Introduction

Numerous studies have shown increased risk of postoperative complications, including infections, cardiac risks, coagulopathies and increased hospital stay in patients who had decreased body temperatures during the perioperative period (1). Suggested mechanisms of hypothermia-induced complications included the vasoconstriction of the blood vessels, impairing oxygen delivery through altered chemotaxis, and impairment of neutrophil and platelet function (2). For example, Schmeid et al. (2) showed a trend towards increased blood loss in patients experiencing mild hypothermia. Of note, patients undergoing endoscopic urology procedures were often aged >65 years and received irrigation fluids. Advanced age was shown to be a risk factor for perioperative hypothermia in several studies including a review performed by Blatteis et al. (3, 4) By studying patients undergoing transurethral procedures, Pit and Singh demonstrated the increased risk of a low body temperature with room temperature irrigation fluids (5, 6).

However, only relatively recently after a growing body of literature showed increased risks associated with decreased body temperature perioperatively did it become standard in most hospitals to measure and maintain body
temperature above 36°C intraoperatively (7, 8). Additionally, in many hospitals, protocols were only implemented if a patient’s body temperature fell below a specific temperature or if the length of procedure exceeded a set length of time (9). At the Veteran’s Affairs Western New York (VAWNY) Medical Center, strategies such as warming blankets and warmed intravenous fluids were implemented when a procedure was projected to last longer than 1 hour or if body temperature dropped below 36°C. However, implementation of warmed irrigation fluids instead of room temperature fluids became a standard of care towards the end of 2013 for all transurethral procedures.

The goal of this study was to examine if hypothermia prevention strategies reduced the risk of decreased body temperature and the subsequent risk of postoperative complications. The primary endpoint of this study was the frequency of mild hypothermia as it was defined by body temperatures <36°C upon arrival of the patients at the postoperative anaesthesia care unit. We hypothesised that heated irrigation fluids would lower the incidence of hypothermia compared to those in whom unheated solutions were used and thereby decreasing postoperative complications.

Methods

A retrospective review of patient records consisting of 2,559 male patients who underwent endoscopic urology procedures between August 2000 and December 2016 was conducted using the Veterans Affairs Surgical Quality Improvement Program (VASQIP) database and computerised patient record system. Study design and protocol were reviewed by the institutional review board at the VAWNY Healthcare System (Buffalo) and were approved for their scientific and ethical merit. Due to its retrospective design, the study was exempted from obtaining informed consent form each individual participant; however, extreme care was given to ensure patient privacy and confidentiality.

A total of 2,559 urologic surgery procedures were performed. Four hundred and sixty anaesthesia records from 1998, 1999 and parts of 2000 were not available due to changes within the computerised record management protocol at the hospital. A total of 349 open surgical cases along with 118 cases <15 minutes in length were excluded from the data (Figure 1). Inclusion criteria for the study included all patients who underwent endoscopic urology procedures with the implementation of general or local anaesthesia methods along with either room temperature or heated irrigation fluids. Exclusion criteria included all surgical procedures that began or converted into open surgical procedures and procedures <15 minutes in length. Anaesthesia warming methods such as warming blankets and warmed intravenous fluids were recorded as well. In addition, anaesthesia computer records allowed for the collection of both postoperative and preoperative temperatures along with the intraoperative temperature trends and medications used during the case.

Prior to 2013, room temperature irrigation fluids were consistently used for transurethral procedures. Starting in January 2014 all patients received warmed irrigation fluids. These patients were separated into two groups and evaluated. Group I incorporated the use of room temperature irrigation fluids while Group II used heated irrigation fluids. Throughout both time periods, the anaesthesia department instituted warming blankets or warmed intravenous fluids if patient’s body temperature fell below 36°C or if cases went beyond 60 minutes. A multi-regression analysis was used to analyse the data. Primary endpoints included risk of hypothermia and a temperature drop below 36°C, while secondary endpoints included postoperative complications such as death, myocardial infarctions, cerebrovascular accidents, pulmonary embolus, infections, transfusion complications and returns to the operating room.

If preoperative or postoperative temperature values were missing on the anaesthesia records, baseline temperatures (from the prior week preoperative visit) and PACU temperatures were implemented respectively. Samples were then analysed based on the groups that were normothermic or hypothermic at the end of the procedures to evaluate postoperative risk factors for comorbidities due to such temperature drops.

The presence of a normal distribution was tested using the Kolmogorov–Smirnov test. Normally distributed data were represented as a mean±standard deviation, and vari-
ables that were not normally distributed were represented as a median (interquartile range). Data that were not normally distributed were analysed using the non-parametric Mann–Whitney U test for intergroup comparison. A sample size of 278 patients was calculated using the power analysis based on results of the incidence of hypothermia from another study (6), in which the overall incidence of hypothermia after the implementation of warmed irrigating fluids was 15%. To detect a drop in the rate of hypothermia to 10%, 232 patients with Type I error (an alpha error of 0.05) and a Type II error (a beta error of 0.2) were required. To account for potential losses, 269 patients were included within the warmed irrigation fluids group. A total of 1,369 patients had room temperature irrigation fluids used during surgery. Paired and unpaired t-tests were used to compare the mean temperatures for both normothermic and hypothermic patients with the incorporation of either heated or room temperature irrigation fluids. Chi-squared tests were implemented to evaluate categorical data, such as preoperative risk factors and postoperative outcomes secondary to temperature changes. A p-value <0.05 was determined as statistically significant.

Results

A total of 1,632 patients (median age, 71 years) underwent anaesthesia for endoscopic urology procedures between August 2000 and December of 2016 at the VAWNY hospital. Preoperative patient characteristics can be seen in Table 1, showing no significant differences between all groups; in addition, all patients included were found to be normothermic (with a temperature recording of at least 36°C) in the preoperative stage, without documented preoperative warming efforts. The median age within the normothermic group versus our hypothermia group was 72 (56–88) and 70 (57–83) years, respectively (p=0.114). There was no difference between the normothermic and hypothermic patients in body mass index (p=0.423) and body surface area (p=0.784). Haemoglobin A1C levels were on average 0.2% lower in the hypothermic patients, while fasting glucose levels were 5 mg dL⁻¹ lower than in the normothermic patients (Table 2).

In terms of predicted risk of death within 30 days of surgery, the normothermic versus the hypothermic group had equal risks of death, both 0.97% (p=0.127). The risk of develop-

| Table 1. Patient characteristic and the presence of comorbid conditions according to postoperative development of hypothermia with body temperature <36.0°C |
|-------------------------------------------------|---------------------------------|----------------|----------------|----------------|----------------|----------------|
| Normothermia (n=1382) | Hypothermia (n=368) | Odds Ratio [95% Confidence interval] | p |
|------------------------|-------------------|----------------|----------------|----------------|----------------|----------------|
| Hypertension | 830 | 816.6 | 204 | 217.4 | 0.38 [0.66–1.04] | 0.109 |
| Diabetes mellitus | 389 | 375.9 | 87 | 100.1 | 0.79 [0.61–1.03] | 0.084 |
| Insulin injection | 80 | 74.2 | 14 | 19.8 | 0.43 [0.36–0.15] | 0.133 |
| Oral hypoglycaemic drugs | 309 | 301.7 | 73 | 80.3 | 0.67 [0.65–1.14] | 0.298 |
| benzodiazepines | 844 | 877.9 | 268 | 234.1 | 1.70 [1.32–2.19] | <0.001 |
| Propofol | 1218 | 1216.2 | 322 | 323.8 | 0.94 [0.67–1.34] | 0.74 |
| Inpatient status | 381 | 387 | 109 | 103 | 1.11 [0.86–1.42] | 0.436 |
| Prior myocardial infarction | 26 | 23.7 | 4 | 6.3 | 0.57 [0.20–1.65] | 0.297 |
| Prior coronary revascularisation | 204 | 197.4 | 46 | 52.6 | 0.83 [0.59–1.16] | 0.271 |
| Congestive heart failure | 48 | 46.6 | 11 | 12.4 | 0.86 [0.44–1.67] | 0.648 |
| Prior cerebrovascular event | 183 | 189.5 | 57 | 50.5 | 1.20 [0.87–1.66] | 0.265 |
| Chronic obstructive pulmonary diseases | 293 | 294.6 | 80 | 78.4 | 1.03 [0.78–1.37] | 0.823 |
| Active smoking | 377 | 375.9 | 99 | 100.1 | 0.98 [0.76–1.27] | 0.885 |
| Chronic kidney disease | 6 | 6.3 | 2 | 1.7 | 1.26 [0.25–6.24] | 0.782 |
| Haemodialysis | 7 | 6.3 | 1 | 1.7 | 0.54 [0.07–4.36] | 0.533 |
| Alcohol use | 67 | 71.9 | 24 | 19.1 | 1.37 [0.85–2.22] | 0.199 |
| Peripheral vascular disease | 43 | 41.1 | 9 | 10.9 | 0.78 [0.38–1.62] | 0.504 |
| Transfusion-related issues | 10 | 10.3 | 3 | 2.7 | 1.13 [0.31–4.12] | 0.856 |
| Previous sepsis | 5 | 3.9 | 0 | 1.1 | 0.79 [0.77–0.81] | 0.248 |
| Emergent surgery | 16 | 16.6 | 5 | 4.4 | 1.18 [0.43–3.23] | 0.735 |
| Operating room time greater than 60 minutes | 383 | 394.9 | 117 | 105.1 | 1.04 [0.99–1.10] | 0.124 |
Table 2. Laboratory values of the patients according to the status of hypothermia as defined by body temperature <36°C

|                       | Normothermia (n=1,382) | Hypothermia (n=368) | p    |
|-----------------------|------------------------|---------------------|------|
|                       | Preoperative | Postoperative | Preoperative | Postoperative |      |      |
|                       | Median  | IQR  | Median  | IQR  | Median  | IQR  |      |      |
| Haematocrit (percentage) | 40.6  | 6.6  | 35.1  | 6.4  | 41.3  | 5.9  | 35.2  | 5.2  | 0.055 |
| White blood cell (count nL⁻¹) | 7.2  | 2.9  | 10.5  | 5.7  | 7.1  | 2.6  | 9.9  | 4.4  | 0.975 |
| Serum creatinine (mg dL⁻¹) | 1.1  | 0.5  | 14.7  | 1.18 | 1.2  | 0.4  | 1.50  | 0.88 | 0.876 |
| Prothrombin time (sec) | 12.9  | 1.8  | 12.5  | 4.6  | 0.166 |
| Partial thromboplastin time (Sec) | 30.6  | 10.0 | 29.5  | 12.0 | 0.881 |
| Serum sodium (mEq L⁻¹) | 140  | 3    | 139   | 3    | 0.061 |
| Potassium (mEq L⁻¹) | 4.1  | 0.6  | 4.0   | 0.6  | 0.186 |
| Blood glucose (mg dL⁻¹) | 103  | 45   | 127   | 105  | 0.053 |
| Haemoglobin A1C | 7.6  | 1.8  | 6.9   | 0.9  | 0.022 |
| Blood urea nitrogen (mg dL⁻¹) | 20.3  | 9.0  | 21.9  | 13.0 | 0.032 |
| Serum albumin (g dL⁻¹) | 3.6  | 0.5  | 3.7   | 0.5  | 0.108 |
| Serum bilirubin (mg dL⁻¹) | 0.56  | 0.30 | 0.52  | 0.23 | 0.039 |
| Serum alkaline phosphatase (IU L⁻¹) | 92  | 43   | 99    | 62   | 0.065 |
| Aspartate-glutamate transaminase (IU L⁻¹) | 23  | 16   | 21    | 10   | 0.094 |

The top panel (measurements for haematocrit, white blood cell count and serum creatinine concentrations) were measured both before and after surgery, and analysis was performed with repeated measures. The p-values for these variables indicated the effect of hypothermia on the operative changes of these laboratory parameters. The remaining variables were measured only prior to surgery, and they were compared using independent t-tests.

Table 3. Adverse postoperative outcomes secondary to the development of hypothermia with body temperature <36.0°C

|                       | Normothermia (n=1,382) | Hypothermia (n=368) | Odds Ratio [95% Confidence interval] | p    |
|-----------------------|------------------------|---------------------|------------------------------------|------|
| Overall deaths        | 470 | 479.4  | 137  | 127.6 | 1.03 [0.98–1.09] | 0.249 |
| Deaths within 30 days | 10  | 11.1   | 4    | 2.9   | 1.11 [0.79–1.54] | 0.487 |
| MACE-30               | 19  | 19     | 5    | 5     | 0.10 [0.81–1.23] | 0.981 |
| Cardiac arrest        | 3   | 3.2    | 1    | 0.8   | 1.05 [0.60–1.86] | 0.845 |
| Troponin leak         | 5   | 4.6    | 1    | 1.4   | 0.91 [0.64–1.31] | 0.676 |
| Myocardial infarction | 4   | 3.9    | 1    | 1.1   | 0.99 [0.64–1.53] | 0.955 |
| Cerebrovascular accident | 4   | 3.2    | 0    | 0.8   | — | 0.301 |
| Renal failure         | 7   | 6.1    | 1    | 1.9   | 0.87 [0.67–1.13] | 0.447 |
| Acute kidney injury   | 111 | 114.5  | 34   | 30.5  | 1.03 [0.94–1.14] | 0.455 |
| Transfusion-related issue | 10 | 10.3   | 3    | 2.7   | 1.13 [0.31–4.12] | 0.856 |
| Return to the operating room | 98 | 98.1  | 31   | 30.9  | 1.01 [0.66–1.54] | 0.980 |
| Other bleeding complications | 2 | 1.6    | 0    | 0.4   | — | 0.465 |
| Haematocrit drop <30  | 138 | 135    | 33   | 36    | 0.98 [0.90–1.06] | 0.559 |
| Failure-to-wean       | 8   | 7.9    | 2    | 2.1   | 0.99 [0.72–1.35] | 0.936 |
| Re-intubation         | 5   | 5.5    | 2    | 1.5   | 1.11 [0.69–1.77] | 0.624 |
| Wound infections      | 3   | 3.2    | 1    | 0.8   | 1.05 [0.60–1.86] | 0.845 |
| Urinary tract infections | 66 | 70.3   | 23   | 18.7  | 1.07 [0.94–1.21] | 0.253 |
| Clostridium difficile infection | 4 | 4.7    | 2    | 1.3   | 1.19 [0.67–2.09] | 0.459 |
| Systemic sepsis       | 22  | 21.3   | 5    | 5.7   | 0.97 [0.81–1.16] | 0.747 |
| Organ-specific sepsis | 4   | 3.2    | 0    | 0.8   | — | 0.324 |
| Outpatient sepsis     | 9   | 8.7    | 2    | 2.3   | 0.97 [0.73–1.28] | 0.816 |
| New sepsis            | 23  | 22.5   | 5    | 5.5   | 0.98 [0.82–1.17] | 0.823 |
| Pulmonary embolus     | 1   | 1.6    | 1    | 0.4   | 1.58 [0.40–6.32] | 0.314 |
| Deep venous thrombosis| 2   | 2.4    | 1    | 0.6   | 1.19 [0.53–2.64] | 0.601 |
| PACU length of stay (min) | 108±62 | 114±65 | 3.0 [−12.7–2.4] | 0.182 |
| Total hospital length of stay (Day) | 7.5±18.8 | 5.0±22.7 | 2.5 [−1.5–6.5] | 0.225 |

*Major adverse cardiac event within 30 days
ing postoperative complications as predicted by the VASQIP model was not different in the normothermic and hypothermic patients (5.9%; p=0.930). Regardless of the trend in increasing the risk of death and perioperative complications, the actual frequency of all postoperative complications and mortality was similar between the hypothermic and the normothermic patients (Table 3). Cox regression model also demonstrated a similar hazard risk of death over an average of 140 months (follow-up period) for both normothermic and hypothermic patients regardless of heating the irrigation solutions (Figure 2).

In Group I, 1,369 patients received room temperature irrigation fluids between 2000 and 2013, while 264 patients between 2014 and 2016 received heated irrigation fluids. There was a temperature loss of 0.10°C in Group I, while body temperature increased by 0.32°C in Group II in which patients were operated after the heated irrigating fluids protocol was implemented (p<0.001) (Figure 3a). Despite decreasing the risk of hypothermia, there was no difference in the frequency of postoperative complications between the two groups (Table 4). Similarly, patients in whom warming blankets were applied (n=479 total; n=332 in Group 1 and n=16 in Group 2) had increases in body temperature by 0.22°C, while those in whom warming blankets were not used (n=1,153), had a temperature loss of 0.14°C (p=0.015) (Figure 3b).

From all potential factors that may have led to development of hypothermia <36°C, a multivariate regression model revealed that the duration of operation was an independent factor that affected the changes in body temperature during transurethral procedures, with a rise in 0.002°C per minute of procedures (Table 5). In addition, it was discovered that the implementation protocols for heating irrigation fluids in Group II significantly reversed the perioperative heat loss when compared to Group I using room temperature fluids (p<0.001).

**Discussion**

Anaesthesia literature has shown that the management of core body temperatures is vital to limit iatrogenic outcomes in patients, especially in the hospital setting (2, 10). According to these findings, advanced age, length of procedure and implementation of room temperature irrigation fluids during endoscopic procedures each increased the risk of perioperative hypothermia (3, 5, 6). Numerous studies also showed that decreased body temperatures increased the risk of postoperative complications (2, 10). As a result, many investiga-
tors have suggested that protocols such as warmed irrigation fluids should be considered when managing patients in the operating room. Few studies have evaluated this specifically in urologic patients and related procedures (6).

This study revealed that warmed irrigation fluids had a significant impact on the prevention of postoperative hypothermia, but failed to present any statistically significant changes in postoperative clinical outcomes. A randomised control trial by Pit et al. (5) found similar outcomes, though it exhibited a much smaller sample size (29 patients receiving warmed irrigation fluids) than this trial included (269 patients receiving warmed irrigation fluids. It is possible that the VA’s reactive warming strategies such as warming blankets, which were used both before and after 2014, were enough to prevent temperature decreases significantly enough to impact postoperative outcomes (8, 9).

A longer procedure duration has been also shown to result in larger body temperature losses (9, 11). However, these studies implemented room temperature irrigation fluids, while our study sample was exposed to warmed irrigation fluids during the length of the procedures, possibly explaining the rise in temperature with increasing procedure length within our patient sample. Also, less than one-third of the transurethral procedures at our institution were >60 minutes. Similar to other studies which showed low complication risks associated with transurethral procedures (9, 12), this study demonstrated no differences in complications due to perioperative hypothermia. The overall complication risk remained non-significant despite the average patient age being >70 years, which has been shown to put patients at a greater risk during endoscopic surgeries (13).

As a retrospective review, this study was also limited. One factor that cannot be underappreciated was the fact that the

| Table 4. Adverse postoperative outcomes secondary to irrigation fluid temperature selected |
|-----------------------------------------------|
| Group I (n=1,363) | Group II (n=269) | Odds Ratio |
|                  | Observed | Expected | Observed | Expected | [95% Confidence interval] | p       |
| Deaths within 30 days | 10 | 10 | 2 | 2 | 1.01 [0.22–4.65] | >0.999 |
| MACE-30 | 19 | 18 | 2 | 3.5 | 0.53 [0.12–2.29] | 0.538 |
| Cardiac arrest | 3 | 3.3 | 1 | 0.7 | 1.69 [0.19–16.3] | 0.514 |
| Myocardial infarction | 6 | 5 | 0 | 1 |                |        |
| Stroke | 4 | 3.3 | 0 | 0.7 | 1.00 [0.99–1.01] | <0.001 |
| Temperature <36°C | 332 | 291 | 16 | 57 | 0.20 [0.12–0.33] | 0.057 |
| Acute kidney injury | 126 | 118 | 15 | 23 | 0.58 [0.33–1.01] | 0.057 |
| Bleeding | 1 | 1.7 | 1 | 0.3 | 1.68 [0.42–6.71] | 0.303 |
| Transfusion | 13 | 11 | 0 | 2 | 0.99 [0.98–1.00] | 0.144 |
| Failure-to-wean | 7 | 8.4 | 3 | 1.6 | 1.20 [0.80–1.80] | 0.236 |
| Re-intubation | 6 | 6 | 1 | 1 | 0.98 [0.72–1.32] | >0.999 |
| Wound infections | 4 | 3.3 | 0 | 0.7 | 1.00 [0.99–1.01] | >0.999 |
| Urinary tract infections | 78 | 74 | 10 | 14 | 0.64 [0.33–1.25] | 0.236 |
| C.diff infection | 4 | 5 | 2 | 1 | 2.55 [0.46–14.0] | 0.259 |
| Systemic sepsis | 22 | 22 | 4 | 4 | 0.92 [0.31–2.69] | >0.999 |
| Organ non-specific sepsis | 4 | 3.3 | 0 | 0.7 | 1.00 [0.99–1.01] | >0.999 |
| Outpatient pneumonia | 10 | 9 | 1 | 2 | 0.51 [0.06–3.96] | >0.999 |
| New sepsis | 23 | 21 | 4 | 6 | 0.66 [0.23–1.94] | 0.631 |
| Venous thromboembolism | 4 | 4.2 | 1 | 0.8 | 1.00 [0.99–1.01] | >0.999 |

*Major adverse cardiac cerebral event within 30 days

| Table 5. Multivariate linear regression model in predicting the change in body temperature from its preoperative values |
|-----------------------------------------------|
| Coefficient | Std. error | Beta | T- Value | p | Lower bound | Upper bound |
| Constant | −0.515 | 0.210 | −2.450 | 0.014 | −0.928 | −0.103 |
| Body surface area (M²) | −0.131 | 0.067 | −1.957 | 0.051 | −0.262 | 0.0001 |
| Age (year) | 0.002 | 0.002 | 1.244 | 0.214 | −0.001 | 0.005 |
| Heating irrigation fluids | 0.428 | 0.047 | 9.126 | <0.001 | 0.336 | 0.521 |
| General anaesthesia | 0.013 | 0.055 | 0.241 | 0.809 | −0.094 | 0.120 |
| Duration of the procedure (minutes) | 0.002 | 0.001 | 4.485 | <0.001 | 0.001 | 0.002 |
method of both postoperative and preoperative body temperature recordings was not always consistent or available within the anaesthesia or nursing record system. For example, the method and location of collection may have been different depending on whether postoperative temperature recording was taken by the PACU nurses or the anaesthesiologist in the operating room. Anaesthesiologists tend to use forehead temperature stickers, whereas PACU nurses often utilise oral temperature or forehead skin recordings from electronic thermometers (14, 15). The current literature suggests that skin surface temperatures are, on average, 2°C lower than core temperatures, indicating that such routes of body surface temperature procurement do not accurately reflect the patient’s core temperature (9). Temperature measurement recorded from the rectal route is still considered the closest reading reflecting the patient’s core body temperature, and all other routes are generally compared to the rectal temperature (14). In comparison, oral thermometry obtains more accurate data, and attaining temperatures are, on average, 0.25°C lower than core temperatures (15). Such discrepancies offer a major limitation in the standardisation procedures of this study.

Although similar studies have evaluated the risk of hypothermia in within high-risk patients from the perspective of both anaesthesiologists and urologists, our study demonstrated a positive statistical effect with no clinical significance in terms of implementation of heated irrigation fluids when monitoring for postoperative complications (2, 15). Several studies have focused on the risks for specific medical complications due to the temperature drops during the perioperative period specifically in the urologic patient population; however, such results may have been influenced due to evaluating smaller sample sizes (1, 6). This trial further supports the previously identified hypotheses in the setting of a large sample size.

**Conclusion**

Rewarming strategies such as heated irrigation fluids effectively raise the body temperature and reduce the risk of developing perioperative hypothermia. Despite the reduced risk of hypothermia observed in patients who received warmed irrigation fluids, no change in postoperative complications within the urologic patient sample was observed. The relatively shorter duration of the transurethral procedures and lower overall risk of postoperative complications might have been the reasons for the benign findings related to hypothermia observed in this study. Heat-preserving policies that incorporate the use of warmed fluids for irrigation, especially in patients undergoing higher risk surgeries may be beneficial in decreasing unwanted events secondary to postoperative hypothermia.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Veterans Affairs Western New York Healthcare System on June 13, 2016 (Study number: 891664).

**Informed Consent:** The study was waived from obtaining a written informed consent from each individual participant due to the chart review nature of the study.

**Peer-review:** Externally peer-reviewed.

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