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Thermal Burn Injury from a Forced-Air Warming Device in an Anesthetized Dog with Peripheral Hypoperfusion

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Abstract : A 13-year-old female Poodle presented with gallbladder rupture caused by a mucocele and hypoperfusion. The animal had a thermal burn injury caused by a forced-air warming device used for hypothermia during surgery. This could be attributed to two causes. First, the forced-air warming device was used with direct hosing, without attachment to an air blanket, and the heat was concentrated in a single area. Second, perioperative peripheral hypoperfusion hampered heat dissipation and increased the susceptibility to a burn injury. These findings suggest that an air blanket should be used with a forced-air warming device according to the manufacturer's instructions. Furthermore, patients with peripheral hypoperfusion are at a higher risk of burn injuries and require close monitoring.

Key words **:** burn injury, dog, forced-air warming device, hypoperfusion.

Introduction

Hemodynamic monitoring and management for the maintenance of tissue perfusion during the perioperative period are critical for minimizing patient mortality and postoperative complications. Hypoperfusion causes decreased blood flow to the organs and peripheral tissues during circulation, resulting in hypothermia (2). To mitigate and prevent complications of perioperative hypothermia, prewarming, active warming, and rewarming methods are used in humans and small animals. Before anesthetic induction, raising the peripheral temperature minimizes the loss of heat during its redistribution from the core to the extremities throughout the early stages of anesthesia (7). It is necessary to control the operating room temperature because the heat loss caused by the convection and radiation from the skin and evaporation from open surgical sites can often be controlled by the environmental temperature during surgery (7,17). In addition, various methods have been suggested for the treatment of hypothermia, such as the use of warmed intravenous fluids, airway heating and humidification; however, the efficacy of these methods remains debatable (10,12,13,19,20). For the prevention of intraoperative hypothermia, active surface warming methods, including the use of circulating warm water blankets, electric blankets, and forced-air warming devices such as the Bair Hugger, are used in general, as they have proven to be more effective in increasing the body temperature. A circulating warm water blanket is relatively less effective than is a forced-air warming device because it provides a smaller area of direct contact with the patient's skin; this area is also gravitationally compressed, resulting in the interference of heat transmission within decreased blood flow (7,14). It can therefore result in side effects depending on how the device is used and the patient's underlying condition. In the present case study, we describe a thermal burn injury associated with the intraoperative use of a forced-air warming device in an anesthetized dog with peripheral hypoperfusion.

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Case

A 13-year-old, 5.0-kg female Poodle presented at the Veterinary Medical Teaching Hospital of Seoul National University with vomiting and anorexia refractory to symptomatic treatment. On physical examination, the dog was slightly depressed, and hypoperfusion was suspected because of a pale mucous membrane, prolonged capillary refill time (CRT; 2.5 seconds), low rectal temperature (37.3°C), and low systolic blood pressure (BP; 70 mmHg). The heart rate (HR) and respiratory rate (RR) were within the normal range. Systolic blood pressure was indirectly measured three times from the left forelimb using a Doppler sphygmomanometer [811-B Doppler flow detector (Parks Medical Electronics Inc.; Aloha, OR, USA)] with a size-2 cuff. Abnormalities other than abdominal pain were not noted in the physical examination.

Results of a complete blood count were within reference ranges, except for leukocytosis (21,430 cells/μl; reference range, 5,200-17,000 cells/μl). Serum biochemical analysis revealed high alanine aminotransferase (669 U/l; reference range, 17-78 U/l), aspartate aminotransferase (185 U/l; reference range, 17-44 U/l), alkaline phosphatase (2796 U/l; reference range, 47-254 U/l), and γ-glutamyl transferase (162 U/l;

reference range, 5-14 U/l) levels; hyperbilirubinemia (3.60 mg/dl; reference range, 0-0.5 mg/dl); a high fasting bile acid level (1170 mmol/l; reference range, 0-10 mmol/l); and low calcium (8.9 mg/dl; reference range, 9.3-12.1 mg/dl) and high phosphorus (7.3 mg/dl; reference range, 1.9-5.0 mg/dl) levels. The canine C-reactive protein level was increased to 163 mg/l (reference range, 0-20 mg/l), while electrolyte concentrations were within the reference ranges. Lactate and D-dimer levels were 0.5 mmol/l (reference range, 0.5-2.5 mmol/l) and 1.1 μg/ml (reference range, < 0.25 μg/ml), respectively. A coagulation test was performed before surgery; the prothrombin time, activated partial thromboplastin time, and other values determined by thromboelastography were within reference ranges, although the maximum amplitude value in thromboelastography was increased (72.1 mm; reference range, 42.9-67.9 mm). Urinalysis indicated a specific gravity of 1.027, trace proteinuria, and moderate bilirubinuria.

Decreased serosal detail in the right upper quadrant of the abdomen was observed on abdominal radiographs, and ultrasonography was performed to identify the cause. Abdominal ultrasonography revealed a stellate, finely striated pattern in the dilated gallbladder, with echogenic materials in the common bile duct lumen, which was dilated to 0.56 cm. Although discontinuation of the gallbladder wall integrity was not seen, a small amount of echogenic peritoneal fluid and hyperechoic peritoneal fat was confirmed throughout the abdomen. Analysis of peritoneal fluid, confirmed during ultrasonography, revealed a total nucleated cell count of 28,840 cells/μl and total protein level of 6.2 g/dl; this suggested the presence of exudate. The fluid bilirubin level was 3.4 mg/dl, which was lower than the serum bilirubin (4.4 mg/dl) level. Eosinophilic material, but no bacteria was found on cytological examination of the fluid smear. Thus, bile peritonitis caused by bile leakage was strongly suspected.

Emergency surgery was scheduled, and the patient was premedicated with cefazolin [22 mg/kg, intravenous (IV), Cefazolin Injection; Chong Kun Dang]. Anesthesia was induced with alfaxalone (2 mg/kg, IV, Alfaxan Multidose; Careside). After endotracheal intubation (standard endotracheal tube with an internal diameter of 5.0 mm), general anesthesia was maintained with 2% isoflurane in 2 l/min oxygen delivered through a semi-closed circle rebreathing system [Multiplus MEVD Anesthesia Machine (Royal Medical; Korea)]. Analgesia was provided with a combination of remifentanil [3-6 μg/kg/min, continuous rate infusion (CRI), IV, Remiva Injection; Hana Pharm. Co.], lidocaine (1.5-3 mg/kg/h, CRI, IV, Daihan Lidocaine HCl Hydrate injection; Daihan Pharm. Co.), and ketamine (0.3-0.6 mg/kg/h, CRI, IV, Yuhan Ketamine 50 Injection; Yuhan) and epidural anesthesia with bupivacaine (0.5 mg/kg, Bupivacaine HCl Heavy Injection; Myungmoon) and morphine (0.1 mg/kg, Morphine HCl Injection; Myungmoon). To maintain normothermia, a circulating warm water blanket [40ºC; HTP-1500 Heat (Adroit Medical Systems; Chicago, IL, USA)] was placed under the patient during surgery. After intubation, the patient showed cyanosis and hypotension with a mean arterial blood pressure of < 45 mmHg. Following abdominal incision, bile ascites was identified and aspirated, and the abdominal cavity

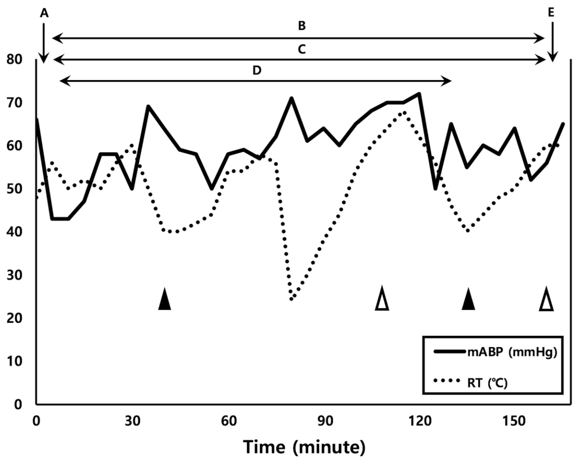

Fig 1. Graph of mean arterial blood pressure (mABP, solid line; mmHg) and rectal temperature (RT, dotted line; ºC) versus the time from endotracheal intubation to extubation (total 2 hr and 45 min) in a female Poodle with a ruptured gallbladder accompanied by peripheral hypoperfusion A forced-air warming device was used for intraoperative hypothermia in this patient. The specific time points for endotracheal intubation (A); constant-rate infusion of dobutamine (B) (5-10 μg/kg/min, IV), dopamine (C) (5-10 μg/kg/min, IV), and vasopressin (D) (0.003-0.006 unit/kg/h, IV); and the application (filled arrowhead) and discontinuation (unfilled arrowhead) of the forced-air warming device are shown.

was explored. A gallbladder rupture measuring approximately 2 cm was confirmed, and the gallbladder was resected after it was separated from the surrounding tissue. Duodenotomy, retrograde common bile duct flushing, and liver biopsy were also performed. Invasive blood pressure monitoring during surgery revealed sustained hypotension (systolic blood pressure, 70-120 mmHg; mean arterial blood pressure, 43-72 mmHg; diastolic blood pressure, 28-63 mmHg; Fig 1). For stable hemodynamics, aggressive fluid therapy (Hartmann's solution, 10-20 ml/kg/h, IV) and dobutamine (5-10 μg/kg/min, IV, Dobutamine HCl injection; Myungmoon), dopamine (5-10 μg/kg/min, IV, Dopamine injection; Huons), and vasopressin (0.003-0.006 unit/kg/h, IV, Vasopressin Injection; Hanlim Pharm. Co.) were administered since the beginning of the anesthesia. However, the effect of the treatment for hypotension was transient, and blood pressure was not maintained at an appropriate level. Therefore, the treatment was continued during anesthesia (Fig 1). The patient continued to have hypothermia, with a body temperature of < 36ºC (Fig 1). Subsequently, a Bair Hugger warming device [3M™ Bair Hugger™ Full Body Blanket Model 300 (Arizant Healthcare Inc., 3M Co.; Eden Prairie, MN, USA)] turned to the medium setting was used for an hour. The nozzle of the device was not connected to an inflatable blanket and was placed under the surgical drape. The total duration of anesthesia was 2 h and 45 min. After extubation, the patient's blood pressure (systolic blood pressure, 121 mmHg; mean arterial blood pressure, 86 mmHg; diastolic blood pressure, 66 mmHg) and rectal temperature (38.7ºC) were within the normal ranges.

On histopathologic examination, any abnormalities other

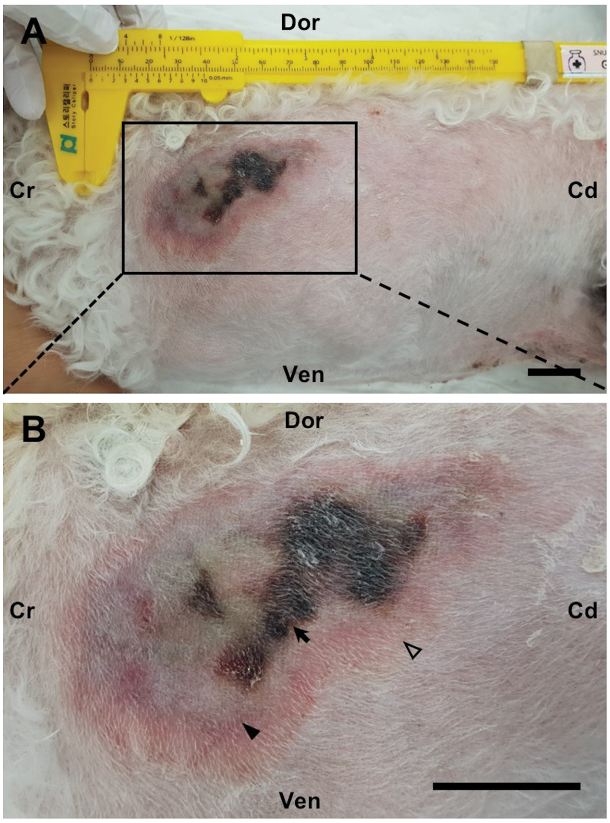

Fig 2. Photograph of a burn injury in the left dorsocranial flank region on day 7 after surgery in a female Poodle that presented with a ruptured gallbladder accompanied by hypoperfusion (A). A forced-air warming device was used for intraoperative hypothermia in this patient. In the magnified image of the burn area (B), the characteristic zones [coagulation (arrow), stasis (filled arrowhead), and hyperemia (unfilled arrowhead)] of a burn injury, as described by Jackson in 1947 (9), can be identified. Cr, cranial; Cd, caudal; Dor, dorsal; Ven, ventral. Scale bars = 2 cm.

than gallbladder mucocele and cholestasis of the liver were not revealed. In addition, it was found to be negative on bacteria culture test of bile and ascites. The dog was hospitalized for 9 days after surgery and recovered from bile peritonitis and the consequent pancreatitis without any complication. However, on the fourth day after surgery, a bruise measuring 4.6 × 3.0 cm was noted on the left trunk. At the time of detection, the cause of the lesion could not be specified. By the seventh day after surgery, the lesion became more evident, and the characteristic three zones described by Jackson in 1947 were confirmed: zone of coagulation, which is the most central area with maximum damage caused by coagulation of the constituent proteins; zone of stasis, which is characterized by hypoperfusion surrounding the zone of coagulation; and zone of hyperemia, which is the outermost zone with increased perfusion relative to that in the other two zones. The lesion was presumed to be a burn injury secondary to the use of a warm air device, given its location and features (Fig 2) (9). It was managed with laser therapy and dressing, following which it gradually became necrotic from the center to the periphery and healed as the crust formed and fell off. The crust was completely eliminated by 6 weeks, and the treatment was subsequently terminated.

Discussion

The patient in this case study showed some evidence of hypoperfusion. Initially, the patient was considered to have sepsis caused by bile peritonitis at the time of presentation. Physical examination before surgery revealed hypothermia, a prolonged CRT, a weak femoral pulse, and a low systolic pressure. In addition, intraoperative invasive blood pressure monitoring revealed a low mean blood pressure; this is a more accurate parameter of tissue perfusion than is systolic blood pressure (2,7). The plasma lactate level is a generally used parameter for monitoring tissue perfusion in human and veterinary medicine (2); however, the preoperative plasma lactate level was within the reference range. Lactate is considered a late marker of systemic hypoperfusion because its level increases in response to oxygen depletion in tissues and the consequent anaerobic metabolism (7). Several previous studies confirmed that the decrease in blood flow to non-vital organs, such as the gastrointestinal tract and skin, is more severe in the early stage of systemic hypoperfusion (6,18). Furthermore, vasoconstriction via alpha-1 adrenergic receptors is a compensatory mechanism for low perfusion; thus, skin perfusion is more severely compromised because of the high density of these receptors (7). In human medicine, studies have attempted to evaluate epithelial and endothelial perfusion as an early marker of septic shock (1,8), but this has not been evaluated in the veterinary setting. Therefore, patients with suspected hypoperfusion should be managed perioperatively with consideration of the possibility of complications due to reduced skin perfusion.

Because body temperature is directly associated with the regulation of metabolic functions such as pharmacokinetics and the immune system, maintenance of perioperative normothermia is an important prognostic factor (15,20). Inadvertent hypothermia is a common condition in surgical patients and results from the exposure of incision sites and skin to low environmental temperatures as well as depression of the central thermoregulatory control mechanisms using anesthetic agents. In small animals, particularly dogs, the following classification was previously suggested for inadvertent hypothermia: mild (38.49ºC-36.5ºC), moderate (36.49ºC-34.0ºC), and severe (< 34.0ºC) (17). The authors also showed that most cases (83.6%) of dogs without active heating during anesthesia had developed hypothermia (< 36.5ºC) by the end of an anesthetic procedure (17). Hypothermia decreases the sensitivity to inhalation anesthetics, such as isoflurane, and increases their solubility in tissues. In addition, increased fentanyl and propofol concentrations in blood cause changes in metabolism and redistribution (7,20). Perioperative hypothermia causes vasoconstriction, which delays healing by reducing blood flow to the wound, and impaired immunity, which increases the possibility of surgical site infection. In addition, it increases the incidence of complications such as disordered hemostasis, arrhythmia, and cardiac arrest (7,23). In human medicine, postoperative shivering caused by hypothermia increases oxygen consumption, resulting in an increased incidence of hypoxemia when there is no supplementary oxygen supply (24). Therefore, patients need to be kept warm, and maintenance of normothermia should be a priority whenever possible during the perioperative phase. In the present case, the temperature of the surgical preparation room and operating room was maintained at 20ºC, and the patient was covered with a blanket to prevent heat loss before surgery. During surgery, in addition to the warm water blanket, the Bair Hugger was used, with the hosing placed under the surgical drape and at a reasonable distance from the patient.

With increased awareness and understanding of the importance of hypothermia prevention, guidelines for perioperative warming in humans have been suggested. The use of a forced-air warming device in the perioperative phase is recommended by the Association of periOperative Registered Nurses and the American Society of PeriAnesthesia Nurses (5,13). A forced-air warming device generally consists of a power unit that generates warmed air, an electrical blower, and a flexible hose that provides the warmed air to patients through disposable blankets. Theses disposable blankets are classified into various types according to the application time (preoperative, intraoperative, and postoperative blankets), the body parts covered (upper, lower, and full body), and the specialty of use (surgical and cardiac access) (3). A forced-air warming device conveys warmed air to the patient through convection, effectively transferring heat and reducing the possibility of heat-induced skin damage. Previous studies have shown that usage as per the manufacturer's guidelines effectively maintains the body temperature, with a very low complication rate (16,23). However, other studies have reported burn injuries caused by using forced-air warming devices in patients with underlying disease or the improper use of these devices, such as the use of hosing without the attachment of the air blanket (21,22).

The dog in our case report sustained a burn injury caused by using the Bair Hugger during surgery. The manufacturer's usage guidelines warn about the possibility of burn injury when this device is used for hosing, for several reasons. When warmed air is blown through the hose, the nozzle is heated, and if this comes into contact with the patient's skin, it can result in injury. Moreover, warmed air that is passed through the hose is concentrated into a narrow area, which can result in burn injury, even if the nozzle is not in direct contact with the patient (23). We have previously used the Bair Hugger after applying a circulating warm water blanket when additional warming treatment was needed. However, we performed direct hosing without the attachment to an air blanket, a method that does not conform to the manufacturer's instructions, in several cases (n = 3520). In these cases, the warming hose was placed under the surgical drapes and fixed with a gap of at least 10 cm between the hose and the patient. Notably, none of these cases developed burn injuries. Our patient had peripheral hypoperfusion in the perioperative phase; this may have increased the patient's risk of burn injury as this would have reduced the blood flow to organs and peripheral tissues through the circulatory system, resulting in poor heat transfer from the skin (where warmed air was concentrated) to other areas.

This study has several limitations. First, there is a possibility that the burn injury could have been directly caused by use of the forced-air warming device without connection to an air blanket. Second, we did not perform serial measurements of variables that can confirm hypoperfusion, such as lactate levels, in order to establish a clear causal relationship.

Conclusions

Although the use of a forced-air warming device is a relatively safe and effective way to prevent intraoperative hypothermia, vigilant monitoring is required for dogs with hypoperfusion or suspected hypoperfusion. In addition, to decrease the risk of thermal burn injuries, the use of a blanket between the warming device and the patient's skin is recommended for all patients undergoing surgery (4,21,22).

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