Original Article

What is the incidence of inadvertent hypothermia in elderly hip fracture patients and is this associated with increased readmissions and mortality?

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ABSTRACT

Background: Globally the incidence of fragility hip fractures is rising with increasingly elderly and co-morbid patients. These injuries are associated with a high morbidity and mortality.

Aims: This clinical study's primary outcome is to establish the rate of operative inadvertent hypothermia ($< 36^{\circ}\text{C}$) in elderly hip fracture patients (> 65 years old). We also aimed to identify risk factors and outcomes in patients with inadvertent hypothermia.

Patients and Methods: A single centre, retrospective study of 929 hip fracture patients managed operatively between June 2015 and July 2017 was conducted. Patients' demographic, anaesthetic and surgical variables were analysed together with outcomes for length of stay (LoS), 30-day re-admissions, and 30-day mortality.

Results: Overall rates of inadvertent hypothermia in elderly hip fracture patients undergoing surgery were 10%, with increasing age ($p = 0.006$) and pre-operative hypothermia ($p < 0.0001$) as risk factors. Patient's hypothermic pre-operatively compared with normothermic patients were 1.9 times more likely to be $< 36^{\circ}\text{C}$ on leaving theatre. There was a trend towards a higher 30-day mortality ($\chi^2(1) = 2.818$, $p = 0.093$), and a significantly higher mortality in patients undergoing SHS ($p = 0.03$). No survival differences for LoS were observed between hypothermic and $\geq 36^{\circ}\text{C}$ patients ($\chi^2(1) = 0.069$, $p = 0.79$). 30-day re-admissions were higher in hypothermic patients ($\chi^2(1) = 16.301$, $p < 0.0001$).

Conclusion: Rates of inadvertent hypothermia are high in operatively managed hip fracture patients and are significantly associated with a higher 30-day readmission rate with a trend towards higher 30-day mortality.

1. Introduction

Around 65,000 hip fractures occur annually in the UK, with a reported incidence between 349 per 100,000 for females and 140 per 100,000 for males.¹ According to epidemiologic predictions and as a result of an aging population, the incidence of hip fractures is projected to increase to 6.26 million globally by the year 2050.² Currently, the majority are managed operatively but often with a poor prognosis; in the United Kingdom the average 30-day mortality rate for all hip fractures is 6.7% and the one year mortality is up to 30%.^{3,4} Despite recent improvements in reducing mortality, these patients remain high risk with significant opportunities existing to improve their care.

The World Health Organisation (guidelines for safe surgery) and the National Institute for Health and Care Excellence (NICE Guidelines - CG65) offer recommendations for maintaining perioperative normothermia (defined as a core body temperature $> 36^{\circ}\text{C}$), to minimise morbidity and mortality.^{5,6} Despite this, Gurunathan et al, observed up to one third of hip fracture patients experience inadvertent

hypothermia on entering the recovery ward. In addition, they report an average 0.7°C drop in patient's core body temperature during hip fracture surgery.⁷ As a consequence of inadvertent hypothermia, patients may experience unpleasant shivering post-operatively.^{8,9} Furthermore, in non-orthopaedic cohorts, perioperative inadvertent hypothermia is associated with significant complications such as surgical site infection, raised mortality together with an increased need for blood transfusion and assisted ventilation.^{10,11} Inadvertent hypothermia also has subsequent cost implications, with longer reported ITU stays and overall length of stay (LoS).^{9,12,13} Orthopaedic surgeons have extrapolated these findings and aim to maintain patient normothermia by warming fluids and using patient warming devices. However, little evidence delineates the risk factors and outcomes associated with hypothermia in hip fracture patients. The null hypothesis that hypothermia is associated with no difference in post-operative complications, in hip fracture patients, requires further examination.

We hypothesise that elderly hip fracture patients experiencing operative hypothermia have poorer outcomes. This study aims to

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Fig. 1. Flowchart of patients who underwent surgery for hip fracture included in the study.

determine the rates and risk factors for developing hypothermia and the outcomes of hypothermia including mortality (which has not been previously published).

2. Methods and patients

We conducted a single centre, retrospective study of 1052 consecutive hip fracture operations (1052 patients) from June 2015 to July 2017. Patients under 65 years old and those with missing temperature data were excluded from analysis ($n = 123$), giving 929 operations for analysis, (Fig. 1).

Surgeries were performed per standard practice using the following treatment algorithm: Intracapsular fractures (Arbeitsgemeinschaft für Osteosynthesefragen (AO) 31-B2 and B3) underwent either Exeter total hip replacement (THA) or hemiarthroplasty with cement (Exeter bipolar or Thompson hemiarthroplasty). Patient selection for THA was at the operating surgeon's discretion. Surgeons in our institute tend to employ a two-hole SHS for intracapsular fractures selected for fixation. 1 patient had 3 cannulated screws for an undisplaced intracapsular fracture, however they were subsequently excluded based on age criteria.

Extracapsular fractures were fixed depending on fracture characteristics, with either a sliding hip screw (SHS) (typically for AO 31-A1 and A2) or intramedullary (IM) nail (typically for AO 31-A3).¹⁴ Fractures with a subtrochanteric extension were managed with IM nails and included in the analysis. No change to warming protocols or change in device supplier or manufacturer occurred during the study period. Our hip fracture patients are not routinely followed up, apart from THA

patients who are seen at 6 weeks and 1 year.

The primary outcome measure was presence of hypothermia, defined as core temperature $< 36^{\circ}\text{C}$, measured upon entering recovery after surgery was concluded. Tympanic membrane/auxiliary temperature was used as it is readily obtained, reflects current practice and has been validated to reflect core temperature.¹⁵

An enquiry of theatre records obtained demographic data to include: age, gender, American Society of Anaesthesiology (ASA) grade, and ethnicity. Anaesthetic and surgical data collected included: surgical procedure and side, anaesthetic type, theatre location (all within same building), operative time, time in theatre, and presence of active re-warming devices (blanket, forced air blanket, fluid warmer, and/or heated mattress).

Secondary outcome measures included 30-day mortality, LoS, 30-day readmissions, and subsequent diagnosis (chest infection, wound complication, deep vein thrombosis (DVT), pulmonary embolism (PE), prosthesis complication, joint pain, and complications unrelated to surgery). All patients received a dose of prophylactic antibiotic at induction prior to incision and all were prescribed chemical thromboprophylaxis whilst inpatients.

2.1. Statistical analysis

Statistical analysis was performed on two cohorts: hypothermia patients and $\geq 36^{\circ}\text{C}$ patients. Nominal and ordinal data are described as case numbers and percentages with comparison using chi-squared analysis. Continuous data is presented as mean and range with comparison using t-test. A binary logistic regression was performed to

Table 1Demographics, characteristics and anaesthetic variables of patients undergoing **hip fracture surgery** in the inadvertent hypothermic and normothermic groups.

	All	< 36 °C	> 36 °C	P value
Number of Patients (%)	929	92 (9.9)	837 (90.1)	
Mean Age $\pm$ SD (range)	84.9 yrs $\pm$ 7.8 (65.0 – 103.5)	87.1 yrs $\pm$ 7.8 (68.6 – 98.5)	84.7 yrs $\pm$ 7.8 (65.0 – 103.5)	0.006
Operation (%)				0.2
SHS	233 (25.1)	30 (32.6)	203 (24.3)	
IM nail	108 (11.6)	11 (12.0)	97 (11.6)	
Hemi	507 (54.6)	47 (51.1)	460 (55.0)	
THA	81 (8.7)	4 (4.3)	77 (9.2)	
Gender (%)				0.78
Male	271 (29.2)	28 (30.4)	243 (29.0)	
Female	658 (70.8)	64 (69.6)	594 (71.0)	
Laterality (%)				0.30
Left	475 (51.9)	43 (46.7)	432 (52.5)	
Right	440 (48.1)	49 (53.3)	391 (47.5)	
Mean ASA grade $\pm$ SD	2.70 $\pm$ 0.65	2.76 $\pm$ 0.60	2.69 $\pm$ 0.66	0.34
Ethnicity (%)				0.60
White (British/Irish)	893 (96.6)	91 (98.9)	802 (96.4)	
Other White Background	18 (1.9)	1 (1.1)	17 (2.0)	
Unable ^a	11 (1.2)	0	11 (1.3)	
Other	2 (0.2)	0	2 (0.2)	
Theatre (%)				0.12
Th1	107 (11.5)	9 (9.8)	98 (11.7)	
Th2	325 (35.0)	23 (25.0)	302 (36.1)	
Th3	40 (4.3)	5 (5.4)	35 (4.2)	
Th4	457 (49.2)	55 (59.8)	402 (48.0)	
Anaesthesia type (%)				0.87
Regional block	532 (57.3)	55 (59.8)	477 (57.0)	
General	346 (37.2)	32 (34.8)	314 (37.5)	
LA + Sedation	51 (5.5)	5 (5.4)	46 (5.5)	
Pre-Operative Temperature				< 0.001
Hypothermic	182 (19.6)	83 (90.2)	99 (11.8)	
Normothermic	699 (75.2)	8 (8.7)	691 (82.6)	
Hyperthermic	48 (5.2)	1 (1.1)	47 (5.6)	
Operative time $\pm$ SD (range)	69.0 $\pm$ 29.3 (16 – 300)	64.6 $\pm$ 30.0 (16 – 210)	69.5 $\pm$ 29.2 (18 – 300)	0.13
Time in theatre $\pm$ SD (range)	107.1 $\pm$ 33.4 (40 – 329)	104.5 $\pm$ 34.9 (46 – 233)	107.4 $\pm$ 33.2 (40 – 329)	0.43
Warming Device (%)				0.49
Blanket				
Yes	43 (8.4)	5 (11.1)	38 (8.1)	
No	469 (91.6)	40 (88.9)	429 (91.9)	
Fluid Warmer				0.94
Yes	310 (60.5)	27 (60)	283 (60.6)	
No	202 (39.5)	18 (40)	184 (39.4)	
FAWB				0.61
Yes	501 (97.9)	45 (100)	456 (97.6)	
No	11 (2.1)	0	11 (2.4)	
Heated Mattress				1.0
Yes	2(0.4)	0 (0)	2 (0.4)	
No	510 (99.6)	2 (100)	465 (99.6)	

SHS, sliding hip screw; IM nail, intramedullary nail; Hemi, Hemiarthroplasty; THA, total hip replacement, FAWB – Forced air warming blanket.

^a Patient too unwell to ask/declined.

ascertain the effects of age, theatre, ASA, anaesthetic type, operative type, pre-operative temperature, operative time and time in theatre on the likelihood that participants have inadvertent hypothermia. Comparing LoS was performed with a Kaplan Meire survival analysis. Further sub-group analysis by operative type was performed for primary and secondary outcome measures. Statistical significance is set at the 95% confidence interval. SPSS (IBM Corp. in Armonk, NY) was used for analysis.

3. Results

In total 929 patients with an average age of 84.9 years $\pm$ 7.8

(65.0–103.5) and 3:7 male:female ratio were analysed. A total of 25.1% underwent SHS (n = 233), 11.6% IM nail (n = 108), 54.6% hemiarthroplasty (n = 507) and 8.7% THA (n = 81). (Table 1)

3.1. Primary outcome

The overall rate of hypothermia was nearly 10% (n = 92), with the highest rates seen in SHS and IM nail patients (12.9% and 10.1% respectively). The hypothermia group were significantly older (87.1yrs $\pm$ 7.8) than those in the ≥ 36 °C group (84.7 yrs $\pm$ 7.8), t (929) = –2.764, p = 0.006. 57.3% (n = 532) of patients underwent regional blocks and 37.2% (n = 346) received general anaesthesia. A

significant association was found between pre-operative temperature and presence of hypothermia on entering recovery, $\chi^2(2) = 324.0$, $p < 0.001$. Single variant analysis demonstrated no significant differences between hypothermia and $\geq 36^\circ\text{C}$ groups for gender ($p = 0.78$), laterality ($p = 0.3$), ethnicity ($p = 0.6$), and ASA grade ($p = 0.34$), anaesthesia type ($p = 0.87$), operative group ($p = 0.2$), theatre used ($p = 0.12$) or warming devices used (Table 1). Both operative time and time in theatre were comparable between groups ($p = 0.13$ and 0.43 respectively).

The logistic regression model was statistically significant, $\chi^2(14) = 327.107.162$, $p < 0.001$. The model explained 51.3% (Nagelkerke R2) of the variance in inadvertent hypothermia and correctly identified 90.0% of cases. Patients who were hypothermic pre-op were 40.54 and 1.9 times more likely to be < 36 on entering recovery than hyperthermic and normothermic patients pre-operatively, respectively.

3.2. Secondary outcomes

A trend towards a higher 30-day mortality rate was seen in hypothermia patients, with ten (10.9%) hypothermia patient deaths versus 52 (6.2%) $\geq 36^\circ\text{C}$ patient deaths ($\chi^2(1) = 2.818$, $p = 0.093$). Sub-group analysis of SHS patients with hypothermia demonstrated significantly higher 30-day mortality rates ($p = 0.03$). A similar pattern was seen for IM nail patients but was not statistically significant ($p = 0.19$). No THA patients died within 30-days, likely reflecting patient selection (Table 2). Considering SHS patients, the hypothermia group had a significantly lower mean ASA grade of 2.40 ± 0.6 compared with 2.68 ± 0.8 in $\geq 36^\circ\text{C}$ patients ($p = 0.049$). No differences in ASA grade was observed in patients receiving an IM nail ($p = 0.96$). Comparable mean LoS was observed for hypothermia and $\geq 36^\circ\text{C}$ patients 8.9 ± 7.1 versus 8.6 ± 4.9 . A log rank test was run to determine if there were differences in the survival distribution regarding length of stay for hypothermic and $\geq 36^\circ\text{C}$ patients. The survival distributions for the 2 groups were not statistically significantly different, $\chi^2(1) = 0.02$, $p = 0.88$. (Chart).

In total 3.0% ($n = 28$) of patients were readmitted within 30 days, with a rate of 9.8% ($n = 9$) for hypothermia patients versus 2.3% ($n = 19$) in $\geq 36^\circ\text{C}$ patients ($\chi^2(1) = 16.301$, $p < 0.0001$). Hemiarthroplasty patients in the hypothermia group were significantly more likely to be re-admitted than their $\geq 36^\circ\text{C}$ counterparts ($p < 0.01$). A trend towards higher readmission in SHS patients in the hypothermia group was seen ($p = 0.069$). Analysis of re-admission cause revealed higher re-admissions as a result of chest infections ($p < 0.001$), wound problems ($p = 0.01$) and deep vein thrombosis ($p = 0.01$) in the hypothermia group (Table 3).

4. Discussion

Factors leading to inadvertent hypothermia during surgery include uncovered and exposed tissues/skin, anaesthesia eliminating normal thermo-regulatory protective reflexes,¹⁶ and the use of fluids both intravenous and for wound irrigation intraoperatively. Overall, this study

demonstrates a 10% rate of inadvertent hypothermia over a two-year period of retrospective analysis, with age identified as a risk factor. Physiological issues such as skin changes, metabolic alterations, and age-related changes in musculoskeletal and cardiorespiratory systems could also account for this, and have been shown to affect thermoregulation in the elderly.¹⁷ Hip fracture patients are invariably at risk of hypothermia given that heat loss from distal extremities has been shown to contribute significantly towards core temperature cooling.¹⁸ Similarly, Firsch et al demonstrated a significant inadvertent hypothermia rate of 17% in hip fracture patients with increasing age and lower BMI as risk factors.¹⁹ Our study did not evaluate body mass index as patient's weights are not routinely obtained prior to surgery.

General anaesthesia (GA) produces a dose dependent decrease in core body temperature by affecting the body's thermoregulatory systems, such as arteriovenous shunt vasoconstriction and shivering.²⁰ However, in our study the proportion of patients receiving GA was not different in the hypothermia versus $\geq 36^\circ\text{C}$ groups. Our data demonstrates high inadvertent hypothermia rates in patients undergoing operations using a traction table (i.e. SHS and IM nail). In these cases, a proportionally greater exposure of the lower limbs to air may have resulted in greater heat loss by convection.

There was a trend towards higher 30-day mortality rates in the hypothermia group. SHS patients with inadvertent hypothermia had a significantly higher mortality compared to other surgeries which given they had a lower mean ASA grade, is a finding we are unable to explain. To the authors knowledge no study has looked at the effect of inadvertent hypothermia on mortality; Frisch et al excluded all patients that died within 6 weeks of surgery from their analysis.¹⁹

Findings from non-orthopaedic cohorts postulate that the resultant vasoconstriction from intra-operative inadvertent hypothermia slows healing and increases surgical wound infection rates. Indeed, pre-operative warming in addition to intra-operative warming is associated with lower wound infection rates in general surgical patients.^{21, 22} Frisch et al, report a 1% overall deep surgical site infection (DSSI) rate and demonstrated inadvertent hypothermia was associated with an increased rate of DSSI (odds ratio, 3.30; 95% CI 1.19–9.14; $p = 0.022$).¹⁹ Given that other studies have quoted the incidence of DSSI at 0.7% to 1.6% for hip fracture patients, we expected to observe 7 to 15 DSSIs.^{23, 24} Our 30-days readmission interval did not capture any DSSI cases. However, a separate arthroplasty infection audit in our department identified only one hemiarthroplasty DSSI from June 2015 to September 2017.

Our retrospective study analysed readmissions which may underestimate the complications. That is, superficial wound infections may be adequately managed in the community and therefore not captured in the re-admission data.

Several studies have demonstrated greater rates of complications in inadvertent hypothermia individuals after elective orthopaedic and trauma surgery, including hip fracture patients.^{11, 25} Our study supports this trend, with higher readmission rates (most markedly in hemiarthroplasty patients) for hypothermia hip fracture patients. We demonstrated increased readmissions for chest infections, wound problems and deep vein thrombosis in the hypothermia patients. Capturing true complications rates in hip fracture patients is challenging; the authors suspect many post-operative complications are managed in the community given the frailty of the patient population.

Studies in multiple surgical specialty cohorts have found pre-operative warming, active warming, high baseline core temperature, and high ambient temperature is protective against inadvertent hypothermia.²⁶ It is postulated that the beneficial effects of warming are mediated through increased blood flow and oxygen tension at tissue level.²⁷ For arthroplasty surgery an ethos of ensuring an adequate ambient theatre temperature exists.²⁸ Our study demonstrates patients who arrive to theatre hypothermic are nearly twice as likely to be hypothermic on leaving theatre. Strict adherence to pre-operative warming for hip fracture patients cannot be assumed and to the authors

Table 2
30-day mortality of patients undergoing hip fracture surgery with two cohorts: Inadvertent hypothermic and normothermic groups.

Variable	All (n = 929)	< 36 °C (n = 92)	> 36 °C (n = 837)	P value
30-day Mortality (%)	62 (6.7)	10 (10.9)	52 (6.2)	0.089
Operative Group				
SHS (n = 233)	15 (1.6)	5 (16.7)	10 (4.9)	0.03
IM nail (n = 108)	8 (0.9)	2 (18.2)	6 (6.2)	0.19
Hemi (n = 507)	39 (4.1)	3 (6.4)	36 (7.8)	1.0
THA (n = 81)	0	0	0	–

Chart 1. Kaplan-Meier survival chart demonstrating length of stay of patients following hip fracture surgery with two cohorts: inadvertent hypothermic and normothermic groups. A log rank test the 2 groups were not statistically significantly different, $\chi^2(1) = 0.069$, $p = 0.79$.

Table 3

Analysis of 30-day readmissions in inadvertent hypothermic and normothermic groups following hip fracture surgery. DVT; Deep Vein Thrombosis.

30-day Readmissions	All n = 929	< 36 °C n = 92	> 36 °C n = 837	P value
Readmission related to surgery (%)	28 (3.0)	9 (9.8)	19 (2.3)	< 0.001
Operative Group (%)				
SHS (n = 233)	8 (28.6)	3 (33.3)	5 (26.3)	0.069
IM nail (n = 108)	2 (7.1)	1 (11.1)	1 (5.3)	0.19
Hemi (n = 507)	14 (50)	5 (55.6)	9 (47.4)	0.006
THA (n = 81)	4 (14.3)	0	4 (11.8)	1.0
Readmission Cause (%)				
Chest infection	10 (35.7)	6 (66.7)	4 (11.8)	< 0.001
Wound complication ^a	1 (3.6)	1 (11.1)	0	0.01
DVT	1 (3.6)	1 (11.1)	0	0.01
Prosthesis complication ^b	7 (25)	1 (11.1)	5 (9.5)	0.48
Joint pain	7 (25)	0	7 (6.8)	1.0
Leg swelling	2 (7.1)	0	2 (23.7)	1.0
Anaemia	1 (3.6)	0	1 (5.3)	1.0

^a Wound ooze – non infected.

^b Dislocation/periprosthetic fracture.

knowledge has not been studied in detail, therefore this issue requires further research.

A limitation of this study was the single-centre, retrospective design making it difficult to identify causative mechanisms. However, the authors believe this study has good external validity given that our population and the surgery performed reflects common clinical practice in the United Kingdom. Using an isolated temperature measurement taken after surgery to define hypothermia may underestimate inadvertent hypothermia rates, as a single time interval fails to capture/reflect all patients with intra-operative hypothermia. The use of continuous temperature monitoring would more accurately identify patient groups and their outcomes. We present these significant findings to highlight that hip fracture patients are at high-risk of inadvertent hypothermia with associated adverse outcomes.

5. Conclusion

Overall, the inadvertent hypothermia rate in our hip fracture population was 10%, with increasing age and pre-operative temperature as risk factors. Hypothermia was associated with a trend towards higher

30-day mortality and significantly higher 30-day readmission rates. These findings re-affirm the importance of maintaining normothermia prior to and during the operative management of elderly hip fracture patients. Further research is required to determine compliance with recommendations for maintaining normothermia in elderly hip fracture patients, in order to reduce morbidity and mortality.

Conflict of interest

None declared.

Ethical statement

This study does not require ethical committee approval according to the NHS National research ethics service guide because it is an observational study, which does not involve a medical device evaluation or exposure to ionising radiation. Furthermore, the surgical procedures performed is well recognised as the treatment of the pathology. All patients with capacity provided informed consent.

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