# Intraoperative anaesthetic complications in dogs undergoing general anaesthesia for thoracolumbar hemilaminectomy: a retrospective analysis

**Abstract**

**Objective** To establish the incidence of intra-operative anaesthetic complications in dogs undergoing general anaesthesia (GA) for thoracolumbar hemilaminectomy (TH), to determine whether GA duration affects incidence of intra-operative complications and to identify associations between intra-operative complications.

**Study design** Retrospective observational study.

**Animals** Two hundred and twenty four client owned dogs of various breeds undergoing TH for intervertebral disc extrusion.

**Methods** Anaesthetic records of dogs undergoing TH at a university teaching hospital between 2010-2016 were analysed. Data recorded included: breed, sex, bodyweight, GA duration, magnetic resonance imaging (MRI) under the same GA, pharmacological intervention to increase heart rate (PIHR), hypotension (MAP < 60mmHg for ≥ 10 minutes), mechanical ventilation (MV) for inadequate ventilation, hypothermia (oesophageal temperature < 37°C), oesophageal temperature ≥ 39°C (T ≥ 39°C), temperature trend, regurgitation and use of alpha-2 adrenoreceptor agonists, acepromazine, ketamine or lidocaine. Multivariate logistic regression models were fitted for hypothermia, T ≥ 39°C, hypotension and PIHR with forced inclusion of GA duration.

**Results** Hypothermia was the most common complication (63.8% incidence), followed by MV implementation (63.4%), hypotension (33.9%), PIHR (24.6%), T ≥ 39°C (20.5%) and regurgitation (4.9%). Multivariate models revealed MRI and hypotension were associated with an increased risk of hypothermia whilst increasing bodyweight, alpha-2 adrenoreceptor agonists and MV were associated with a reduced risk. Alpha-2 adrenoreceptor agonists and GA duration were associated with an increased risk of T ≥ 39°C whilst hypotension was associated with a reduced risk. PIHR and hypothermia were associated with an increased risk of hypotension whilst increased bodyweight was associated with a reduced risk. MV and hypothermia were associated with an increased risk of PIHR whilst increased bodyweight was associated with a reduced risk.

**Conclusions and clinical relevance** Increasing GA duration was associated with increased risk of oesophageal temperature ≥ 39°C but not any other intra-operative complications.

**Introduction**

Decompressive spinal surgery via hemilaminectomy is commonly performed in dogs with thoracolumbar intervertebral disc extrusion and is recommended when neurological signs are progressive, when deep pain sensation is absent or when the animal is non-ambulatory (Toombs & Waters 2002). The duration of general anaesthesia (GA) in these cases may be long, particularly if a large amount of disc material is extruded, multiple discs are affected or magnetic resonance imaging (MRI) is performed under the same GA.

Intra-operative anaesthetic complications include hypotension, bradycardia, body temperature derangements, regurgitation and major complications such as life-threatening arrhythmias, cardiac arrest and anaphylaxis. The incidence of intra-operative anaesthetic complications has been reported by several authors for dogs undergoing various procedures (Gaynor et al. 1999; Redondo et al. 2007; Brodbelt et al. 2008; Burns et al. 2014; Posner et al. 2014; McMillan & Darcy 2016) but not specifically for thoracolumbar hemilaminectomy (TH).

Literature concerning the incidence of intra-operative anaesthetic complications in relation to GA duration in dogs is relatively sparse. Prolonged GA has been associated with increased incidence of post-operative hypothermia (Redondo et al. 2012). Post-operative hypothermia can result in prolonged time to tracheal extubation (Kleine et al. 2014) and delayed recovery from anaesthesia (Clark-Price 2015). Prolonged recovery from GA is undesirable as it has been shown that almost 50% of canine anaesthesia-related mortalities occur post-operatively (Brodbelt et al. 2008). Additionally, prolonged GA duration has been shown to increase the risk of developing post-operative pulmonary complications in dogs undergoing laparotomy (Brainard et al. 2006) and spinal surgery (Java et al. 2009), increase the risk of developing post-operative wound infections (Beal et al. 2000), increase the risk of visible regurgitation (De Miguel García et al. 2013) and increase the risk of gastro-oesophageal reflux and post-operative vomiting (Torrente et al. 2017).

This study had three aims. The first aim was to establish the incidence of intra-operative complications in dogs undergoing GA for TH due to intervertebral disc extrusion at a university teaching hospital. The second aim was to determine whether GA duration affected the incidence of intra-operative complications and the third aim was to identify any associations between intra-operative complications via multivariate logistic regression analysis. The authors hypothesised that the incidence of intra-operative complications would increase with a greater duration of GA.

**Materials and methods**

This study was approved by the University of Liverpool Veterinary Research Ethics Committee (VREC445/RETH000765). Owner consent to allow anonymous use of patient clinical data was obtained upon admission to the hospital.

A retrospective analysis of the medical records database of the Small Animal Teaching Hospital (SATH) at the University of Liverpool was performed to identify all dogs that had been anaesthetised for spinal surgery between March 2010 and January 2016. Dogs were included in the study if their anaesthetic records contained the following data: heart rate (HR), mean arterial blood pressure (MAP), end tidal carbon dioxide concentration (PE´CO2), respiratory rate (*f*R), implementation of mechanical ventilation (MV) and oesophageal temperature. The anaesthesia and analgesia protocols employed were at the discretion of the individual anaesthetists involved in managing the cases.

Dogs were excluded from the study if they had cervical or lumbosacral spinal surgery or if they had spinal surgery for any reason other than intervertebral disc extrusion, such as spinal fracture or neoplasia. Further exclusion criteria included missing or illegible anaesthetic records. Some anaesthetic records contained incomplete data sets, particularly for blood pressure and temperature data. In these cases, each anaesthetic record was reviewed closely and the whole record was excluded if a data set was completely missing because one of the study aims was to assess associations between different intra-operative complications. However, to avoid losing valuable data and to account for missing data points during animal transport between rooms, anaesthetic records were still included if they contained at least two measurements (recorded at five-minute intervals) for every parameter described above.

The following data were recorded for each patient: breed, sex, bodyweight (kg), total GA duration (minutes), whether MRI was performed under the same GA [Yes or No (Y/N)]; premedication with alpha-2 adrenoreceptor agonists (Y/N) or acepromazine (Y/N) and intra-operative administration of alpha-2 adrenoreceptor agonists (Y/N), ketamine (Y/N) or lidocaine (Y/N). Anaesthetic records were checked for the following intra-operative complications: pharmacological intervention to increase HR, hypotension, hypothermia, oesophageal temperature ≥ 39°C, inadequate ventilation with implementation of MV and regurgitation.

Any dogs in which the anaesthetist administered pharmacological treatment to increase HR i.e. anti-cholinergics (atropine or glycopyrrolate), alpha-2 adrenoreceptor antagonists (atipamezole) or beta-2 adrenoreceptor agonists (terbutaline) for one of the following reasons were recorded: a HR of ≤ 60 beats minute-1, a sudden reduction in HR by ≥ 20% compared to the previous reading, development of a bradyarrhythmia deemed clinically significant by the anaesthetist or HR ≤ 60 beats minute-1 with concurrent hypotension (MAP < 60 mmHg). This definition was used in order to identify cases that the anaesthetist deemed to have clinically significant bradycardia or bradyarrhythmias that warranted treatment. Hypotension was defined as MAP < 60 mmHg for at least two consecutive recordings (≥ 10 minutes) in order to allow for one spurious blood pressure recording. Any interventions implemented for hypotension were also recorded. Any dogs in which MV was implemented for one of the following reasons: PE´CO2 ≥ 55mmHg (7.3 kPa), PE´CO2 ≤ 35mmHg (4.7 kPa), development of apnoea or an irregular respiratory pattern including panting were identified as cases of inadequate ventilation. This definition was used due to the potential haemodynamic consequences of MV and hence potential association with other anaesthetic complications. However, the decision as to whether or not to implement MV was at the discretion of the anaesthetist and the reason for implementing MV could only be presumed by examining the concurrent PE´CO2, *f*R and any clinical notes made on the anaesthetic records. Hypothermia was defined as core body temperature < 37°C as measured by an oesophageal temperature probe and any dog which had an oesophageal temperature measurement ≥ 39°C was also recorded. These thresholds reflect management of temperature derangements in dogs at our institution, with additional active warming implemented at < 37°C and active cooling implemented at ≥ 39°C during GA and in the recovery period. The overall temperature trend throughout GA (increase or decrease) and oesophageal temperature at the end of surgery were recorded. If the temperature trend was biphasic then the trend was defined as an increase or decrease depending on which of these accounted for the greatest proportion of the duration of GA. Regurgitation was defined as the presence of visible gastric material in the oropharynx or nares. Any major complications were also recorded and were defined as any complication that resulted in an immediate or sustained threat to life e.g. cardiac arrest, anaphylaxis, haemorrhage warranting fluid resuscitation and cardiac arrhythmias that warranted specific intervention.

Statistical analyses were performed using SPSS for Macintosh (IBM SPSS statistic version 22; SPSS, IL, USA). Each intra-operative complication was recorded as a dichotomous variable (Y/N) as to whether the complication occurred in each dog at any point during the GA. The time at which each complication first occurred in each dog (total number of minutes elapsed from GA induction) was also recorded. Incidence of each intra-operative complication was then calculated as a percentage of dogs presenting with that complication at any point during the GA. GA duration was divided into five categories: 0 - 60 minutes, 61 - 120 minutes, 121 - 180 minutes, 181 - 240 minutes and ≥ 241 minutes to allow data pertaining to when complications first occurred to be displayed graphically. Statistical analysis of this data was performed using Chi-square test of homogeneity or Fisher's exact tests with post hoc analysis (pairwise comparisons using the z-test of two proportions with a Bonferroni correction) to identify any statistically significant differences in proportion of dogs presenting with a complication in each of these GA duration time groups. A *p*-value of < 0.05 was considered to indicate statistical significance. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed as well as visual assessment of histograms to assess for normality. Univariate logistic regression analyses were performed initially to identify variables associated with each intra-operative anaesthetic complication identified (hypothermia, oesophageal temperature ≥ 39°C, hypotension, pharmacological intervention to increase HR and regurgitation), using Pearson Chi-square or Fisher's exact tests for categorical data and independent t-tests or Mann-Whitney U tests for parametric and non-parametric continuous data respectively. A *p*-value of < 0.05 was considered to indicate statistical significance. Any variables with *p* < 0.25 identified in univariate analyses were selected for entry into multivariate logistic regression models. Four multivariate models were constructed for hypothermia, oesophageal temperature ≥ 39°C, hypotension and pharmacological intervention to increase HR. A stepwise selection procedure was used to determine the final models with forced inclusion of GA duration as a continuous variable (one-minute intervals from GA induction at time zero) in each of the final models. Cox & Snell and Nagelkerke R-squared tests were performed to quantify the proportion of explained variance in the models and models with the highest R-squared values were chosen. The overall fit of the final models was ascertained using the Hosmer and Lemeshow goodness of fit test. Receiver operating characteristic (ROC) curves were constructed for the final models with area under the curve (AUC) and 95% confidence intervals calculated.

**Results**

A total of 265 dogs that underwent TH at the SATH during the period examined were identified from the initial database search. Of these, 22 had missing or incomplete anaesthetic records, 15 did not have appropriate owner consent, three were duplicate records and one underwent surgery due to a compressive spinal tumour. This resulted in 224 anaesthetic records that met the inclusion criteria.

Demographic data are presented in Table 1. The mean **±** standard deviation bodyweight and age of dogs was 12.9 **±** 8.8 (95% CI: 11.7 - 14) kg and 76 **±** 30 (95% CI: 72 - 80) months respectively. The GA duration was 289 **±** 79 (95% CI: 279 - 299) minutes, ranging from 110 to 645 minutes. A total of 126 out of 224 dogs (56.3%) received an MRI scan under the same GA. Overall incidence of intra-operative complications is reported in Table 2. The most common pharmacological intervention to increase HR was anti-cholinergic treatment [51 of 55 dogs (92.7%)]. Atipamezole was administered to six of 55 dogs (10.9%) and terbutaline to one of 55 dogs (1.8%). Some dogs received more than one treatment to increase HR. Twenty-four out of 55 dogs were treated for a HR ≤ 60 beats minute-1 with concurrent hypotension (MAP < 60 mmHg) (43.6%), 13 were treated due to development of a bradyarrhythmia deemed clinically significant by the anaesthetist (23.6%), 12 were treated for a HR ≤ 60 beats minute-1 (21.8%) and six were treated due to sudden decrease in HR ≥ 20% from the previous recording (10.9%). The HR at the time of pharmacological intervention was 47 ± 14 (95% CI: 43 - 51) beats minute-1, ranging from 15 to 76 beats minute-1.

Of the 76 hypotensive dogs, 68 were treated (89.5%). The most common treatments implemented were volatile agent reduction in 54 dogs (79.4%) and crystalloid fluid administration in 25 dogs (36.8%). Colloids were administered to 19 dogs (27.9%) and sympathomimetic drugs (ephedrine, dopamine, dobutamine or medetomidine) were administered to 13 dogs (19.1%). Of the 142 dogs in which MV was implemented, 96 were due to PE´CO2 ≥ 55mmHg (67.6%), 27 were due to PE´CO2 ≤ 35mmHg (19%), six were due to development of apnoea (4.2%) and six were due to development of an irregular respiratory pattern such as panting (4.2%). In the remaining seven dogs in which MV was implemented (4.9%), the reason for this was not immediately clear from the anaesthetic record due to missing PE´CO2 and *f*R readings immediately prior to MV implementation.

Three major complications were identified. One dog suffered from cardiac arrest after 240 minutes of GA and two dogs developed severe bradyarrhythmias that warranted specific intervention after 140 minutes and 195 minutes respectively. The dog that developed cardiac arrest was successfully resuscitated but the cause of arrest was unknown. Of the two dogs with bradyarrhythmias, one was later confirmed to have sick sinus syndrome and the other developed multiple intra-operative arrhythmias that responded to anti-cholinergic treatment. As the incidence of major complications was very low, no meaningful analysis of risk factors could be performed.

Data pertaining to the time at which each intra-operative complication was first observed are presented in Figure 1. Ninety-five of the 143 hypothermic dogs (66.4%) had an MRI scan performed under the same GA. There were no differences in the number of dogs in which regurgitation was first observed in any of the time groups (*p* = 0.71).

The results of the univariate logistic regression analyses are presented in Table S1 and results of the multivariate logistic regression models are presented in Table 3. The incidence of regurgitation was too low to construct a multivariate model for this complication and no significant associations were identified on univariate analyses.

Implementation of MV, alpha-2 adrenoreceptor agonist premedication and increased bodyweight were associated with a reduced risk of hypothermia, whereas hypotension and MRI performed under the same GA were associated with an increased risk. The GA duration was not significantly associated with the risk of hypothermia.

An increased bodyweight was associated with a reduced risk of hypotension, whereas pharmacological intervention to increase HR and hypothermia were associated with an increased risk. The GA duration was not significantly associated with the risk of hypotension.

An increased bodyweight was also associated with a reduced risk of pharmacological intervention to increase HR, whereas implementation of MV and hypothermia were associated with an increased risk. The GA duration was not significantly associated with the risk of pharmacological intervention to increase HR.

Hypotension was associated with a reduced risk of an oesophageal temperature ≥ 39°C, whereas GA duration and alpha-2 adrenoreceptor agonist premedication were associated with an increased risk. Of the 46 dogs that developed an oesophageal temperature ≥ 39°C, 17 reached a maximum temperature of 39 - 39.2°C (37%), 17 reached a maximum temperature of 39.3 - 39.6°C (37%), nine reached a maximum temperature of 39.7 - 40°C (19.5%) and three reached a maximum temperature of ≥ 40.1°C (6.5%). The highest recorded temperature was 41°C, but this dog was hyperthermic at the start of surgery with a pre-operative rectal temperature recording of 41.2°C. However, another dog reached an intra-operative oesophageal temperature of 40.5°C despite a pre-operative rectal temperature of 37.2°C and the other reached an intra-operative temperature of 40.1°C despite an initial oesophageal temperature reading of 38.5°C.

**Discussion**

This study investigated the incidence of intra-operative anaesthetic complications in dogs undergoing TH, whether GA duration was associated with the incidence of these complications and whether there were any statistical associations between intra-operative complications. We identified a 0.5% increase in risk of reaching an oesophageal temperature ≥ 39°C for every one-minute increase in GA duration in dogs undergoing TH for intervertebral disc extrusion. Therefore, after 200 minutes of GA duration, the risk of developing an oesophageal temperature ≥ 39°C doubles in this subpopulation. The GA duration was not significantly associated with any other intra-operative complication in the present study.

To the authors' knowledge, this is the first report of increased risk of an oesophageal temperature ≥ 39°C with increased GA duration in dogs. Whether this is a unique occurrence with TH is as of yet unknown and further studies in different canine populations undergoing different surgical procedures are warranted. A trend for temperature to increase occurred in 94.2% dogs in this study and if oesophageal temperature continued to increase above 39°C, this would have been likely to increase the risk of developing hyperthermia. Hyperthermia can be caused by pyrogens, hypermetabolic disease such as malignant hyperthermia or may be iatrogenic due to drug-impaired thermoregulation or excessive environmental heat exposure (Grimm 2015; Haskins 2015). Severe hyperthermia (> 41.6°C) can result in reduced cellular integrity, impaired enzyme function and subsequent cell death, resulting in electrolyte and acid-base derangements, disseminated intravascular coagulation, multiple organ damage (Miller 2009) and in some cases, death (Thomson et al. 2014). None of the dogs in this study reached a core temperature > 41.6°C and the highest recorded temperature was 41°C. The consistent finding of a temperature trend increase in this study population and the fact that increased GA duration was associated with a significantly increased risk of an oesophageal temperature ≥ 39°C warrants consideration of earlier discontinuation of active warming in these cases and perhaps implementation of active cooling methods, particularly if alpha-2 adrenoreceptor agonists have been administered as this was also found to be associated with an increased risk of an oesophageal temperature ≥ 39°C.

Reports of hyperthermia during veterinary anaesthesia are rare. Three out of 1281 dogs anaesthetised for various procedures developed severe hyperthermia (> 41°C) in one study (Redondo et al. 2007). Although only one dog reached a temperature of 41°C in the present study, 20.5% of dogs developed an oesophageal temperature ≥ 39°C. The difference in reported incidence may therefore be due to different subpopulations of dogs undergoing different surgical procedures or that a different temperature threshold was used in the present study. The chosen upper temperature threshold in our study reflects temperature management of anaesthetised dogs at our institution, with active cooling implemented once body temperature ≥ 39°C. This is partly pre-emptive due to reduced ability to thermoregulate under GA (Grimm 2015) and in the authors' experience, development of clinical signs associated with hyperthermia e.g. panting, are seen to develop at ≥ 39°C. However, Redondo et al. 2007 defined canine hyperthermia > 39.2°C.

Hypothermia is a common complication of canine GA and is associated with prolonged time to recovery (Pottie et al. 2007; Kleine et al. 2014). Hypothermia may result in development of bradycardia (Palo et al. 2000) and may enhance anaesthesia-induced depression of the baroreflex function (Tanaka et al. 2001). Hypothermia has also been associated with delayed clot formation (Taggart et al. 2012). Hypothermia was the most common intra-operative complication reported in this study with 63.8% of dogs affected. This is higher than that reported by Redondo et al. 2007, where 4.8% of 1281 dogs anaesthetised for various procedures developed hypothermia (< 37.5°C). In a later study of 1525 dogs, the incidence of hypothermia at the end of GA was 51.5% for mild hypothermia (36.5 - 38.49°C), 29.3% for moderate hypothermia (34 - 36.49°C) and 2.8% for severe hypothermia (< 34°C) (Redondo et al. 2012). The severity of hypothermia was not classified in the present study and a different definition of hypothermia was used (< 37°C). A recent canine study defined normothermia as 37 - 39°C (Kropf & Hughes 2018) and canine hypothermia has previously been defined as a core body temperature < 37°C (Armstrong et al. 2005). The chosen threshold for hypothermia in the present study reflects management of hypothermia in dogs at our institution, with additional active warming implemented when body temperature < 37°C in the intra-operative and post-operative period. Although active warming methods were not evaluated specifically in this study, standard intra-operative temperature management at our institution involves the use of a heat and moisture exchanger and a heated mat (HotDog® Patient Warming System, Augustine Surgical) in every patient plus forced warm air blankets or fluid warming devices as required.

Bradycardia under GA may be associated with the development of bradyarrhythmias and hypotension (Posner et al. 2014). Intra-operative hypotension has been associated with a reduction in intra-operative somatosensory and motor evoked potentials with resultant post-operative paraparesis in people undergoing thoracic spinal surgery (Zuckerman et al. 2014). Intra-operative hypotension can impair auto-regulation of blood flow to vital organs and may result in renal or cerebral dysfunction (Haskins 1987; Mason 1993) with poor long-term outcome (Walsh et al. 2013). However, neither occurrence, duration nor severity of intra-operative hypotension were significantly associated with whether dogs regained motor and urinary function following thoracolumbar spinal surgery in one recent study (Dixon & Fauber 2017).

Hypotension was observed in 33.9% of dogs in the present study. This is similar to that reported by Redondo et al. 2007 where 37.9% of anaesthetised 1281 dogs developed hypotension. The same threshold for hypotension was used and the incidence was very similar to the present study despite mean GA duration being much shorter in the study by Redondo et al. 2007. However, an earlier study reported only 7% incidence of hypotension in 2556 anaesthetised dogs (Gaynor et al. 1999). These authors used the same MAP threshold for hypotension but GA duration was not reported. The reason for the difference in incidence of hypotension between both studies is unclear and may reflect differences in anaesthetic drugs used or in how blood pressure was measured.

Intra-operative pharmacological intervention to increase HR was implemented in 24.6% of dogs in the present study. This is lower than that reported by Posner et al. 2014 where 65% of 157 dogs undergoing cervical and thoracolumbar spinal surgery developed bradycardia requiring treatment with an anti-cholinergic drug. Additionally, intra-operative bradycardia was reported in 36.3% of 1281 dogs (Redondo et al. 2007) and only 19% of 2556 dogs (Gaynor et al. 1999) anaesthetised for various procedures at two university hospitals. The difference in incidence in this study compared to other studies may be due to differences in definition of bradycardia and treatment intervention points. The definition in this study was chosen in an attempt to only identify cases where haemodynamically significant bradycardia or bradyarrhythmias occurred that warranted treatment and to take into consideration that different anaesthetic protocols were used and different anaesthetists may have different minimum acceptable heart rates.

Even though administration of mu agonist opioids has previously been shown to induce vagally-mediated bradycardia (Lamont & Mathews 2007), the use of pre-operative and intra-operative mu agonist opioids was not considered as a separate variable in this study because every dog received at least one mu agonist opioid (most commonly methadone or fentanyl) and this was therefore considered unlikely to significantly affect our results.

Regurgitation under GA may result in oesophagitis, oesophageal stenosis or aspiration pneumonitis (Rodríguez-Alarcón et al. 2015). The incidence of regurgitation in the present study was 4.9% and a multivariate model was not constructed. Reported incidence of regurgitation in dogs under GA varies between 0.42 - 5.55% (Galatos & Raptopoulos 1995; Wilson et al. 2005; Wilson et al. 2006; Lamata et al. 2012; De Miguel García et al. 2013). Risk of regurgitation was found to significantly increase with GA duration in a retrospective study with 5736 dogs (De Miguel García et al. 2013). This study used a similar definition of regurgitation to our study but the mean GA duration was not reported to allow a direct comparison. GA duration was not associated with regurgitation in the present study. However, although not statistically significant, more dogs first developed regurgitation after ≥ 241 minutes GA duration than in any other time group. The difference in findings between the two studies may reflect the different surgical procedures performed, the lower number of dogs in our study or lower mean bodyweight of dogs in our study, as increased bodyweight has been identified as a risk factor for regurgitation (Lamata et al. 2012; De Miguel García et al. 2013).

Increased bodyweight was found to be associated with a reduced risk of developing hypothermia, hypotension and pharmacological intervention to increase HR in this study. This is unsurprising as relative exposed body surface area decreases with increasing body size and therefore less body surface is exposed to allow heat loss by radiation. Higher total body surface area was found to be associated with a higher temperature at the end of anaesthesia and was therefore considered a protective factor against the development of hypothermia in dogs (Redondo et al. 2012). As hypothermia can lead to the development of bradycardia (Palo et al. 2000), it is possible that the protective effect of increased bodyweight on hypothermia may therefore also be protective against the development of bradycardia. The results of our study demonstrated that hypothermia more than doubles the risk of requiring pharmacological intervention to increase HR. It is also possible that the reduced incidence of pharmacological intervention to increase HR and hypotension in larger dogs may be inter-related. Bradycardia under GA may reduce cardiac output which could result in hypotension (Mazzaferro & Wagner 2001; Kruse-Elliott 2002). This is supported by the finding in this study that both pharmacological intervention to increase HR and hypothermia were associated with more than double the risk of developing hypotension. Redondo et al. (2007) reported simultaneous bradycardia and hypotension in only 2.9% of 959 dogs but the present study was not designed to assess simultaneous occurrence of these two complications in individual dogs.

Alpha-2 adrenoreceptor agonist premedication was associated with a decreased risk of hypothermia and increased risk of an oesophageal temperature ≥ 39°C in this study. As alpha-2 adrenoreceptor agonists cause peripheral vasoconstriction, this can be expected to result in reduced core to peripheral heat redistribution and hence reduced redistribution hypothermia (Vainionpää et al. 2013). Similar results were demonstrated in another study where dogs premedicated with alpha-2 adrenoreceptor agonists prior to GA for MRI were found to have higher temperatures at the end of the procedure compared to those that did not receive these drugs (Khenissi et al. 2017).

The occurrence of intra-operative hypotension was associated with an increased risk of developing hypothermia in this study. One possible explanation for this association is that hypotension under GA may occur due to vasodilation secondary to administration of various drugs including acepromazine and inhalational volatile agents (Mazzaferro & Wagner 2001). Peripheral vasodilation is likely to increase peripheral heat redistribution and hence increase the risk of developing hypothermia. This would also support the finding that hypotension was associated with a decreased risk of developing an oesophageal temperature ≥ 39°C, but this is speculative.

Performing MRI under the same GA more than doubled the risk of developing hypothermia in this study. Maintenance of normothermia in animals undergoing MRI can be challenging due to the requirement for a low environmental temperature to keep the magnet cool and lack of availability of non-magnetic and electrically non-conductive active warming devices (Khenissi et al. 2017).

There are several limitations to the present study. Due to the retrospective nature of the study, dogs were anaesthetised by different anaesthetists and the anaesthetic protocol was not standardised. Management of intra-operative complications was at the discretion of each anaesthetist, so intervention points and treatment choices were variable. Additionally, valuable data were lost due to incomplete or missing anaesthetic records. For example, temperature data were often missing for the first 30 - 60 minutes of GA as temperature was not measured during MRI and surgical preparation (primarily due to lack of availability of an MRI compatible temperature probe). Therefore, data pertaining to the timing of first occurrence of complications could be inaccurate. In seven dogs in which MV was implemented, the reason was unclear due to missing PE´CO2 and *f*R readings. Perhaps these data should have been excluded from statistical analyses but were considered unlikely to significantly affect our results. Additionally, different definitions for complications were used in this study compared to previous studies, making comparison of incidence of intra-operative complications more difficult. Our study examined intra-operative complications and reported statistical relationships between complications. However, it is unable to determine the cause and effect relationships between variables. Additionally, odds ratios have been reported from the multivariate models but it was not possible to establish baseline risks which makes it difficult to quantify their clinical significance. No post-operative follow up was performed so the potential impact of intra-operative anaesthetic complications and GA duration on incidence of post-operative complications or long term outcome is unknown.

In conclusion, increased GA duration was associated with an increased risk of developing an oesophageal temperature ≥ 39°C in dogs undergoing TH for intervertebral disc extrusion at our institution but increased GA duration was not significantly associated with the risk of any other intra-operative complications. Further prospective studies in different canine populations are required to determine the clinical significance of an oesophageal temperature ≥ 39°C in dogs undergoing GA, whether development of an intra-operative oesophageal temperature ≥ 39°C is unique to dogs undergoing prolonged TH and to establish optimum management to prevent development of hyperthermia in these cases.

**References**

Armstrong SR, Roberts BK, Aronsohn M (2005) Perioperative hypothermia. J Vet Emerg Crit Care 15(1), 32-37.

Beal MW, Brown DC, Shofer FS (2000) The Effects of Perioperative Hypothermia and the Duration of Anesthesia on Postoperative Wound Infection Rate in Clean Wounds: A Retrospective Study. Vet Surg 29, 123-127.

Brainard BM, Alwood AJ, Kushner LI et al. (2006) Postoperative pulmonary complications in dogs undergoing laparotomy: anesthetic and perioperative factors. J Vet Emerg Crit Care 16(3), 184-191.

Brodbelt DC, Blissitt KJ, Hammond RA et al. (2008) The risk of death: the Confidential Enquiry into Perioperative Small Animal Fatalities. Vet Anaesth Analg 35, 365-373.

Burns BR, Hofmeister EH, Brainard BM (2014) Anesthetic complications in dogs undergoing hepatic surgery: cholecystectomy versus non-cholecystectomy. Vet Anaesth Analg 41, 186-190.

Clark-Price S (2015) Inadvertent Perianesthetic Hypothermia in Small Animal Patients. Vet Clin Small Anim 45, 983-994.

De Miguel García C, Pinchbeck GL, Dugdale A, Senior JM (2013) Retrospective Study of the Risk Factors and Prevalence of Regurgitation in Dogs Undergoing General Anaesthesia. Open Vet Sci J 7, 6-11.

Dixon A, Fauber AE (2017) Effect of anesthesia-associated hypotension on neurologic outcome in dogs undergoing hemilaminectomy because of acute, severe thoracolumbar intervertebral disk herniation: 56 cases (2007–2013). J Am Vet Med Assoc 250, 417-423.

Galatos AD, Raptopoulos D (1995) Gastro-oesophageal reflux during anaesthesia in the dog: effect of age, positioning and type of surgical procedure. Vet Rec 137, 513-516.

Gaynor JS, Dunlop CI, Wagner AE et al. (1999) Complications and Mortality Associated With Anesthesia in Dogs and Cats. J Am Anim Hosp Assoc 35, 13-17.

Grimm KA (2015) Perioperative Thermoregulation and Heat Balance. In: Lumb and Jones' Veterinary Anesthesia and Analgesia (5th edn) Grimm KA, Lamont LA, Tranquilli WJ et al. (eds). Wiley Blackwell, Iowa, USA. pp 371-379.

Haskins SC (1987) Monitoring the anesthetized patient. In: Principles and Practice of Veterinary Anesthesia, Short CE (ed). Williams & Wilkins, Maryland, USA. pp 455-477.

Haskins SC (2015) Monitoring Anesthetized Patients. In: Lumb and Jones' Veterinary Anesthesia and Analgesia (5th edn) Grimm KA, Lamont LA, Tranquilli WJ et al. (eds). Wiley Blackwell, Iowa, USA. pp 86-113.

Java MA, Drobatz KJ, Gilley RS et al. (2009) Incidence of and risk factors for postoperative

pneumonia in dogs anesthetized for diagnosis or treatment of intervertebral disk disease. J Am Vet Med Assoc 235, 281-287.

Khenissi L, Covery-Crump G, Knowles T et al. (2017) Do heat and moisture exchangers in the anaesthesia breathing circuit preserve body temperature in dogs undergoing anaesthesia for magnetic resonance imaging? Vet Anaesth Analg 44, 452-460.

Kleine S, Hofmeister E, Egan K (2014) Multivariable analysis of anesthetic factors associated with time to extubation in dogs. Res Vet Sci 97, 592-596.

Kropf J, Hughes JML (2018) Effects of midazolam on cardiovascular responses and isoflurane requirement during elective ovariohysterectomy in dogs. Irish Vet J 71(26), 1-10.

Kruse-Elliott KT (2002) Cardiac dysrhythmias. In: Veterinary Anesthesia and Pain Management Secrets. Greene SA (ed). Hanley & Belfus, Pennsylvania, USA. pp 141-152.

Lamata C, Loughton V, Jones M et al. (2012) The risk of passive regurgitation during general anaesthesia in a population of referred dogs in the UK. Vet Anaesth Analg 39, 266-274.

Lamont LA, Mathews KA (2007) Opioids, nonsteroidal anti-inflammatories, and analgesic adjuvants. In: Lumb & Jones’ Veterinary Anesthesia and Analgesia (4th edn) Tranquilli, WJ, Thurmon JC and Grimm KA (eds). Blackwell Publishing, Iowa, USA. pp 241-271.

Mason DE (2003) Urinary System. In: Textbook of Small Animal Surgery (3rd edn) Slatter D (ed). Saunders, Pennsylvania. pp 2545-2552.

Mazzaferro E, Wagner AE (2001) Hypotension During Anesthesia in Dogs and Cats: Recognition, Causes, and Treatment. Comp Cont Educ Pract Vet 23(8), 728-737.

McMillan M, Darcy H (2016) Adverse event surveillance in small animal anaesthesia: an intervention based, voluntary reporting audit. Vet Anaesth Analg 43, 128-135.

Miller JB (2009) Hyperthermia and Fever. In: Small Animal Critical Care Medicine. Silverstein DC and Hopper K (eds). Saunders Elsevier, Missouri, USA. pp. 21-26.

Palo M, Lauri T, Timisjarvi J (2000) Effects on dogs of surface-induced hypothermia and rewarming on the right heart function and pulmonary circulation. Eur J Appl Physiol 81, 391-396.

Posner LP, Mariani CL, Swanson C et al. (2014) Perianesthetic morbidity and mortality in dogs undergoing cervical and thoracolumbar spinal surgery. Vet Anaesth Analg 41, 137-144.

Pottie RG, Dart CM, Perkins NR et al. (2007) Effect of hypothermia on recovery from general anaesthesia in the dog. Aust Vet J 85, 158-162.

Redondo JI, Rubio M, Soler G et al. (2007) Normal Values and Incidence of Cardiorespiratory complications in Dogs During General Anaesthesia. A Review of 1281 Cases. J Vet Med 54, 470-477.

Redondo JI, Suesta P, Serra I et al. (2012) Retrospective study of the prevalence of postanaesthetic hypothermia in dogs. Vet Rec 171(15), 374-378.

Rodríguez-Alarcón CA, Berinstain-Ruiz DM, Riveira-Barreno R et al. (2015) Gastroesophageal reflux in anesthetized dogs: a review. Rev Colomb Cienc Pecu 28, 144-155.

Taggart R, Austin B, Hans E et al. (2012) In vitro evaluation of the effect of hypothermia on coagulation in dogs via thromboelastography. J Vet Emerg Crit Care 22, 219-224.

Tanaka M, Nagasaki G, Nishikawa T (2001) Moderate Hypothermia Depressed Arterial Baroreflex Control of Heart Rate during, and Delays Its Recovery after, General Anesthesia in Humans. Anesthesiology 95, 51-55.

Thomson SM, Burton CA, Armitage-Chan EA (2014) Intra-operative hyperthermia in a cat with a fatal outcome. Vet Anaesth Analg 41(3), 290-296.

Toombs JP, Waters DJ (2002) Intervertebral disc disease. In: Textbook of Small Animal Surgery. Slatter DH (ed). Saunders, Philadelphia, USA. pp 1202–1203.

Torrente C, Vigueras I, Manzanilla EG et al. (2017) Prevalence of and risk factors for intraoperative gastroesophageal reflux and postanesthetic vomiting and diarrhea in dogs undergoing general anesthesia. J Vet Emerg Crit Care 27(4), 397-408.

# Vainionpää M, Salla K, Restitutti F et al. (2013) Thermographic imaging of superficial temperature in dogs sedated with medetomidine and butorphanol with and without MK-467. Vet Anaesth Analg 40, 142-148.

Walsh M, Devereaux PJ, Garg AX et al. (2013) Relationship between Intraoperative Mean Arterial Pressure and Clinical Outcomes after Noncardiac Surgery: Toward an Empirical Definition of Hypotension. Anesthesiology 119(3), 507-515.

Wilson DV, Evans AT, Miller R (2005) Effects of preanaesthetic administration of morphine on gastroesophageal reflux and regurgitation during anaesthesia in dogs. Am J Vet Res 66, 386-390.

Wilson DV, Evans AT, Mauer WA (2006) Influence of metoclopramide on gastroesophageal reflux in anesthetized dogs. Am J Vet Res 67, 26-31.

Zuckerman SL, Forbes JA, Mistry AM et al. (2014) Electrophysiologic deterioration in surgery for thoracic disc herniation: impact of mean arterial pressures on surgical outcome. Eur Spine J 23, 2279-2290.

**Figure 1** Time elapsed from induction of general anaesthesia (GA) (minutes) when a) hypothermia (*n* = 143 dogs) b) mechanical ventilation (MV) implementation (*n* = 142 dogs) c) hypotension (*n* = 76 dogs) d) pharmacological intervention to increase heart rate (*n* = 55 dogs) e) oesophageal temperature ≥ 39°C (*n* = 46 dogs) and f) regurgitation (*n* = 11 dogs) first occurred. \*, † and ‡ indicate a statistically significant difference in the number of dogs in that time group compared to other time groups not labelled with the same symbol (*p* < 0.05).



**Table 1** Breed and sex distribution of 224 dogs undergoing thoracolumbar hemilaminectomy at the Small Animal Teaching Hospital between March 2010 to January 2016.

|  |  |  |
| --- | --- | --- |
| **Variable** | **Number of dogs (*n*)** | **Percentage of dogs (%)** |
| Breed | Dachshund | 49 | 21.9 |
| Miniature Dachshund | 20 | 8.9 |
| Cocker Spaniel | 18 | 8 |
| Other breeds  | 137 | 61.2 |
| Sex | Female entire | 22 | 9.8 |
| Female neutered | 47 | 21 |
| Male entire | 60 | 26.8 |
| Male neutered | 95 | 42.4 |

**Table 2** Incidence of intra-operative complications in 224 dogs undergoing GA for thoracolumbar hemilaminectomy at the Small Animal Teaching Hospital between March 2010 and January 2016.

|  |  |  |
| --- | --- | --- |
| **Intra-operative complication** | **Number of dogs (*n*)** | **Percentage of dogs (%)** |
| Hypothermia | 143 | 63.8 |
| MV implementation | 142 | 63.4 |
| Hypotension | 76 | 33.9 |
| PIHR | 55 | 24.6 |
| T ≥ 39°C | 46 | 20.5 |
| Regurgitation | 11 | 4.9 |
| Temperature trend decrease | 9 | 4 |
| Temperature trend increase | 211 | 94.2 |
| Major complication | 3 | 1.3 |

GA - general anaesthesia; MV - mechanical ventilation; PIHR - pharmacological intervention to increase heart rate; T ≥ 39°C = oesophageal temperature ≥ 39°C.

**Table 3** Final multivariate logistic regression models demonstrating covariates significantly associated with the risk of hypothermia, oesophageal temperature ≥ 39°C, hypotension and pharmacological intervention to increase heart rate in 224 dogs undergoing thoracolumbar hemilaminectomy at the Small Animal Teaching Hospital between March 2010 and January 2016. GA duration is highlighted in italics to indicate forced inclusion in the final models for hypothermia, hypotension and pharmacological intervention to increase heart rate. For categorical variables, N/Y represents 'No' or 'Yes' with 'No' as the reference category. The odds ratio is the odds of the outcome per unit increase in the continuous variable or the odds of the outcome when the categorical variable is present. A p-value of < 0.05 was considered to indicate statistical significance.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Intra-operative complication** | **Covariates included in final model** | **Odds ratio** | **95% CI** | ***p*-value** |
| Hypothermia (N/Y) | Bodyweight (kg) | 0.954 | 0.918-0.991 | 0.015 |
| Alpha-2 adrenoreceptor agonist premedication (N/Y) | 0.448 | 0.221-0.911 | 0.027 |
| MV implementation (N/Y) | 0.392 | 0.200-0.770 | 0.007 |
| MRI under same GA (N/Y) | 2.684 | 1.394-5.167 | 0.003 |
| Hypotension (N/Y) | 2.028 | 1.006-4.092 | 0.048 |
| *GA duration (minutes)* | *1.000* | *0.995-1.004* | *0.923* |
| T ≥ 39°C (N/Y) | Alpha-2 adrenoreceptor agonist premedication (N/Y) | 2.888 | 1.191-7.007 | 0.019 |
| Hypotension (N/Y) | 0.357 | 0.154-0.828 | 0.016 |
| GA duration (minutes) | 1.005 | 1.001-1.009 | 0.02 |
| Hypotension (N/Y) | Bodyweight (kg) | 0.948 | 0.906-0.992 | 0.021 |
| PIHR (N/Y) | 2.692 | 1.379-5.257 | 0.004 |
| Hypothermia (N/Y) | 2.301 | 1.172-4.517 | 0.015 |
| *GA duration (minutes)* | *1.003* | *0.999-1.007* | *0.101* |
| PIHR (N/Y) | Bodyweight (kg) | 0.899 | 0.842-0.960 | 0.001 |
| MV implementation (N/Y) | 3.927 | 1.805-8.542 | 0.001 |
| Hypothermia (N/Y) | 2.156 | 1.014-4.586 | 0.046 |
| *GA duration (minutes)* | *1.000* | *0.996-1.005* | *0.869* |

GA - general anaesthesia; 95% CI - 95% confidence interval; T ≥ 39°C - oesophageal temperature ≥ 39°C; PIHR - pharmacological intervention to increase heart rate; MV - mechanical ventilation; MRI - magnetic resonance imaging.

**Table S1** Results of univariate logistic regression analyses of intra-operative complications reported in 224 dogs undergoing thoracolumbar hemilaminectomy at the Small Animal Teaching Hospital between March 2010 and January 2016. \* indicates statistically significant result (*p* < 0.05). † indicates variables with 0.05 ≤ *p* < 0.25 that were included in initial multivariate logistic regression analyses. Chi-square or Fisher’s exact test were used to compare categorical variables and Mann-Whitney U (non-parametric data) or independent t-test (parametric data) for continuous variables. The odds ratio is the odds of the outcome per unit increase in the continuous variable or the odds of the outcome when the categorical variable is present. 'Ref' indicates the reference category for comparisons between sexes. The additional *p*-values reported for sex are the results from Pearson Chi-square and Fisher's exact tests which were used to decide whether sex was included as a covariate in the multivariate analyses.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **Intra-operative complication** | **Odds ratio** | **95% CI** | ***p*-value** |
| Bodyweight (kg) | Hypothermia (N/Y) | 0.948  | 0.918-0.979 | <0.001 \* |
| T ≥ 39°C (N/Y) | 1.031 | 0.997-1.067 | 0.035 \* |
| Hypotension (N/Y) | 0.934  | 0.896-0.974 | <0.001 \* |
| PIHR (N/Y) | 0.901 | 0.85-0.956 | <0.001 \*  |
| Regurgitation (N/Y) | 0.995  | 0.926-1.068 | 0.97  |
| **Sex:** Hypothermia                                                                                                                                      0.821T ≥ 39°C                                                                                                                                      0.235 †Hypotension                                                                                                                                       0.191 †PIHR                                                                                                                                         0.645Regurgitation                                                                                                                                     0.656 |
| - Female entire | Ref | Ref | Ref | Ref |
| - Female neutered | Hypothermia  | 0.996  | 0.336-2.951 | 0.994 |
| T ≥ 39°C | 1.935  | 0.481-7.788 | 0.353 |
| Hypotension  | 0.621  | 0.223-1.725 | 0.36 |
| PIHR  | 0.655  | 0.213-2.012 | 0.46 |
| Regurgitation  | 1.953  | 0.205-18.582 | 0.56 |
| - Male entire | Hypothermia | 0.7  | 0.249-1.971 | 0.499 |
| T ≥ 39°C | 2.504  | 0.655-9.571 | 0.18 † |
| Hypotension  | 0.538  | 0.2-1.449 | 0.22 † |
| PIHR | 0.847  | 0.294-2.441 | 0.759 |
| Regurgitation  | 0.724  | 0.062-8.407 | 0.796 |
| - Male neutered | Hypothermia  | 0.8  | 0.297-2.151 | 0.658 |
| T ≥ 39°C  | 1.187  | 0.312-4.52 | 0.801 |
| Hypotension  | 0.377  | 0.146-0.974 | 0.044 \* |
| PIHR  | 0.571  | 0.205-1.591 | 0.284 |
| Regurgitation  | 0.923  | 0.098-8.689 | 0.944 |
| Age (months) | Hypothermia  | 0.997  | 0.988-1.006 | 0.509 |
| T ≥ 39°C | 0.998 | 0.987-1.009 | 0.79 |
| Hypotension  | 0.996 | 0.987-1.006 | 0.47 |
| PIHR | 0.996 | 0.986-1.007 | 0.416 |
| Regurgitation  | 0.995  | 0.974-1.061 | 0.608 |
| GA duration (minutes) | Hypothermia  | 1.000  | 0.996-1.003 | 0.936 |
| T ≥ 39°C | 1.004 | 1.000-1.008 | 0.05 † |
| Hypotension  | 1.001  | 0.998-1.005 | 0.36 |
| PIHR | 0.999 | 0.995-1.003 | 0.683 |
| Regurgitation  | 0.999 | 0.991-1.007 | 0.63 |
| End temperature (°C) | Hypothermia  | 0.186  | 0.114-0.304 | <0.001 \*  |
| T ≥ 39°C  | 59.224 | 16.771-209.135 | <0.001 \*  |
| Hypotension  | 0.642  | 0.495-0.831 | 0.001 \* |
| PIHR  | 0.815 | 0.63-1.054 | 0.126 † |
| Regurgitation  | 0.801  | 0.502-1.28 | 0.219 † |
| Temperature trend (Decrease/Increase) | Hypothermia  | 0.960  | 0.232-3.969 | 1.000  |
| T ≥ 39°C  | 0.911  | 0.182-4.564 | 1.000  |
| Hypotension  | 0.561  | 0.145-2.167 | 0.467  |
| PIHR  | 0.686  | 0.165-2.853 | 0.698  |
| Regurgitation  | 1.057  | 1.021-1.095 | 1.000  |
| MV implementation (N/Y) | Hypothermia | 0.353  | 0.190-0.655 | 0.001 \* |
| T ≥ 39°C | 1.247  | 0.628-2.48 | 0.608  |
| Hypotension  | 0.904  | 0.51-1.602 | 0.77  |
| PIHR  | 2.898  | 1.399-6.001 | 0.004 \* |
| Regurgitation  | 0.679  | 0.201-2.3 | 0.536  |
| MRI under same GA (N/Y) | Hypothermia  | 2.938  | 1.672-5.161 | <0.001 \* |
| T ≥ 39°C | 0.584  | 0.304-1.122 | 0.133 † |
| Hypotension  | 2.167  | 1.212-3.874 | 0.01 \* |
| PIHR | 0.913  | 0.495-1.682 | 0.876  |
| Regurgitation  | 1.382  | 0.393-4.863 | 0.759 |
| Alpha-2 adrenoreceptor agonist premedication (N/Y) | Hypothermia | 0.46  | 0.244-0.867 | 0.015 \* |
| T ≥ 39°C | 3.004  | 1.269-7.111 | 0.012 \* |
| Hypotension  | 0.506  | 0.281-0.911 | 0.032 \* |
| PIHR  | 0.721  | 0.379-1.37 | 0.401  |
| Regurgitation | 0.774  | 0.219-2.735 | 0.742  |
| Acepromazine premedication (N/Y) | Hypothermia  | 1.457  | 0.806-2.632 | 0.211 † |
| T ≥ 39°C | 0.409  | 0.186-0.901 | 0.035 \* |
| Hypotension  | 1.759  | 0.987-3.134 | 0.072 |
| PIHR  | 0.947  | 0.496-1.81 | 1.000  |
| Regurgitation  | 0.729  | 0.188-2.832 | 0.754  |
| Intra-operative ketamine (N/Y) | Hypothermia  | 0.997  | 0.475-2.095 | 0.995 |
| T ≥ 39°C  | 3.262  | 0.954-11.159 | 0.069 † |
| Hypotension  | 1.201  | 0.556-2.594 | 0.704  |
| PIHR | 1.763  | 0.692-4.49 | 0.293  |
| Regurgitation  | 1.966  | 0.244-15.855 | 1.000 |
| Intra-operative alpha-2 adrenoreceptor agonist (N/Y) | Hypothermia | 0.832  | 0.355-1.949 | 0.672  |
| T ≥ 39°C | 0.963  | 0.341-2.721 | 1.000 |
| Hypotension | 1.62  | 0.697-3.765 | 0.27  |
| PIHR | 0.24 | 0.055-1.051 | 0.048 \* |
| Regurgitation  | 0.945  | 0.914-0.977 | 0.617  |
| Intra-operative lidocaine (N/Y) | Hypothermia  | 0.421  | 0.159-1.113 | 0.074  |
| T ≥ 39°C | 2.725  | 0.993-7.479 | 0.064 † |
| Hypotension  | 0.971  | 0.35-2.698 | 1.000  |
| PIHR  | 2.095  | 0.77-5.701 | 0.157  |
| Regurgitation  | 2.736  | 0.544-13.752 | 0.218 † |
| Hypothermia (N/Y) | T ≥ 39°C | 0.094  | 0.043-0.205 | <0.001 \* |
| Hypotension | 2.937  | 1.549-5.569 | 0.001 \* |
| PIHR  | 2.175  | 1.087-4.354 | 0.035 \* |
| Regurgitation  | 1.541  | 0.397-5.978 | 0.75  |
| T ≥ 39°C (N/Y) | Hypothermia  | 0.094  | 0.043-0.205 | <0.001 \* |
| Hypotension  | 0.341  | 0.15-0.773 | 0.008 \* |
| PIHR | 0.587  | 0.255-1.348 | 0.251  |
| Regurgitation  | 0.854  | 0.178-4.093 | 1.000  |
| Hypotension (N/Y) | Hypothermia  | 2.937  | 1.549-5.569 | 0.001 \* |
| T ≥ 39°C | 0.341  | 0.15-0.773 | 0.008 \* |
| PIHR  | 3.559  | 1.89-6.701 | <0.001 \*  |
| Regurgitation  | 1.119  | 0.317-3.948 | 1.000  |
| PIHR (N/Y) | Hypothermia | 2.175  | 1.087-4.354 | 0.026 \*  |
| T ≥ 39°C | 0.587  | 0.255-1.348 | 0.251  |
| Hypotension  | 3.559  | 1.89-6.701 | <0.001 \* |
| Regurgitation | 1.161  | 0.297-4.538 | 0.734 |
| Regurgitation (N/Y) | Hypothermia  | 1.541  | 0.397-5.978 | 0.75  |
| T ≥ 39°C | 0.854  | 0.178-4.093 | 1.000  |
| Hypotension  | 1.119  | 0.317-3.948 | 1.000  |
| PIHR  | 1.161  | 0.297-4.538 | 0.734  |

For categorical variables, N/Y represents 'No' or 'Yes' with 'No' as the reference category. 95% CI - 95% confidence interval; T ≥ 39°C - oesophageal temperature ≥ 39°C; PIHR - pharmacological intervention to increase heart rate; GA - general anaesthesia; MV - mechanical ventilation; MRI - magnetic resonance imaging.