Anesthesiologists; EBL, estimated blood loss; IVF, intravenous fluid administration.

^aP<.05 is statistically significant.

nificantly less common in the hypothermia group (CAD, $P=.016$; arrhythmia, $P=.004$; **Table 1**). Analysis of perioperative data demonstrated no significant associations between preoperative hemoglobin, ASA classification, operative time, EBL, or IVF administration (**Table 2**).

Univariate analysis of postoperative complications revealed no significant associations with hypothermia or complications, including infection, transfusion requirement, cardiovascular or thromboembolic complication, LOS, or 30-day readmission. Overall, the infection rate was 1.2% for DSSI, 1.5% for SSSI, and 4.6% for NSSI (**Table 3**). A multivariate logistic regression analysis was performed to adjust for risk factors for infection and control for the other variables in the model (**Table 4**). Results revealed the adjusted odds ratio for DSSI associated with hypothermia was 3.30 (95% confidence

interval, 1.19-9.14; $P=.022$). In addition, the presence of arrhythmia revealed an adjusted odds ratio of 0.60 (95% confidence interval, 0.41-0.87; $P=.007$).

DISCUSSION

Current guidelines recommend perioperative normothermia as a goal of perioperative patient care, designed to decrease avoidable complications associated with surgery.⁷⁻⁹ Most studies evaluating the success of these guidelines at decreasing surgical-site infection looked at bundled measure adherence's effect, and little is known about the individual influence of each guideline measure.²⁹ There is a paucity of evidence regarding the effect of intraoperative hypothermia on orthopedic patients. To the current authors' knowledge, this is the largest series evaluating the effect of intraoperative hypothermia on complications and outcomes in pa-

tients undergoing operative fixation of a hip fracture.

Three landmark studies are commonly cited as the evidence supporting the recommendation for perioperative normothermia.^{14,15,26} Although each of these studies was well designed, there are some inherent flaws, and their findings have generally been applied to orthopedic patients. These studies occurred prior to the current guidelines for perioperative antimicrobial prophylaxis. In the study by Kurz et al,¹⁵ antibiotics were administered in all patients at the time of induction and continued for 4 days postoperatively. The study by Melling et al¹⁴ noted prophylactic antibiotic use in 26% to 34%, and the timing/duration was not provided. The results of these studies are confounded by these inconsistencies in prophylactic antimicrobial use. In fact, Melling et al¹⁴ goes on to state that the use of rewarming techniques "may provide an alternative to prophylactic antibiotics." This statement reveals the dated nature of these studies and underscores the necessity of further orthopedic research on this subject. In addition, there are inherent differences in the surgical care of orthopedic patients compared with those studied in the aforementioned series. Each of these patient populations and surgical procedures is different and demonstrates differential rates of surgical-site infection. Again, orthopedic (and specifically hip fracture) patients have unique physiologies, comorbid health profiles, and care-specific considerations.

In the current study, more than 90% of patients received appropriate perioperative prophylactic antibiotics, and the multivariate logistic regression model revealed a significant association between hypothermia and DSSI. To the authors' knowledge, these are the first data specific to orthopedic patients demonstrating an association between perioperative hypothermia and surgical-site infection. The DSSI rate has been reported to range from 0.7% to 1.6% in patients who undergo operative treatment of a hip fracture.³⁰⁻³²

The observed rates of DSSI in the current study correlate with these previously published findings. Deep surgical-site infection can be a catastrophic complication in orthopedic surgery, often requiring reoperation, which significantly affects patient morbidity, mortality, quality of life, and patient- and health care-associated costs.

The current study found an overall mean rate of intraoperative hypothermia in operatively treated hip fractures of 17.0%. The incidence of perioperative hypothermia in orthopedic procedures has been reported to remain high, despite use of active rewarming devices. Leijten et al³³ recently found that up to 28% of patients undergoing total knee arthroplasty and THA experienced perioperative hypothermia despite active rewarming. The current study's findings demonstrate an incidence of hypothermia lower than that reported by Leijten et al,³³ possibly due to the nature of operative fixation of hip fractures. On average, operative fixation of hip fractures typically has a shorter operative time and less surgical exposure compared with total joint arthroplasty procedures. The current authors observed that of those patients who had an active warmer, 15.8% experienced hypothermia. Anesthesia at the authors' institution adheres to an algorithm where all patients undergoing general anesthesia have an active rewarming device used, whereas those patient with regional anesthesia only receive active rewarming if intraoperative hypothermia is documented or if the operative time is expected to be greater than 60 minutes. It is possible that the sustained increased rate of hypothermia with active warmer use is the result of those devices being applied in response to intraoperative hypothermia rather than as a preventative measure.

Erdling et al³⁴ demonstrated the effect of BMI on hypothermia via different intraoperative temperature measurement techniques, but little is present in the orthopedic literature regarding BMI and intraoperative hypothermia. The current authors also identified a significant as-

Table 3

Univariate Analysis of Complications Associated With Hypothermia				
Complication	All Patients (N=1525)	Normothermic Patients (n=1265)	Hypothermic Patients (n=260)	P
DSSI				
No	99% (n=1501)	99% (n=1251)	98% (n=250)	.084
Yes	1% (n=19)	1% (n=13)	2% (n=6)	
SSSI				
No	98% (n=1497)	99% (n=1248)	97% (n=249)	.079
Yes	2% (n=23)	1% (n=16)	3% (n=7)	
NSSI				
No	95% (n=1450)	95% (n=1203)	96% (n=247)	.549
Yes	5% (n=70)	5% (n=60)	4% (n=10)	
Transfusion, mean±SD, units PRBC	1.6±1.7 (n=1525)	1.6±1.8 (n=1265)	1.4±1.6 (n=260)	.101
MI				
No	94% (n=1427)	93% (n=1179)	96% (n=248)	.099
Yes	6% (n=93)	7% (n=83)	4% (n=10)	
Stroke				
No	97% (n=1468)	97% (n=1221)	96% (n=247)	.827
Yes	3% (n=50)	3% (n=41)	4% (n=9)	
DVT				
No	96% (n=1461)	96% (n=1212)	97% (n=249)	.321
Yes	4% (n=58)	4% (n=51)	3% (n=7)	
PE				
No	97% (n=1475)	97% (n=1223)	98% (n=252)	.148
Yes	3% (n=45)	3% (n=41)	2% (n=4)	
LOS, mean±SD, d	7.5±6.9 (n=1525)	7.6±6.9 (n=1265)	7.1±6.6 (n=260)	.317
30-day readmission				
No	82% (n=1248)	82% (n=1031)	83% (n=217)	.455
Yes	18% (n=277)	18% (n=234)	17% (n=43)	

Abbreviations: DSSI, deep surgical-site infection; DVT, deep venous thrombosis; LOS, length of stay; MI, myocardial infarction; NSSI, nonsurgical-site infection; PE, pulmonary embolism; PRBC, packed red blood cells; SSSI, superficial surgical-site infection.

sociation between lower BMI and mean intraoperative hypothermia. Both general and regional anesthesia profoundly affect the body's thermoregulatory control.^{35,36} The current study's results suggest that patients with a lower BMI may have further impairment of their thermoregulation, with less physiologic tolerance to

alteration of thermoregulatory control, potentially affecting their likelihood of experiencing intraoperative hypothermia. Also observed in the univariate analysis of comorbid conditions was that patients with CAD and arrhythmia had a lower incidence of hypothermia. This was also true in the multivariate logistic regression

Table 4

Multivariable Logistic Regression Analysis of Complications With Hypothermia

Characteristic	Adjusted OR (95% CI)	P
DSSI		
Yes vs no	3.30 (1.19-9.14)	.022 ^a
Smoking		
Smoker vs nonsmoker	0.96 (0.70-1.32)	.881
Unknown vs nonsmoker	0.80 (0.30-2.09)	
Hypertension		
Yes vs no	1.15 (0.82-1.62)	.416
Diabetes mellitus		
Yes vs no	0.87 (0.61-1.22)	.411
Chronic kidney disease		
Yes vs no	1.23 (0.87-1.74)	.235
Arrhythmia		
Yes vs no	0.60 (0.41-0.87)	.007 ^a
ASA classification		
1 vs 2	3.46 (0.44-27.28)	
1 vs 3	3.10 (0.40-24.01)	
1 vs 4	2.30 (0.29-18.32)	.481
1 vs 5	6.35 (0.30-136.46)	
Operative time, min	1.00 (0.99-1.00)	.077
Transfusion		
Yes vs no	0.90 (0.67-1.19)	.455

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; DSSI, deep surgical-site infection; OR, odds ratio.

^aP<.05 is statistically significant.

intraoperative temperature. Most patients receiving spinal anesthesia are not intubated, so esophageal and endotracheal probe measurements are not feasible. In addition, if their urinary catheter does not have a temperature probe, this would require exchange just prior to surgery, which is costly and potentially increases the risk of urinary tract infection. Also, neuraxial anesthesia requires patients to be exposed for a period of time while the anesthesia team administers the anesthetic. During this time, invasive core temperature measurement is not feasible, and temperature monitoring must be performed by less accurate methods. For those patients undergoing general anesthesia, invasive core temperature monitoring can only be done while the patient is anesthetized and cannot capture significant portions of time before intubation, leading up to extubation, and directly after extubation. The current authors acknowledge this limitation but contend that their results are generalizable because many hospitals are experiencing the same issues. Because limited evidence is available in the orthopedic literature, there is no distinct method for temperature monitoring in these patients. Perhaps a hybrid method of temperature monitoring is required, and further prospective study in this regard is required.

There are other limitations to this study. The retrospective nature is an inherent limitation. The minimum follow-up of 6 weeks could potentially exclude late complications if patients presented to another health care system. The authors acknowledge that any complication not returning to their health care system was not recognized; however, their results were consistent with the existing literature, and most surgical-site infections occur within 30 days of operative intervention.³⁷ In the setting of implanted hardware, risk of DSSI can extend to 1 year or greater postoperatively, and for this reason, study with long-term follow-up is needed.³⁷ The ambient temperature in the operating rooms at the authors' in-

model for arrhythmia, but not for CAD. The authors are unaware of this finding being described elsewhere in the literature. One possible explanation for this is that patients with known cardiac comorbidities are more carefully monitored for hypothermia and perhaps preferentially receive enhanced pre- and intraoperative management by the anesthesia team. Further study with larger patient populations is required to further evaluate this finding.

A limitation of this study is the methodology of measuring perioperative temperature at the authors' institution. There is no standard protocol for measuring intraoperative temperature, and different methods are used based on multiple

patient and anesthesia factors. Pre- and postoperatively, temperature is measured using skin surface probes. Intraoperatively, many factors contribute to temperature measurements. First, many patients who present with an operative hip fracture have a urinary catheter (without temperature probe, for cost reasons) placed upon admission to prevent patient discomfort and avoid fracture displacement. It is well documented that core body temperature measurements are accurate and reproducible (by urinary catheter probe, esophageal/endotracheal probe, or with tympanic membrane measurement).³⁵ For patients who have neuraxial anesthesia, there are multiple issues with measuring accurate

stitution is not standardized, which could also represent a potential confounder. Multiple studies have evaluated intraoperative hypothermia, but each has measured patient temperature by different, unstandardized methods.^{13-15,17,26,33,38,39} To accurately study intraoperative hypothermia in orthopedic patients, standardized temperature monitoring protocols in prospective trials with long-term follow-up are needed.

CONCLUSION

The incidence of intraoperative hypothermia in operatively treated hip fractures was 17.0% in this study. Mean intraoperative hypothermia was significantly associated with DSSI. Increasing age and lower BMI increased the risk for intraoperative hypothermia. To the authors' knowledge, this is the first and largest study that specifically analyzes the effect of intraoperative hypothermia in patients undergoing operative treatment of hip fractures.

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