A clinical audit cycle of post-operative hypothermia in dogs

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Abstract

Objectives: Use of clinical audits to assess and improve perioperative hypothermia management in client-owned dogs.

Methods: Two clinical audits were performed. Audit 1: data were collected to determine the incidence and duration of perioperative hypothermia (defined rectal temperatures < 37.5˚C). The results from Audit 1 were presented to clinic staff and a consensus reached on changes to be implemented to improve temperature management. Following one month with the changes in place, Audit 2 was performed to assess performance.

Results: Audit 1 revealed a high incidence of post-operative hypothermia (88.9%) and prolonged time periods for animals to reach normothermia. Following discussion, a consensus was reached to: 1. measure rectal temperatures hourly post-operatively until a temperature ≥ 37.5˚C was achieved and 2. use a forced air warmer on all dogs until rectal temperature was ≥ 37˚5. After one month with the implemented changes, Audit 2 identified a significant reduction in the time to achieve a rectal temperature of ≥ 37.5˚C, with 75% of dogs achieving this goal by 3.5 hours (7.5 hours for Audit 1, p = 0.01). The incidence of hypothermia at extubation remained high in Audit 2 (97.3% with a rectal temperature < 37.5˚C).

Clinical significance: Post-operative hypothermia was improved through simple changes in practice, showing that clinical audit is a useful tool for monitoring post-operative hypothermia and improving patient care. Overall management of perioperative hypothermia could be further improved with earlier intervention.

Key words: anaesthesia, surgery, canine, temperature, normothermia

Introduction

The development of hypothermia during anaesthesia is a common occurrence in both humans and animals and has been associated with numerous side effects (Sessler 1997; Sessler 2001; Torossian 2008; Pottie et al. 2007; Redondo et al. 2012a; Redondo et al. 2012b; Waterman 1975; Evans et al. 1973). In humans, a temperature drop as small as 1˚C results in clinically important consequences. Hypothermia is associated with prolonged anaesthetic recovery, prolonged hospitalisation, increased surgical site infection, increased bleeding, impaired immunity, postoperative shivering and thermal discomfort (Scott and Buckland 2006; Sessler 2001; Torossian 2008; Kurz 2008; Kurz et al. 1995). Limited investigations in veterinary medicine have identified delayed anaesthetic recovery as consequences of post-operative hypothermia (Pottie et al. 2007; Redondo et al. 2012b). The relationship between hypothermia and wound infection rate remains unclear (Beal et al. 2000).

Despite clear evidence of negative outcomes associated with hypothermia in humans, the reported incidence of post-operative hypothermia is high, ranging between 53%-85%. However, the recent development and implementation of hypothermia management guidelines has created a mechanism for improvement (Sessler 2009; Torossian 2007; Alexander et al. 2008; Slotman et al. 1985; Vaughan et al. 1981; Stewart et al. 1987). In veterinary medicine, two large scale studies (n= 275 cats and 1525 dogs) reported an incidence of post-operative hypothermia (defined as an oesophageal temperature less than 38.5°C) of 83.6% of dogs and 96.7% of cats (Redondo et al. 2012a; Redondo et al. 2012b). There are currently no management guidelines or standards of care for peri-operative hypothermia.

Clinical audit is a quality improvement tool for evaluating and improving patient care (Rose et al. 2016; Burgess 2011; Mosedale 1998). As a standard of care in human medicine, clinical audit has been successful in generating continued improvements in patient care though its application in veterinary medicine is currently limited (Patel et al. 2013; Shonfeld et al. 2011; ; Rose et al. 2016).

In light of the evidence of adverse effects associated with post-operative hypothermia, and the suspected incidence of prolonged hypothermia in our clinic, we sought to quantify and reduce the incidence of post-operative hypothermia by performing a clinical audit.

Materials and methods

This prospective clinical audit was conducted at a small animal veterinary referral hospital. Client consent was not sought following discussion with the clinic manager and animal health technicians involved in data collection. This decision was based on the study design and potential outcomes: 1. there was no randomisation to treatment, 2. the proposed changes in patient care were not a radical departure from standard practice, 3. the interventions to improve care were not expected to increase risk of harm to the patient, 4. no identifying patient data were collected and 5. critical resources were not diverted from other patients during the study period.

Data were collected from a convenience sample of dogs scheduled for surgery with an American Society of Anesthesiologists physical (ASA) status of I/II. Exclusion criteria were aggression, procedures preventing rectal temperatures from being taken (such as perineal surgery or the placement of a purse string suture) and age < 6 months.

Rectal temperatures were measured with one of five digital thermometers (Accuflex Pro Model 016-639, Montreal, QC, Canada). Thermometers were tested for accuracy against a calibrated immersion thermometer (Fluke 80PK-22 SureGrip Immersion Temperature Probe connected to Fluke 561 Infrared Thermometer, Fluke Corp., Everett, WA, USA) using water baths at 33˚C and 36˚C. All thermometers were within 0.1˚C of water bath temperature. Temperature measurement was standardised: each thermometer was covered with a new device-specific plastic sheath prior to use and inserted 3 cm in to the rectum and held until a reading was obtained (Greer et al. 2007). The following temperatures were measured and recorded during both clinical audits at the following time points: baseline (prior to premedication), pre-induction (immediately before induction of general anaesthesia), pre-incision (time between completion of surgical preparation [clipping and aseptic cleaning] and start of surgery), and extubation. Post-operative temperatures were recorded on each dog's treatment sheet, which accompanied them to the recovery ward. Temperature information was also shared verbally during case transfer to the animal health technicians responsible for post-operative recovery.

The choice of anaesthetic protocol was at the discretion of the supervising veterinarian though all dogs were maintained with isoflurane carried in oxygen. All dogs were actively warmed during surgery with a forced air warmer attached to a proprietary blanket (FAW; Bair Hugger Model 505, 3M Canada, London, ON, Canada) set at 45˚C. Blanket placement was determined by surgical procedure. As per clinic policy, the FAW was switched on after surgical drapes were placed. All dogs were recovered in the same recovery ward. Room temperatures in the surgical preparation area, operating theatres and recovery ward were maintained between 20-22˚C.

The clinical audit was performed according to the "Plan", "Do", "Study", "Act" model (Burgess 2011; Rose et al. 2016). "Plan" was based on the initial perception that post-operative hypothermia was prolonged and sub-optimally managed. A strategy to collect data was agreed upon with the practice manager. Audit 1 was the period of data collection ("Do") during which standard clinic practice for post-operative temperature management was followed: each dog had a temperature recorded at extubation and then sporadically thereafter, varying with the preference of the technician and surgeon responsible for each case. A FAW was placed on all dogs in the recovery ward if their rectal temperature < 37˚C. However, the duration of placement and frequency of subsequent temperature readings was at the discretion of the technician and supervising veterinarian. Data on FAW use in the recovery ward was not recorded on the treatment sheet. Post-operative temperatures recorded on each dog's treatment sheet were collected until normothermia was achieved. Data collection took place from September 23, 2013 to October 22, 2013, inclusive. After completion of data collection during Audit 1, results were presented to animal health technicians. A discussion followed, facilitated by the authors ("Study", early December, 2013), with the goal of discussing peri-operative temperature and reaching a consensus on feasible changes in practice to try and reduce its incidence. Once a consensus was reached, staff were given approximately one month to implement the agreed changes (“Act”). A poster was displayed in the recovery area summarising the main recommendations to serve as a visual reminder.

The audit cycle continued with Audit 2 (January 6, 2014 to March 20, 2014) when the same methodology was used to assess the impact of implemented changes on post-operative temperature.

Statistical analyses

Data were assessed for normality (D’Agostino and Pearson omnibus normality test) and appropriate statistical tests applied. Population and baseline data were compared between audits with unpaired t-tests. Changes in temperature over time within an audit population were analysed with a one-way repeated measures ANOVA and Sidak post-hoc test. Data collected on the post-operative duration of hypothermia were analysed using time to event analysis with interval censoring (midpoint imputation) with normothermia as the event, and a Kaplan-Meier curve was plotted. Resulting curves were compared with an asymptotic log rank two-sample test. The elapsed times between perioperative phases were compared between audits with a Mann-Whitney test. P values < 0.05 were considered significant. Analyses were performed with free (R version 3.1.2 “Pumpkin Helmet”: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria) and commercial (Prism v 6.0f, GraphPad Software, San Diego, CA, USA) software. Reporting was conducted according to the SQUIRE guidelines for quality improvement reporting (Ogrinc et al. 2008).

Results

Twenty-seven dogs were included in Audit 1 and 37 dogs were included in Audit 2. Patient populations were similar between audits with a slight increase in median age (2 years) of dogs in audit 2 (Table 1). Over 80% of the pre-medication protocols included a combination of either hydromorphone hydrochloride (Hydromorphone HP 10; Sandoz) and acepromazine maleate (Atravet 10 mg Injectable;

Boehringer Ingelheim) Audit 1, n = 11; Audit 2, n = 20) or hydromorphone and dexmedetomidine hydrochloride (Dexdomitor; Zoetis), Audit 1, n = 14; Audit 2, n = 12). The most common induction agent was alfaxalone (Alfaxan; Jurox) (n = 26, Audit 1; n = 28, Audit 2). Close to 60% of dogs (Audit 1, n = 16; Audit 2, n = 22) underwent a hindlimb surgical procedure with similar numbers receiving epidural injections with a local anaesthetic (bupivacaine hydrochloride [Marcaine 0.5%; Hospira Healthcare Corporation] or mepivacaine hydrochloride [Carbocaine 2%; Hospira Healthcare Corporation]; Audit 1, n = 16; Audit 2, n = 21).

Rectal temperature decreased in both groups between baseline and extubation but did not differ between groups (Figure 1 and Table 1). The biggest drop in temperature was observed between pre-induction and pre-incision time points with a mean decrease in rectal temperature of 1.6˚C (Audit 1, $p < 0.0001$, 95% CI 1.3 to 2.0˚C) and 1.6˚C (Audit 2, $p < 0.0001$, 95% CI 1.1 to 2.1˚C). Significant, albeit smaller, temperature decreases occurred between the remaining time points. Pre-sedation to pre-induction: 0.7˚C (Audit 1, $p < 0.0001$, 95% CI 0.3 to 1.0˚C) and 0.7˚C (Audit 2, $p < 0.0001$, 95% CI 0.4 to 1.0˚C). Pre-incision to extubation: 0.5˚C (Audit 1, $p \leq 0.01$, 95% CI 0.1 to 0.8˚C) and 1.0˚C (Audit 2, $p < 0.0001$, 95% CI 0.6-1.4˚C). The time elapsed between perioperative phases was similar between audits (Table 2).

In Audit 1, 88.9% of animals were hypothermic on extubation. Post-operative temperature recording and warming was inconsistent with the elapsed time between temperature readings ranging between 1 and 14 hours (median, 2 hours). Following data collection during Audit 1, the consensus discussion identified the following potential areas for improvement: instituting a consistent definition of hypothermia within the clinic and setting a standard practice for temperature monitoring and management of hypothermic dogs in recovery. An important outcome of the consensus discussion between audits was the selection of 37.5˚C as the target for warming. This was selected as the temperature at which staff felt that dogs would be alert, able to ambulate and function appropriately, without the concern of the patient overheating (a FAW could remain in place for a while before normothermia was confirmed). While the discussion included peri-operative temperature management in general, a consensus was reached to focus on the post-operative period where it was felt that there was greater flexibility in changing patient management. Following the group discussion, the following changes were implemented: 1. measure rectal temperatures hourly post-operatively until a temperature ≥ 37.5˚C was achieved and 2. use a forced air warmer on all dogs until rectal temperature was ≥ 37˚5.

In Audit 2, 97.3% of animals were hypothermic on extubation and temperature collection was performed more consistently, ranging between every 1 and 5 hours (median, 1 hour). The median time to achieve normothermia was 3.5 hours for Audit 1 and 2.5 hours for Audit 2 (Figure 2). The time for 75% of the audit population to achieve normothermia differed by 4 hours (Audit 1; 7.5 hours, Audit 2; 3.5 hours). The Kaplan-Meier curves differed significantly (p = 0.01).

Discussion

In performing a cycle of two clinical audits, we initially identified a high incidence of post-operative hypothermia followed by achieving a decrease in incidence through simple changes in practice.

The mechanism of anaesthesia-induced hypothermia is well described (Matsukawa et al. 1995b; Sessler 1997). Essentially, anaesthetics allow an increased deviation in temperature from normothermia before a thermoregulatory response is triggered (increased interthreshold range) (Matsukawa et al. 1995a; Xiong et al. 1996). In conscious adult humans, the interthreshold range is usually 0.2˚C. During general anaesthesia (volatile and injectable agents) the interthreshold range increases to approximately 4˚C allowing a substantial decrease in core temperature before a thermoregulatory response occurs. The increase in interthreshold range results in vasodilation, leading to the redistribution of heat from the core to the periphery, with a rapid narrowing of the core to periphery temperature gradient as core temperature decreases. This heat redistribution accounts for the majority (approximately 80%) of hypothermia occurring over the first 1-3 hours of general anaesthesia (Matsukawa et al. 1995b). The next phase of hypothermia is a more gradual decrease in temperature as metabolic heat production does not compensate for heat loss to the environment. This results from a decrease in the basal metabolic rate by 30-40% and a reduction in muscle activity. Finally, if anaesthesia is sufficiently long (> 3-5 hours), a steady state is achieved between heat production and heat loss, which may result from a combination of external warming/ insulation or activation of vasoconstriction, or both. These three phases of hypothermia have been observed in veterinary medicine (Redondo et al. 2012a; Redondo et al. 2012b). Our data support these findings, showing the biggest temperature drop occurring in the hour or so following the induction of general anaesthesia (between pre-induction and pre-incision), with the magnitude of decrease (1.6˚C) reflecting that reported in humans and dogs (Cabell et al. 1997; Matsukawa et al. 1995b; Redondo et al. 2012b). Additionally, we identified a modest decrease in temperature associated with premedication and speculate that this resulted from decreased activity. Redondo et al. (2012) found that a longer pre-anaesthetic period, the time from premedication to induction of anaesthesia, was associated with lower core body temperatures at the end of anaesthesia (Redondo et al. 2012b). Considered together, this makes a case for avoiding extended pre-anaesthetic periods, once the desired effect(s) of premedication has been achieved.

Our findings support previous observations that post-operative hypothermia is extremely common (Redondo et al. 2012a; Redondo et al. 2012b; Waterman 1975). Comparisons between studies are limited by the varying definitions of hypothermia applied. For example, Redondo et al. (2012) reported 83.6% of dogs as hypothermic (Redondo et al. 2012b). The slightly higher incidence we observed (88.9%) could be explained by the difference in cut-off values for identifying hypothermia (37.5˚C versus 36.5˚C). It is unlikely that the high prevalence of epidural anaesthesia in the study population contributed substantially to the magnitude or time course of intra-operative hypothermia observed but may have contributed to prolongation of post-operative hypothermia. Epidural and spinal anaesthesia widen the interthreshold range but to a lesser extent than general anaesthetics (Emerick et al. 1994; Kurz et al.

1993). However the continued presence of epidural anaesthesia in the recovery period and consequent depression of thermoregulatory control and peripheral vasodilation may have offset attempts to warm our patients.

In dogs, the definition of perioperative hypothermia and subsequent classification (typically, mild, moderate, severe) is highly variable and somewhat arbitrary (Armstrong et al. 2005; Oncken et al. 2001). It would seem more appropriate to base a definition on an important outcome. Unfortunately, this approach is limited by the current evidence base available for important outcomes in dogs. With this current gap, we would suggest applying the well-established human range for mild hypothermia, a decrease in core body temperature of 1-3˚C below normal, which is based on numerous negative outcomes (Alexander et al. 2008; Kurz 2008; Scott and Buckland 2006; Sessler 2001; Torossian 2008). With a mean normal temperature of 37˚C in adult humans, this range represents a 2.7-8% decrease. Applying this percentage decrease to reported mean rectal temperatures in dogs, suggests a temperature range of 35.4 to 37.9˚C may be clinically important (Table 3). There is some evidence to support this: Pottie et al. (2007) demonstrated that dogs recovering from anaesthesia with a temperature between 35.5-35.9˚C took 17.6 ± 14.8 minutes (mean ± SD) to attain sternal recumbency, compared with 7.7 ± 3.8 minutes for those with temperatures above 38.0˚C. A rapid, complication-free recovery is the focus of Enhanced Recovery After Surgery, where perioperative care is optimised through a multimodal multidisciplinary approach (Hasiuk et al. 2015; Adamina et al. 2011; Kehlet 1997). Such an approach may be especially relevant in veterinary medicine given the high percentage of peri-sedation and -anaesthetic deaths occurring during the recovery period (Hasiuk et al. 2015; Brodbelt et al. 2008). Though there is an inherent inaccuracy associated with using rectal temperature as a proxy for core body temperature (pulmonary artery catheter temperature is the gold standard), 94% of rectal temperature measurements are within 0.5˚C of core temperature (Greer et al. 2007; Osinchuk et al. 2014).

Despite the improvements achieved in post-operative hypothermia during this clinical audit cycle, the high incidence of post-operative hypothermia observed is far from ideal. Interestingly, this incidence was high despite our use of active warming (FAW), whereas Redondo et al. (2012) used passive warming (blankets) (Redondo et al. 2012b). While difficult to directly compare between these studies, with inherent differences in populations, procedures and environments, this suggests that the efficacy of active warming is highly dependent on when it is applied. Our current policy, to wait until patient draping is complete before beginning FAW, based on concerns regarding bacterial contamination, offsets the potential gains of using FAW. The risk of surgical site infection associated with FAW is unclear and should be weighed against the increased risk of infection associated with hypothermia (Wood et al. 2014; Huang et al. 2003; Kurz et al. 1996; Sessler et al. 2011). Resistive heating blankets compare favourably to FAW and may offer a suitable alternative with a reduced infection risk (Wood et al. 2014; Negishi et al. 2003). The considerable drawback of waiting until surgical draping is completed before beginning FAW is that the time elapsed often exceeds the initial hypothermic phase when redistribution of blood flow has occurred. By this point, hypothermia is present. A more effective approach to temperature management would be to use a pre-determined temperature to trigger active warming (Alexander et al. 2008). In conjunction with an appreciation of the likely decrease in temperature associated with general anaesthesia, pre-warming patients prior to anaesthesia is increasingly applied in human medicine and a standard of care in some countries (Alexander et al. 2008; Torossian 2008; Sessler et al. 1995). Supporting evidence for this practice in veterinary medicine is currently limited, though further research is required (Rigotti et al. 2015).

The choice of 37.5˚C as the trigger for active warming of the patient was based on our consensus discussion, a compromise to assuage fears of overheating dogs. Further studies in the form of randomised controlled trials are required to determine the critical temperature(s) resulting in negative effects associated with hypothermia.

Furthermore, while clinical audits allow tracking of performance and facilitate improvement in patient care, they do not replace prospective controlled studies in determining the evidence base for best practice. Rather, clinical audit is a tool to assess adherence to best practice (Burgess 2011; Rose et al. 2016). A common weakness of clinical audit is the likelihood of observing the Hawthorne effect; where human behaviour is modified as a result of being observed (Edwards et al. 2013; Parsons 1974). When the outcome is improved patient care, we view this as a positive effect provided improvements in care can be sustained beyond the completion of the audit.

Conclusions

Our results show that simple changes in management, facilitated by clinical audit, can improve the time to attain normothermia following general anaesthesia. However, the incidence of perioperative hypothermia remained high and further work is required for improvement. The choice of interventions was based on consensus discussion within our practice and may not apply to other environments.

Table and figure legends

Table 1: Comparison of population and baseline data.

Table 2: Elapsed time in minutes between the stages of general anaesthesia.

Table 3: mean rectal temperatures for dogs reported in the literature and the calculated temperature decrease equivalent to the decrease associated with clinically important negative side effects in adult humans. [1]This temperature was calculated by taking the mean of the 3 treatment groups studied. Though reported as "preinduction" in the original paper, we have confirmed that the temperatures were measured prior to administration of premedication drugs (personal communication, Dr Sandra Perkowski).

Table 1: Comparison of population and baseline data.

Parameter	**Audit 1 (n= 27)**	**Audit 2 (n=37)**	**P value**	**95% confidence interval of mean difference**
Weight (kg)	24.1 ± 14.4	22.6 ± 14.0	0.67	-8.7 to 5.6
Age 9 (yrs)	4.2 ± 3.2	5.9 ± 3.2	0.03	0.1 to 3.4
Anaesthesia duration (min)	131.7 ± 39.0	118.8 ± 34.8	0.17	-31.4 to 5.6
Surgery duration (min)	59.4 ± 25.6	61.2 ± 23.9	0.79	-11.0 to 14.5
Pre-sedation temp (°C)	38.5 ± 0.5	38.5 ± 0.6	0.80	-0.2 to 0.3
Extubation temp (°C)	35.7 ± 1.3	35.1 ± 1.3	0.06	-0.03 to 1.3

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Table 2: Elapsed time in minutes between the stages of general anaesthesia.

Elapsed time in minutes	Audit 1	Audit 2	P value
Pre-sedation to pre-induction	75.0 (25.0-380.0)	69.5 (2.0-370.0)	0.93
Pre-induction to pre-incision	55.0 (25.0-105.0)	50.0 (25.0-90.0)	0.26
Pre-incision to extubation	90.0 (43.0-167.0)	85.0 (45.0-170.0)	0.69

Table 3: mean rectal temperatures for dogs reported in the literature and the calculated temperature decrease equivalent to the decrease associated with clinically important negative side effects in adult humans.

Mean rectal temperature (˚C)	**2.7-8.0% decrease (˚C)**	**Reference**
38.9	37.9-35.8	Duke
38.7	37.7-35.6	Redondo
38.5	37.5-35.4	This study
38.5	37.5-35.4[1]	Cabell

[1]This temperature was calculated by taking the mean of the 3 treatment groups studied. Though reported as “preinduction” in the original paper, we have confirmed that the temperatures were

measured prior to administration of premedication drugs (personal communication, Dr Sandra Perkowski).

Figure 1. Rectal temperature decreased throughout the peri-operative period in both audit groups but did not differ between groups at any time. Audit 1 is represented in grey, Audit 2 in black. Data are mean ± SD. **, p ≤ 0.01. ****, p < 0.0001

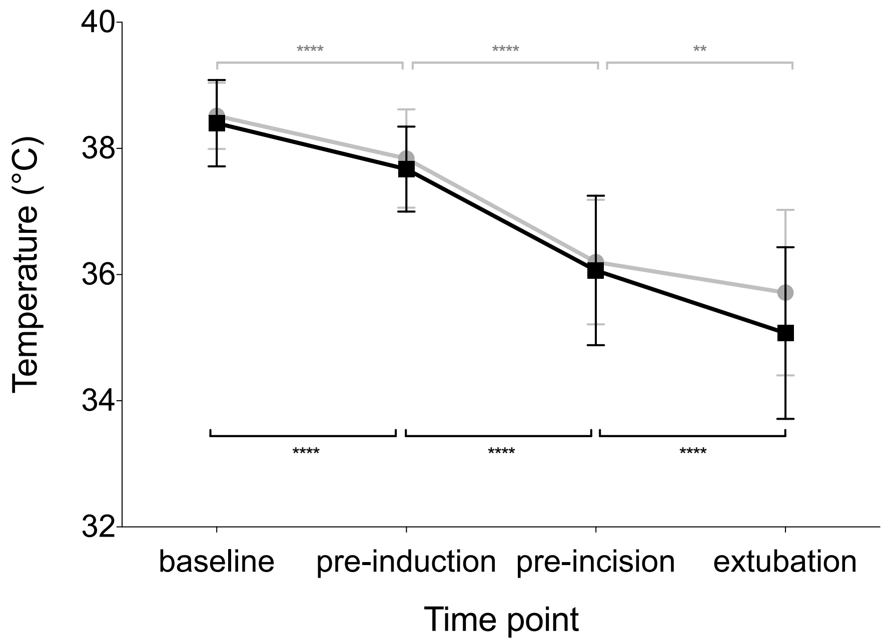
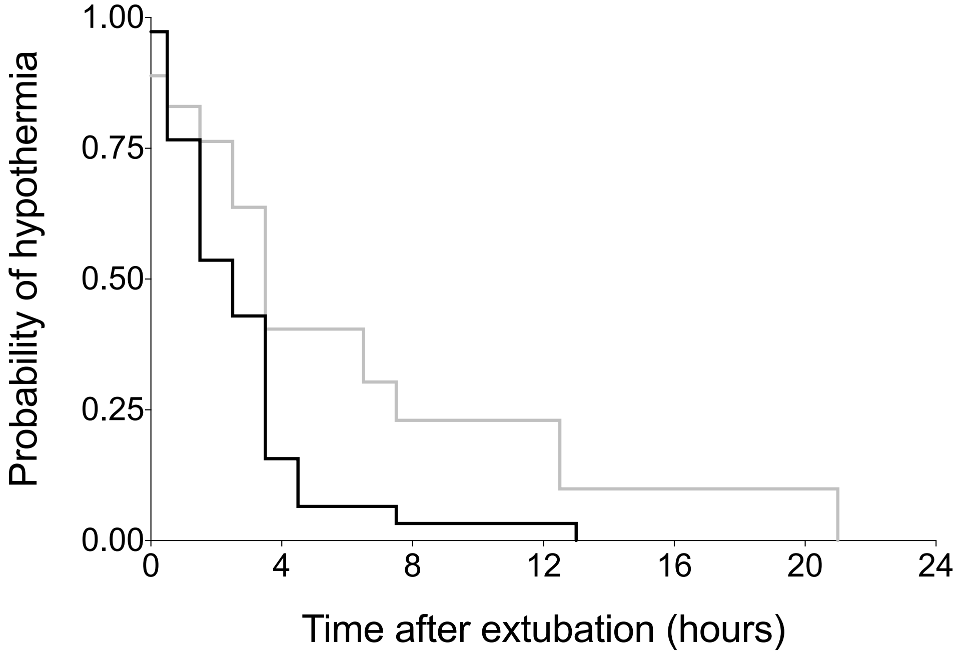


Figure 2. Kaplan-Meier Curves for peri-operative temperature data collected during Audits 1 (grey line) and 2 (black line). Curves differed significantly (p = 0.01) with approximately 75% of dogs achieving normothermia by 3.5 hours in Audit 2 compared with 7.5 hours during Audit 1.


Probability of hypothermia
1.00
0.75
0.50
0.25
0.00
0
4
8
12
16
20
24
Time after extubation (hours)

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