South Afr J Anaesth Analg. 2024;30(1):6-12
https://doi.org/10.36303/SAJAA.3045

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

ORIGINAL RESEARCH

Modelling the incidence and severity of hypothermia during spinal anaesthesia for caesarean delivery: a prospective observational study in a resource-limited setting

NJ Masuku,[1] L du Toit,[2,3] C King,[2] RA Dyer,[3] DO Vawda,[1] DG Bishop[1]

[1] *Department of Anaesthesia, College of Health Sciences, University of KwaZulu-Natal, South Africa*
[2] *Department of Anesthesiology, Washington University School of Medicine, United States of America*
[3] *Department of Anaesthesia and Perioperative Medicine, University of Cape Town, South Africa*
Corresponding author, email: *davidgbishop@gmail.com*

Background: Core temperature changes during obstetric spinal anaesthesia are likely underestimated because monitoring is challenging and often not performed. This study aimed to describe the incidence and severity of perioperative hypothermia in patients undergoing caesarean delivery under spinal anaesthesia in a resource-limited setting.

Methods: We performed a prospective observational study of parturients undergoing either elective or emergency caesarean delivery under spinal anaesthesia in a South African regional hospital. We used dual-sensor heat flux technology to monitor their core temperature during the perioperative period. The primary outcome was the incidence of clinically relevant hypothermia (defined as core temperature decrease from baseline of > 1 °C) following spinal anaesthesia. Smoothing splines were used to estimate maximum changes in core temperature.

Results: We included 166 patients in our analysis. A decrease of > 1 °C occurred in 49% of participants (95% CI 40–63%) while hypothermia (temperature < 36 °C) occurred in 67% (49–78%). Discharge from recovery room with core temperature < 35 °C occurred in 26% (20–34%) of the participants. There was a higher incidence of vomiting in those participants who experienced temperature decreases of > 1 °C (18% vs 6%, $p = 0.03$).

Conclusion: In this resource-constrained environment, clinically relevant hypothermia during obstetric spinal anaesthesia occurred in half of participants. Hypothermia was often severe and participants did not recover by the time of discharge from anaesthesia care. Monitoring of a patient's core temperature should be a standard of care, and further research into the clinical impact of perioperative hypothermia and warming strategies in these settings is warranted.

Keywords: caesarean delivery, hypothermia, obstetric anaesthesia, spinal anaesthesia, thermoregulation

Introduction

Hypothermia, defined as a core temperature below 36 °C or a decrease of > 1 °C from a baseline, is a common and prevalent problem in the perioperative period. Both neuraxial and general anaesthesia (GA) are known to cause hypothermia, which is associated with negative perioperative outcomes.[1] Spinal anaesthesia (SA) is the preferred method for caesarean delivery (CD), although there remain recognised and predictable complications of this technique, such as hypotension and hypothermia.[2,3] Heat loss during SA occurs predominantly through vasodilation below the block level, causing heat redistribution from core to periphery.[1,4] Compounding factors include low ambient temperature and loss of normal physiological compensatory mechanisms.[1,4] Perioperative strategies commonly employed to combat heat loss include forced air warming devices, increasing ambient theatre temperature and warmed intravenous fluids.[5] However, these measures are not fully effective in preventing hypothermia in patients under SA for CD, and are not universally available in resource-limited settings.[5]

Hypothermia is likely under-appreciated during obstetric surgery, due to the lack of practical non-invasive methods of perioperative temperature monitoring.[6] The practical difficulties in obtaining accurate temperature monitoring during CD mean that temperature is often not monitored even in well-resourced environments.[7,8] Recent evidence has shown that the degree and duration of hypothermia in the postoperative period is more severe than previously realised.[6] The clinical impact of hypothermia in this study population has not been adequately evaluated; we aimed to prospectively quantify the incidence and severity of perioperative hypothermia in parturients in a resource-limited setting.

Methods

Approval for this study was obtained from the University of KwaZulu-Natal Biomedical Research Ethics Committee (BREC/00002529/2021), and the provincial Department of Health (NHRD Ref: KZ_202106_037). Informed, written consent was obtained from all participants.

Study design and population

This was a prospective, single-centre cohort study of parturients aged ≥ 18 years, of at least 28 weeks gestation, undergoing CD under SA. Both elective and emergency CDs were included.

Participants were monitored from commencement of spinal anaesthesia until discharge from the recovery room.

Study setting

Harry Gwala Regional Hospital is situated in Pietermaritzburg, KwaZulu-Natal, South Africa. It is a referral centre catering for both routine and complex obstetric cases. There are a total of approximately 10 000 annual deliveries, with a CD rate of 37%. Anaesthesia is commonly administered by trainees, supported by specialist anaesthetist if required. Core temperature monitoring for SA is not routinely available, and theatre temperature regulation is not reliably functional. The post-anaesthesia recovery area is limited to two beds, which means that patients cannot remain in this facility for protracted periods. Ambient temperature is not controlled in this recovery area. We defined the setting as "resource-limited" due to these constraints.

Participants

We recruited consecutive patients scheduled for either elective or emergency CD under SA between 07h30 and 16h00 on normal working days (Monday to Friday, public holidays excluded). Patients undergoing CD after-hours, or on weekends and public holidays, were excluded due to the inability to collect data because of limited staff during these periods. This also precluded collection of data at night when ambient temperatures are likely to be lower. We furthermore excluded patients with age < 18 years, gestational age < 28 weeks, a history suggestive of symptomatic thyroid disease, or with no consent. Participants converted to GA for any reason were also excluded from analysis.

Measurements and outcomes

Temperature monitoring

The primary outcome was the incidence of clinically relevant hypothermia, defined as an intraoperative decrease of core temperature of > 1 °C from a baseline, occurring between the time of SA and discharge from theatre to the recovery room. A disposable sensor (Dräger Tcore™, Drägerwerk AG & Co., Lübeck, Germany) was used to monitor temperature. This is a self-adhesive sensor placed on the participant's forehead, and its accuracy is similar to invasive techniques.[9] It employs dual-sensor heat flux technology, which consists of two temperature sensors separated by an insulating layer. One sensor measures the temperature at the surface of the skin, and the other measures the flow of heat to the environment.[9] Following a short warmup time, the sensor calculates core body temperature continuously and accurately.[9] The technology has been shown to have a high degree of accuracy and precision, comparable to that of the thermistor of the Swan-Ganz catheter,[9] and oesophageal and bladder temperature probes.[10] Other temperature outcomes included the incidence of hypothermia below absolute values (< 36 °C and < 35 °C while in the operating theatre and at the time of discharge from the recovery room, respectively).

We collected additional data concerning the following maternal outcomes: shivering (a score of 2–3 on the bedside shiver assessment scale), vomiting, vasopressor usage, bleeding (estimation by the operating team as recorded at the end of the operation in the surgical safety checklist, comprising a visual estimation of swabs, and measured blood loss in the suction bottle) and postpartum haemorrhage (estimated blood loss ≥ 1 000 mL) prior to discharge from the post-anaesthesia recovery area; and neonatal outcomes: 5-minute Apgar score, requirement for chest compressions and direct admission to the neonatal intensive care unit.

Procedure

The sensor was applied on the right side of the participant's forehead at the same time as the other routine monitors were applied, prior to spinal injection. A baseline temperature was recorded at the time of induction of SA, followed by readings at 10-minute intervals until discharge from the recovery room. Ambient temperature at the time of SA was measured by a fixed, wall-mounted, digital thermometer in the operating theatre. A forced air warmer blanket (Bair Hugger Upper Body Blanket, 3M, Maplewood, Minnesota, United States of America) was applied after insertion of SA, if available.

Conduct of anaesthesia

Normal standards applicable to obstetric anaesthesia at the Harry Gwala Regional Hospital were followed. Interns and trainee anaesthetists were allowed to administer anaesthesia under the supervision of an experienced anaesthetist. Standard SA dosing was 9 mg 0.5% hyperbaric bupivacaine and 10 µg fentanyl injected at the L3/4 interspace, using a 25G atraumatic spinal needle. Hypotension was treated with a bolus of phenylephrine or ephedrine. Refractory hypotension was treated with a phenylephrine infusion. Departmental protocols advise maintaining the blood pressure at 90% of the baseline systolic blood pressure as a target. The protocol further advises rapid administration of one litre of modified Ringer's lactate after insertion of SA, with the aim of administering this fluid by the time of delivery. This approximates a co-load of 15–20 ml/kg. A second litre of fluid is then administered as required over the remainder of the operation. Oxytocin 2.5 international units (IU) was given intravenously after delivery, with a further 7.5 IU as an infusion. There was no routine pre-warming of participants. The unit protocol is to use warmed intravenous fluid from a fluid warmer set at 43 °C, and a forced air warmer blanket if available. The forced air warmer blanket is applied immediately after insertion of SA. All blood and blood products infused were warmed using a blood/fluid warming system set at 38 °C. Data were recorded by the anaesthetic team on a paper-based case report form and stored in a secure area at the end of each day by one of the investigators.

Statistical analysis

We used the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines to report our findings.[11] To estimate a population incidence of 50% with 95% confidence, with a margin of error of 10%, we

Table I: Participant and management characteristics grouped by the primary outcome (those who experienced a temperature decrease of ≥ 1°C versus those who did not)

	Total (*n* = 166)	Normothermia (*n* = 84)	Hypothermia (*n* = 82)	*p*-value	SMD
Age (years)	29 [24–34]	30 [26–34]	29 [23–34]	0.154	0.221
Weight (kg)	80 [71–95]	82 [74–94]	79 [70–95]	0.225	0.092
Body mass index	33 [29–38]	33 [29–38]	31 [28–38]	0.296	0.113
Co-morbidity				0.461	0.194
Diabetes mellitus	3 (1.8)	2 (2.4)	1 (1.2)		
Hypertensive disorder	20 (2.0)	10 (1.9)	10 (2.2)		
Gestational age	39 [38–40]	39 [38–40]	39 [38–40]	0.749	0.010
Gravidity	2 [2–3]	2 [2–3]	3 [2–3]	0.972	0.086
Parity	1 [1–2]	1 [1–2]	1 [1–2]	0.663	0.119
Singleton	150 (90.4)	78 (92.9)	72 (87.8)	0.436	0.199
Multiple	2 (1.2)	2 (2.4)	0 (0.0)		
None	73 (44.0)	39 (46.4)	34 (41.5)		
Other	68 (41.0)	31 (36.9)	37 (45.1)		
Active labour	21 (12.7)	14 (16.7)	7 (8.5)	0.180	0.247
CD category				0.071	0.422
1 (emergency)	11 (6.7)	5 (6.0)	6 (7.3)		
2 (urgent)	30 (18.2)	21 (25.3)	9 (11.0)		
3 (scheduled)	15 (9.1)	9 (10.8)	6 (7.3)		
4 (elective)	109 (66.1)	48 (57.8)	61 (74.4)		
Standard SA dose	159 (95.8)	79 (94.0)	80 (97.6)	0.459	0.176
Spinal block level				0.356	0.282
T4	50 (30.1)	20 (23.8)	30 (36.6)		
T5	11 (6.6)	6 (7.1)	5 (6.1)		
T6	103 (62.0)	57 (67.9)	46 (56.1)		
T8	2 (1.2)	1 (1.2)	1 (1.2)		
Prophylactic phenylephrine	34 (20.5)	16 (19.0)	18 (22.0)	0.559	0.169
Phenylephrine infusion	43 (25.9)	22 (26.2)	21 (25.6)	1.000	0.013
Phenylephrine bolus doses (µg)	200 [0–400]	150 [0–400]	200 [0–400]	0.530	0.030
Ephedrine doses (mg)	0 [0–0]	0 [0–0]	0 [0–0]	0.992	0.128
Ambient temp theatre (°C)	19 [18–21]	19 [19–21]	19 [18–20]	0.013	0.304
Ambient temp recovery (°C)	22 [21–23]	22 [21–24]	22 [21–23]	0.077	0.186
Warming: with FAW	158 (95.2)	83 (98.8)	75 (91.5)	0.065	0.347
Warming: warm fluids	141 (84.9)	72 (85.7)	69 (84.1)	0.959	0.045
Oxytocin bolus	166 (100.0)	84 (100.0)	82 (100.0)	NA	< 0.001
Oxytocin infusion intraop	159 (96.4)	83 (98.8)	76 (93.8)	0.196	0.267
Oxytocin infusion postop	166 (100.0)	84 (100.0)	82 (100.0)	NA	< 0.001

Note: Results expressed as median (IQR [range]) or count (percentage)
CD – caesarean delivery; SA – spinal anaesthesia; GA – general anaesthesia; FAW – forced-air warmer blanket; intraop – intraoperative; postop – postoperative; SMD – standardised mean difference.
CD categories: 1 – immediate threat to the life of the woman or fetus (for example, suspected uterine rupture, major placental abruption, cord prolapse, fetal hypoxia or persistent fetal bradycardia); 2 – maternal or fetal compromise which is not immediately life-threatening; 3 – no maternal or fetal compromise but needs early birth; 4 – birth timed to suit woman or healthcare provider

required 96 participants. To allow for missing and excluded data of up to 15%, we aimed to recruit a minimum of 110 participants. Statistical analysis was done as follows: the baseline characteristics of the included participants are reported as median (interquartile range [IQR]), and categorical variables as count (percent). Comparisons of baseline values between those with and without the primary outcome were conducted using the Mann-Whitney U test. Fisher's exact test was used for differences in categorical variables. Baseline differences were also expressed as standardised mean differences as implemented in the R "tableone" package (version 0.13.2).

The temperature sensors used were observed to take up to ten minutes to reach equilibrium, resulting in potential measurement error of the baseline value. In addition, occasional implausible outlying temperature values were noted as another source of measurement error. To address these concerns, we adopted a smoothing spline regression,[12] and used a linear mixed model to estimate the parameters. That is, an average temporal pattern in

Table II: Temperature changes during spinal anaesthesia for caesarean delivery, derived using smoothing and extrapolation techniques (fitted values) and without these techniques (observed values)

Outcome measure	Fitted count (%) or mean (SD) *n* = 166	Fitted 95% CI	Observed count (%) or mean (SD) *n* = 166	Observed 95% CI
Temp decrease ≥ 1°C	82 (49%)	40–63%	77 (46%)	37–54%
Minimum temp < 36°C	112 (67%)	49–78%	95 (57%)	48–66%
Minimum temp < 35°C	10 (6%)	2–11%	8 (5%)	1–9%
Maximum temp decrease (°C)	-1.0 (0.5)	-1.1–(-0.9)	-0.9 (0.5)	-1.0–(-0.8)
Temp decrease ≥ 1°C at 60 min	54 (33%)	23–42%	51 (31%)	22–39%
Minimum temp < 36°C at 60 min	72 (43%)	35–52%	71 (43%)	34–51%
Minimum temp < 35°C at 60 min	6 (4%)	1–8%	4 (2%)	0–5%
Maximum temp decrease (°C) at 60 min	-0.8 (0.5)	-0.9–(-0.7)	-0.7 (0.5)	-0.8–(-0.6)

Temp – temperature; min – minutes

temperature was estimated, with penalised individual deviations from the global pattern. The per-person minimums in fitted values from this regression were then used as the smoothed estimate of change in core temperature. Supplementary material S1 provides further details of this statistical approach. For participants with missing values, including those whose data collection ended before 90 minutes, we interpolated or extrapolated using the individual smoothed trend. A complete case analysis of the observed values is presented as a sensitivity analysis.

For the primary outcome, we used a binary estimate of temperature decrease of > 1 °C from the baseline. Confidence intervals were calculated by non-parametric bootstrap of the entire procedure. For the secondary outcomes (temperature < 36 °C, and < 35 °C), we modified the analysis plan to use the calculated change in core temperature (defined above), and project the incidence of hypothermia assuming that participants had a normal core temperature (36.8 °C) prior to anaesthesia. We also report temperature outcomes using only the first 60 minutes, to allow for comparison with other research. Post-anaesthesia recovery room temperatures are summarised as complete case analyses of the raw observed values.

R version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria) was used for analyses. A container replicating the analysis environment and code for the analysis is located at https://github.com/cryanking/temp_agreement

Results

Data collection occurred from 2 August 2021 to 28 October 2021. During this period, 863 CDs were performed. Of these, 468 were ineligible for recruitment, due to method of anaesthesia or time of CD. Of the remaining 395 CDs, we recruited 180 patients who fulfilled the eligibility criteria. Consecutive patients were recruited based on availability of the monitor. No patient refused consent. Fourteen recruited participants were subsequently excluded from analysis because they did not meet study criteria (*n* = 8, age < 18 years; *n* = 4, converted to GA; *n* = 2, gestational age < 28 weeks). A total of 1 447 measurements were recorded in the remaining 166 participants, out of a possible maximum 1 660. One participant lacked recovery room temperature data.

The proportion (percentage) of participants who developed hypothermia was 82/166 (49%). Participant and management characteristics, namely obstetric data, patient comorbidities and details of SA, including vasopressor and uterotonic therapy, are summarised in Table I, grouped by the primary outcome.

Further, secondary outcomes were as follows: typical blood loss was estimated at 550 mL (500–700 mL) and 9 participants had estimated blood loss ≥ 1 000 mL; intraoperative shivering was experienced by 34 (20%) participants (18 [21%] in the normothermia versus 16 [20%] in the hypothermia group; p = 0.35); intraoperative vomiting occurred in 5/84 (6%) patients in the normothermia versus 15/82 (18%) in the hypothermia group (rate ratio 3.1, 95% CI 1.2–7.9, p = 0.017). Three neonates required direct admission to the neonatal intensive care unit and two neonates required cardiopulmonary resuscitation. There were no between-group differences in neonatal Apgar scores (p = 0.09).

Table II reports the primary and secondary temperature outcomes during SA for CD using the smoothing and extrapolation techniques (fitted values) and without these techniques (observed values). Temperature changes in the recovery periods are shown in Table III.

Table III: Temperature during the recovery period

	Count (%) or mean (SD) *n* = 165	95% CI
Temp on arrival in recovery (°C)	35.5 (0.75)	35.4–35.6
Proportion < 36°C on arrival in recovery	112 (68%)	60–75%
Proportion < 35°C on arrival in recovery	40 (24%)	18–32%
Temp on discharge from recovery (°C)	35.5 (0.93)	35.3–35.6
Temp < 36°C on discharge from recovery	117 (71%)	63–78%
Temp < 35°C on discharge from recovery	43 (26%)	20–34%

Temp – temperature
Note: Estimates were derived from unadjusted observed temperature measurements.

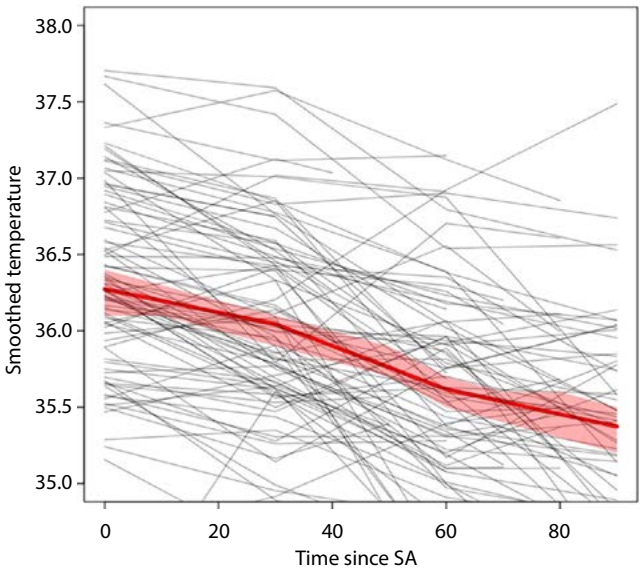

Figure 1: Black lines show the change in smoothed temperatures of the first 100 individual traces; the red line represents the mean smoothed temperature, and the shading shows the 95% CI of the mean

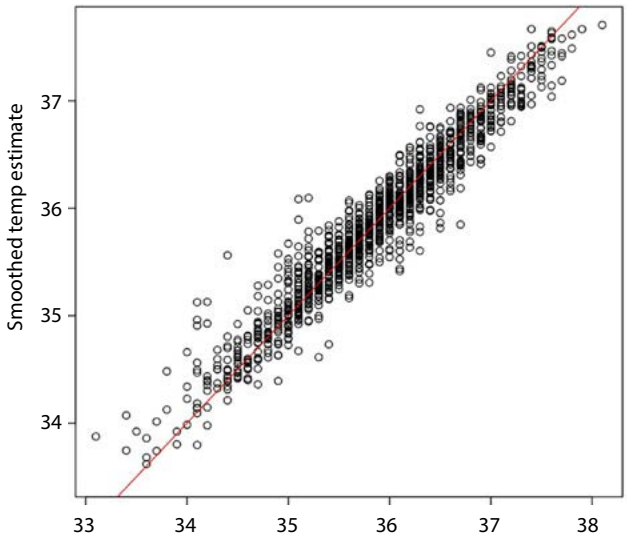

Figure 2: Comparison between smoothed and measured temperatures

Smoothed temperature data for all participants is shown in Figure 1. The impact of smoothing vs raw readings is shown in Figure 2, which shows minimal differences in most observations.

A detailed explanation of the statistical methodology employed is provided in the supplementary material. Several individual raw temperature tracings are shown in Figure S1. Figure S2 shows the distribution of baseline temperatures, and Figure S3 shows the distribution of maximum temperature change.

Discussion

This study showed that nearly half of parturients undergoing CD under SA experienced clinically relevant hypothermia (> 1 °C decrease in core temperature) and approximately a quarter of participants were discharged from the recovery area with severe hypothermia. While no pre-warming was performed, most participants received intraoperative forced air warming with upper body blankets, and warmed intravenous fluids. The high incidence of hypothermia (> 80% of participants experienced a core body temperature < 36 °C), is in agreement with previous studies where incidences of up to 91% have been reported.[13] In one randomised, controlled trial, the incidence of hypothermia was improved to 64% if both a forced air warmer blanket and warmed intravenous fluids were used.[13] This approach was the standard of care in our study and while it may have had an impact on patient temperatures, it did not prevent the high incidence of hypothermia (Table II).

The rate of hypothermia in our study is notably higher than reported in three recent thermoregulation studies in CD populations using similar temperature sensors (zero-heat-flux monitors).[14-16] We report an estimated incidence of core temperature < 36 °C in the operating room of 67%. The MATES study reported an incidence of only 11% for the same outcome.[14] The MATES study differs in that it reports on emergency CD and includes cases that received epidural anaesthesia known to be associated with higher core temperatures. The average room temperature in the MATES study was 22 °C. Cotoia et al. [15] compared the effect of forced air warming, fluid warming and no warming on zero-heat-flux temperature in a population undergoing CD under SA. The incidence of core temperatures < 36 °C this trial was 47% in the "no warming" group and zero in the forced-air warming group.[15] This is contradictory to our study in which both fluid warming and forced-air warming were used without prevention of hypothermia. Notably the room temperature in the Cotoia et al.[15] study was 23–24 °C. Another recent warming trial by Marin et al. [16] used zero-heat-flux technology and compared the effect of active warming to passive warming in women undergoing CD under SA. In their trial, the incidence of temperature < 36 °C in the operating room was 10% and 12% with or without active warming, respectively.[16] They did not report ambient room temperature. The ambient temperature in our operating room was 19 °C. This is notably lower than the World Health Organization (WHO) recommendation[17] of 25–28 °C for delivery room temperature and the more modest target of 23 °C set up by Duryea et al.,[18] and may partly explain our high incidence of hypothermia despite the use of warming measures.

Additional factors that may also have contributed to and compounded the incidence of hypothermia include the heterogeneity of perioperative care (including varying levels of staff experience and unreliable access to dual warming techniques). We used a lower standardised spinal dosing of hyperbaric bupivacaine (9 mg) than in other studies of obstetric hypothermia.[5,6,19] Theoretically, a lower dose should reduce or minimise the incidence of hypothermia, due to a lower level and duration of spinal anaesthesia blockade. We also did not use intrathecal morphine in our study, due to lack of reliable access to preservative-free morphine and concerns regarding a lack of consistent postoperative respiratory monitoring in our setting. Instead, we used fentanyl (10 µg) as a standard dose. Intrathecal morphine is recommended as part of enhanced recovery after surgery programmes, but has been associated with a higher incidence of perioperative hypothermia.[20,21] Case reports have

also described a distinct syndrome of morphine-induced hypothermia.[22] Despite standardised spinal dosing using a low dose of bupivacaine and avoiding intrathecal morphine, the incidence of hypothermia remained high.

We were unable to collect data following discharge to the ward, but it is likely that hypothermia persisted well into this period. A study from Du Toit et al.[6] employed an ingestible telemetric sensor to obtain accurate core temperature measurements for an eight-hour period in 28 patients undergoing SA for elective CD. Fifty percent of participants became hypothermic. The mean temperature decrease was 1.3 °C, and 29% of participants (8/28) had not recovered to baseline temperatures at the end of the eight-hour monitoring period, while median recovery time for the remaining 20 patients was 4.6 hours.[6] Prolonged postoperative hypothermia is thus likely a common occurrence. A quarter of our participants were discharged from the post-anaesthetic recovery area with core temperature < 35 °C, due to the need for rapid turnover in a two-bedded facility. Temperature measurement is not routine following SA at our institution due to the lack of a suitable monitor in awake patients, raising concerns that our findings reflect the typical situation.

Temperature measurement is routinely performed during GA, where hypothermia is a known complication. Most guidelines strongly recommend temperature monitoring under SA for procedures exceeding 30 minutes, including recently released South African Guidelines.[23] Despite this recommendation, it is uncommon to monitor intraoperative temperatures, even in well-resourced environments. A survey of practice in 2014 in the United Kingdom revealed that less than 30% of units routinely monitor temperature during SA for CD, and less than 20% actively warm their patients during CD.[8] This may reflect a lack of suitable monitors in awake patients. Nasopharyngeal monitors commonly used under GA are not suitable for awake patients, and bladder temperature monitoring is expensive and not reliable due to the proximity to the open surgical site. Newer technologies such as dual-sensor heat flux technology provide improved monitoring, with only cost preventing widespread implementation. These monitors are now included in the NICE guidelines for perioperative temperature management.[24]

It is possible that perioperative hypothermia is considered by clinicians to be relatively harmless following CD. In our study, the only adverse outcome significantly increased in the hypothermic group was vomiting. However, our study was primarily powered to determine the incidence of hypothermia, rather than to detect differences in clinical outcomes. Differences in maternal discomfort, difficult neonatal bonding, failure of breastfeeding, and postpartum haemorrhage cannot be ruled out. In the general surgical population, hypothermia is a known risk factor for surgical site infection and for prolonged hospital stay.[25,26] A recent editorial highlighted the lack of similar evidence in obstetrics research.[27] However, improved neonatal outcomes (reduced neonatal hypothermia and acid-base disturbances) and better maternal comfort have been demonstrated.[20] In addition, bundled care that includes active warming, such as used in enhanced recovery protocols, has been shown to reduce hospital stay in CD under SA.[28]

Limitations of this study included resource constraints, limiting data collection outside normal working hours. This excluded night-time cases, which are likely to include more emergency work and lower ambient temperatures. It is possible that our study thus underestimated the incidence and severity of perioperative hypothermia. We did not collect data after discharge from the recovery area, precluding analysis of this important period for outcomes such as surgical site infection, thermal comfort and bonding with the neonate. However, our study is one of the largest cohorts of patients studied under real-world, resource-limited conditions and has shown both a high incidence and degree of perioperative hypothermia.

A further limitation in the use of the dual-sensor heat flux technology in a real-world setting is that initial temperatures recorded may not have allowed for the complete warmup time. This issue was addressed by the statistical methodology employed for data analysis. We performed a sensitivity analysis (Table II), which showed similar results for the fitted and observed outcomes.

Further research into the clinical impact of perioperative hypothermia is warranted, particularly with reference to outcomes such as surgical site infection, bleeding, bonding between mother and baby, neonatal wellbeing, and prolonged hospital stay. These studies should extend beyond the recovery room until discharge from hospital, a period that has been insufficiently investigated.[27] Practical methods of reducing the incidence of hypothermia should also be investigated, including leg wrapping and reduction of time of exposure to ambient temperature. In addition, novel methods of pre-warming that take resource constraints into account, should be considered. While we may be far from the goal of eliminating hypothermia during CD, healthcare systems should at least strive to provide active postoperative warming to 36 °C.

Conclusion

Almost half of our participants undergoing SA for CD experienced clinically relevant hypothermia, and half of these participants were discharged to the ward with hypothermia that was likely to persist some hours into the postoperative period. Temperature monitoring during and after CD should become routine, and the use of dual-sensor heat flux technology offers one solution to the challenges in the monitoring of awake patients. Our findings suggest that the use of active warming and warmed intravenous fluids should be a standard of care that extends into the post-anaesthetic recovery area, and pre-warming patients should be strongly considered. The adverse clinical outcomes of hypothermia after CD require further study.

Conflict of interest

The authors declare no conflict of interest.

Funding source

The Dräger Tcore™ sensors were supplied through an investigator-initiated donation, and Dräger monitors were loaned for the purposes of the study. Dräger (Pty) Ltd. did not have any input into the protocol, statistical analysis or manuscript.

Ethical approval

Approval for this study was obtained from the University of KwaZulu-Natal Biomedical Research Ethics Committee (BREC/00002529/2021), and the provincial Department of Health (NHRD Ref: KZ_202106_037). Informed, written consent was obtained from all participants.

ORCID

NJ Masuku https://orcid.org/0000-0001-6250-2389
L du Toit https://orcid.org/0000-0003-0146-4002
C King https://orcid.org/0000-0002-4574-8616
RA Dyer https://orcid.org/0000-0002-8165-9098
DO Vawda https://orcid.org/0009-0002-6401-0489
DG Bishop https://orcid.org/0000-0001-9861-3646

References

1. McSwain JR, Yared M, Doty JW, Wilson SH. Perioperative hypothermia: Causes, consequences and treatment. World J Anesthesiology. 2015;4(3)58-65. https://doi.org/10.5313/wja.v4.i3.58.
2. Bishop DG. Predicting spinal hypotension during Caesarean section. S Afr J Anaesth Analg. 2014;20(4):14-7. https://doi.org/10.1080/22201181.2015.959336.
3. Gulhas N, Tekdemir D, Durmus M, et al. The effects of ephedrine on maternal hypothermia in caesarean sections: A double blind randomized clinical trial. Eur Rev Med Pharmacol Sci. 2013;17(15):2051-8.
4. Frank SM, El-Rahmany HK, Cattaneo CG, Barnes RA. Predictors of hypothermia during spinal anesthesia. Anesthesiology. 2000;92(5):1330-4. https://doi.org/10.1097/00000542-200005000-00022.
5. Butwick AJ, Lipman SS, Carvalho B. Intraoperative forced air-warming during cesarean delivery under spinal anesthesia does not prevent maternal hypothermia. Anesth Analg. 2007;105(5):1413-9. https://doi.org/10.1213/01.ane.0000286167.96410.27
6. Du Toit L, Van Dyk D, Hofmeyr R, Lombard CJ, Dyer RA. Core temperature monitoring in obstetric spinal anesthesia using an ingestible telemetric sensor. Anesth Analg. 2018;126(1):190-5. https://doi.org/10.1213/ANE.0000000000002326.
7. Frank SM, Nguyen JM, Garcia CM, Barnes RA. Temperature monitoring practices during regional anesthesia. Anesth Analg. 1999;88(2):373-7. https://doi.org/10.1213/00000539-199902000-00028.
8. Aluri S, Wrench IJ. Enhanced recovery from obstetric surgery: a UK survey of practice. Int J Obstet Anesth. 2014;23(2):157-60. https://doi.org/10.1016/j.ijoa.2013.11.006.
9. Gomez-Romero F, Fernandez-Prada M, Fernandez-Suarez F, et al. Intra-operative temperature monitoring with two non-invasive devices (3M Spoton® and Dräger Tcore®) in comparison with the Swan-Ganz catheter. Cirugía Cardiovascular. 2019;26(4):191-6. https://doi.org/10.1016/j.circv.2019.06.002.
10. Kimberger O, Saager L, Egan C, et al. The accuracy of a disposable noninvasive core thermometer. Can J Anesth. 2013;60(12):1190-6. https://doi.org/10.1007/s12630-013-0047-z.
11. Vandenbroucke JP, von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): Explanation and elaboration. Ann Intern Med. 2007;147(8):W-163-W-94. https://doi.org/10.7326/0003-4819-147-8-200710160-00010-w1.
12. Sasieni P. Book review: Generalized additive models. T. J. Hastie and R. J. Tibshirani, Chapman and Hall, London, 1990. No. of Pages: xv + 335. Price: £25. ISBN: 0-412-34390-8. Stat Med. 1992;11(7):981-2. https://doi.org/10.1002/sim.4780110717.
13. Cobb B, Cho Y, Hilton G, Ting V, Carvalho B. Active warming utilizing combined IV fluid and forced-air warming decreases hypothermia and improves maternal comfort during cesarean delivery: a randomized controlled trial. Anesth Analg. 2016;122(5):1490-7. https://doi.org/10.1213/ANE.0000000000001181.
14. Thorburn PT, Monteiro R, Chakladar A, et al. Maternal temperature in emergency caesarean section (MATES): an observational multicentre study. Int J Obstet Anesth. 2021;46:102963. https://doi.org/10.1016/j.ijoa.2021.102963.
15. Cotoia A, Mariotti PS, Ferialdi C, et al. Effectiveness of combined strategies for the prevention of hypothermia measured by noninvasive zero-heat flux thermometer during cesarean section. Front Med (Lausanne). 2021;8:734768. https://doi.org/10.3389/fmed.2021.734768.
16. Marin L, Hocker J, Esser A, et al. Forced-air warming and continuous core temperature monitoring with zero-heat-flux thermometry during cesarean section: a retrospective observational cohort study. Braz J Anesthesiol. 2022;72(4):484-92. https://doi.org/10.1016/j.bjane.2021.10.007.
17. Sultan P, Habib AS, Carvalho B. Ambient operating room temperature: mother, baby or surgeon? Br J Anaesth. 2017;119(4):839. https://doi.org/10.1093/bja/aex307.
18. Duryea EL, Nelson DB, Wyckoff MH, et al. The impact of ambient operating room temperature on neonatal and maternal hypothermia and associated morbidities: a randomized controlled trial. Am J Obstet Gynecol. 2016;214(4):505 e1-e7. https://doi.org/10.1016/j.ajog.2016.01.190.
19. Sultan P, Habib AS, Cho Y, Carvalho B. The effect of patient warming during Caesarean delivery on maternal and neonatal outcomes: a meta-analysis. Br J Anaesth. 2015;115(4):500-10. https://doi.org/10.1093/bja/aev325.
20. Hedderson M, Lee D, Hunt E, et al. Enhanced recovery after surgery to change process measures and reduce opioid use after cesarean delivery: a quality improvement initiative. Obstet Gynecol. 2019;134(3):511-9. https://doi.org/10.1097/AOG.0000000000003406.
21. Hui CK, Huang CH, Lin CJ, et al. A randomised double-blind controlled study evaluating the hypothermic effect of 150 microg morphine during spinal anaesthesia for Caesarean section. Anaesthesia. 2006;61(1):29-31. https://doi.org/10.1111/j.1365-2044.2005.04466.x.
22. Bernstein K, Landau R. neuraxial morphine-induced hypothermia after cesarean delivery managed with nalbuphine: a case report. A A Pract. 2020;14(7):e01220. https://doi.org/10.1213/XAA.0000000000001220.
23. South African Society of Anaesthesiologists. SASA Practice Guidelines 2022. South Afr J Anaesth Analg. 2022;28(4 Suppl 1).
24. Hypothermia: prevention and management in adults having surgery. London: National Institute for Health and Care Excellence (NICE); 2016 Dec. (NICE Clinical Guidelines, No. 65.) Available from: https://www.ncbi.nlm.nih.gov/books/NBK554181/.
25. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. N Engl J Med. 1996;334(19):1209-15. https://doi.org/10.1056/NEJM199605093341901.
26. Rajagopalan S, Mascha E, Na J, Sessler DI. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. Anesthesiology. 2008;108(1):71-7. https://doi.org/10.1097/01.anes.0000296719.73450.52.
27. Allen TK, Habib AS. Inadvertent perioperative hypothermia induced by spinal anesthesia for cesarean delivery might be more significant than we think: are we doing enough to warm our parturients? Anesth Analg. 2018;126(1):7-9. https://doi.org/10.1213/ANE.0000000000002604.
28. Wrench IJ, Allison A, Galimberti A, Radley S, Wilson MJ. Introduction of enhanced recovery for elective caesarean section enabling next day discharge: a tertiary centre experience. Int J Obstet Anesth. 2015;24(2):124-30. https://doi.org/10.1016/j.ijoa.2015.01.003.

Supplementary file available online