Prolonged anesthesia with desflurane and fentanyl in dogs during conventional and laparoscopic surgery

María F. Martín, PD, PhD; Juan R. Lima, DVM; Luis J. Ezquerra, DVM, PhD; María S. Carrasco, MD, PhD; Jesús Usón-Gargallo, DVM, PhD

Objective—To determine the effects of prolonged anesthesia with desflurane in dogs undergoing laparotomy or abdominal laparoscopy.

Design—Randomized prospective study.

Animals—20 adult mixed-breed dogs.

Procedure—Dogs were randomly assigned to 1 of 2 groups with 10 dogs/group. Anesthesia was induced with propofol and maintained with desflurane and fentanyl, and pyloroplasty was performed. In 10 dogs, a ventral midline laparotomy was performed; in the other 10, abdominal laparoscopy was performed. Dogs were monitored for cardiovascular and respiratory responses (ECG, oxygen saturation [Spo_2], arterial blood pressure, rectal temperature, end-tidal partial pressure of carbon dioxide [P_{ETCO_2}], and expired desflurane concentration). Recovery times were recorded.

Results—Mean ± SD duration of anesthesia was 201 ± 25 minutes for dogs undergoing laparotomy and 287 ± 15 minutes for dogs undergoing laparoscopy. Anesthesia was accompanied by hypotension that was less severe in dogs undergoing laparoscopy. Heart rate did not vary significantly during anesthesia. The Spo_2 was > 97% in all dogs at all times, and P_{ETCO_2} remained within reference limits. Recovery times for dogs that underwent laparotomy were not significantly different from those for dogs that underwent laparoscopy. Mean ± SD time to standing was 13.6 ± 2.4 minutes for dogs that underwent laparotomy and 12.5 ± 2.9 minutes for dogs that underwent laparoscopy.

Conclusions and Clinical Relevance—Results suggest that induction of anesthesia with propofol and maintenance with desflurane and fentanyl is safe in dogs undergoing abdominal surgery. (*J Am Vet Med Assoc* 2001;219:941–945)

Desflurane is an inhalant anesthetic agent with a low blood-gas partition coefficient (0.42),[1] allowing for rapid changes in the depth of anesthesia. The minimum alveolar concentration of desflurane in dogs is greatly influenced by concomitant administration of other anesthetic agents; reported values range from 7.2 to 10.3%.[2,3] The cardiovascular effects of desflurane are similar to those of isoflurane at equipotent doses. Desflurane causes an increase in pulse rate, a decrease in arterial blood pressure, and a decrease in systemic vascular resistance.[4]

From the Minimally Invasive Surgery Centre, Avda Universidad s/n 10071, Cáceres, Spain (Martín, Lima, Usón-Gargallo); the Surgery Department, College of Veterinary Medicine, University of Extremadura, Cáceres, Spain (Ezquerra); and the Surgery Department, Cádiz University, Spain (Carrasco).

Abdominal laparoscopy is normally perceived to be associated with few risks. However, there are risks involved that clinicians should be aware of, such as gaseous embolization, a potential inability to control hemorrhage, an increase in the arterial partial pressure of carbon dioxide, and changes in arterial blood pressure and heart rate. As opposed to these, advantages include less postoperative discomfort and pain, reduced recovery time, less frequent development of postoperative adhesions, and a lower rate of infection. Because of this, it is important to understand the hemodynamic and respiratory alterations associated with abdominal laparoscopy, most of which are caused by intra-abdominal pressure resulting from pneumoperitoneum. Understanding these alterations will enable clinicians to improve the quality of anesthesia when performing this kind of surgery.

To our knowledge, little has been published in the veterinary literature on the effects of desflurane in dogs undergoing abdominal surgery. The purpose of the study reported here, therefore, was to determine the effects of prolonged anesthesia with desflurane in dogs undergoing a laparotomy or abdominal laparoscopy.

Materials and Methods

Dogs—The experimental protocol was approved by the Ethical Committee of the Minimally Invasive Surgery Centre. Twenty male and female adult mixed-breed dogs were used; mean ± SD weight was 20.5 ± 6.5 kg (45.1 ± 14.3 lb). All dogs underwent a complete physical examination, serum biochemical analyses, and thoracic radiography prior to inclusion in the study. During the study, dogs were housed in individual kennels with free access to food and water. Dogs were randomly assigned to 1 of 2 groups with 10 dogs/group (7 males and 3 females were assigned to each group). All dogs underwent pyloric surgery. In 10 dogs, a conventional laparotomy was performed; in the other 10, laparoscopy was performed. In all dogs, food, but not water, was withheld for 8 hours prior to surgery.

Surgical procedures—Endoscopy of the esophagus, stomach, and duodenum was performed before and after surgery. Ultrasonography of the pylorus was performed during surgery, before and after pyloroplasty, using a 7.5-MHz probe. The technique used for pyloroplasty was that described by Heineke-Mikulicz. Briefly, a longitudinal incision was made through the serosa and muscularis of the pylorus, down to but not through the gastric mucosa; the incision was then sutured transversally. For dogs undergoing laparotomy, a standard ventral midline approach was used. For dogs undergoing abdominal laparoscopy, 4 laparoscopic ports were inserted. Pneumoperitoneum was created by insufflating CO_2 into the abdominal cavity; intra-abdominal pressure was maintained at 12 to 14 mm Hg.

Anesthesia—Dogs were not sedated. A fresh flow of 100% oxygen was administered at a rate of 5 L/min for 5 minutes, using a face or Hall mask. Anesthesia was induced with propofol administered IV to effect over 60 seconds (mean ± SD dose, 5.2 ± 2.3 mg/kg [2.4 ± 1.0 mg/lb] of body weight). An endotracheal tube[a] was placed and connected to a semiclosed circle anesthetic circuit connected to a ventilator.[b] Desflurane[c] was administered, beginning at a concentration of 14% to rapidly achieve **minimal alveolar concentration** (**MAC**; 7.2%) with a 100% oxygen flow rate of 5 L/min. Once MAC was reached, the vaporizer setting was adjusted as needed to maintain a depth of anesthesia suitable for surgery. A bolus (2.5 µg/kg [1.1 µg/lb]) of fentanyl[d] was administered every 30 minutes. Dogs were positioned in dorsal recumbency. Ventilation was controlled with **intermittent positive-pressure ventilation (IPPV)** to maintain an end-tidal partial pressure of CO_2 ($PETCO_2$) < 45 mm Hg.

After surgery was completed, anesthetic administration was discontinued, and the oxygen flow rate was increased to 10 L/min. Dogs were deemed to have recovered once they were completely conscious and capable of standing up and walking.

Monitoring—Depth of anesthesia was monitored by a trained anesthetist. Time for recovery from anesthesia was determined by recording the following times: time of extubation, time the dog first moved after surgery, time the dog achieved sternal recumbency, and time the dog was first standing.

A lead-II electrocardiogram was monitored[e] continuously; oxygen saturation (SpO_2) was measured with a pulse oximeter[b] with the probe placed on the tongue. A 10.5-cm pressure cuff was placed over the medial artery for noninvasive measurement of arterial blood pressure.[e] Body temperature was measured with an esophageal probe. Expired desflurane concentrations and $PETCO_2$ were measured[b] continuously at the proximal end of the endotracheal tube during anesthesia, and values were recorded every 5 minutes. During recovery from anesthesia, the electrocardiogram, SpO_2, arterial pressure, expired desflurane concentration, $PETCO_2$, and respiratory rate were measured continuously and recorded every minute.

Statistical analyses—Results were calculated as mean ± SD. Data were analyzed by use of 2-factor ANOVA. The Tukey test was used to compare values recorded during anesthesia and recovery with baseline values. Recovery times were analyzed by use of 1-way ANOVA, with surgical technique (laparotomy vs laparoscopy) being the variable of interest. Data were tested for normal distribution by use of the Kolmogorov Smirnov test.[5] For all analyses, values of $P < 0.05$ were considered significant.

Results

Anesthesia was smoothly induced in all dogs; excitement was minimal, with no signs of hypertonia, myoclonia, or involuntary movement. No excessive salivation or vomiting was observed during this phase. Dogs were intubated without difficulty after administration of propofol; none of the dogs developed apnea during induction of anesthesia. Heart rate did not increase significantly after induction of anesthesia.

Mean ± SD duration of anesthesia was 201 ± 25 minutes for dogs that underwent laparotomy and 287 ± 15 minutes for dogs that underwent laparoscopy. This difference was mainly attributable to a difference in the time needed to complete the pyloroplasty (174 ± 20 minutes for dogs undergoing laparotomy vs 245 ± 18 minutes for dogs undergoing laparoscopy).

Mean ± SD expired desflurane concentration was 8.0 ± 0.6% during anesthesia. Total dose of fentanyl administered was 17.0 ± 1.9 µg/kg (7.7 ± 0.9 µg/lb) in dogs undergoing laparotomy and 24.2 ± 1.2 µg/kg (11.0 ± 0.5 µg/lb) in dogs undergoing laparoscopy. The last bolus was administered 20 minutes before the end of anesthesia in all dogs.

Anesthesia with desflurane resulted in significant ($P < 0.001$) decreases in systolic and mean arterial pressures but no change in diastolic arterial pressure (**Table 1**). Systolic, diastolic, and mean arterial pressures were significantly higher in dogs undergoing laparoscopy. Heart rate did not vary significantly during anesthesia.

Although ventilatory depression was observed following propofol administration, none of the dogs developed apnea. Respiratory rate decreased after propofol administration by a mean of 63%; ventilation was controlled during surgery to maintain $PETCO_2$ in the reference range. The maximum $PETCO_2$ that was observed was 40 mm Hg in 1 dog undergoing laparoscopy. Values for $PETCO_2$ did not vary significantly over time or between groups (laparotomy vs laparoscopy). The SpO_2 was > 97% in all animals; SpO_2 was significantly higher for dogs undergoing

Table 1—Heart rate and arterial blood pressures in dogs anesthetized with desflurane and fentanyl and undergoing laparotomy or abdominal laparoscopy

			Arterial blood pressure (mm Hg)					
	Heart rate (beats/min)		Systolic		Diastolic		Mean	
Time (min)	Laparotomy	Laparoscopy	Laparotomy	Laparoscopy†	Laparotomy	Laparoscopy	Laparotomy	Laparoscopy†
0 (baseline)	111 ± 18	107 ± 20	146 ± 17	149 ± 11	77 ± 13	75 ± 14	94 ± 19	99 ± 10
1	116 ± 26	106 ± 17	144 ± 19	147 ± 10	76 ± 19	68 ± 7	94 ± 21	97 ± 5
30	118 ± 19	114 ± 19	140 ± 23	148 ± 8	70 ± 12	60 ± 10	92 ± 18	90 ± 7
60	116 ± 14	111 ± 16	128 ± 26	140 ± 18	67 ± 16	73 ± 15	80 ± 17	99 ± 10
90	109 ± 12	111 ± 20	129 ± 28	148 ± 12	72 ± 15	68 ± 14	81 ± 19	95 ± 4
120	111 ± 16	114 ± 9	125 ± 29	141 ± 21	66 ± 16	70 ± 9	78 ± 17*	91 ± 6*
150	115 ± 18	114 ± 12	122 ± 27	139 ± 16	64 ± 14	71 ± 11	75 ± 12*	92 ± 8*
180	110 ± 20	113 ± 10	117 ± 25	141 ± 19	63 ± 17	65 ± 11	68 ± 6*	89 ± 6*
210	105 ± 23	111 ± 17	116 ± 26*	136 ± 18*	66 ± 15	67 ± 4	70 ± 9*	89 ± 5*
Final	103 ± 19	109 ± 17	114 ± 24*	122 ± 5*	62 ± 16	70 ± 10	66 ± 4*	89 ± 7*

Data are expressed as mean ± SD.
*Significantly ($P < 0.05$) different from baseline value. †Significantly ($P < 0.05$) different from values for dogs undergoing laparotomy.

Table 2—Blood oxygen saturation (Spo_2), end-tidal partial pressure of carbon dioxide ($PETCO_2$), and expired desflurane concentration in dogs anesthetized with desflurane and fentanyl and undergoing laparotomy or abdominal laparoscopy

	Spo_2 (%)		$PETCO_2$ (mm Hg)		Desflurane (%)	
Time (min)	Laparotomy	Laparoscopy†	Laparotomy	Laparoscopy	Laparotomy	Laparoscopy
0 (baseline)	99.6 ± 0.5	99.3 ± 0.8	36 ± 2	35 ± 2	0.0 ± 0.0	0.0 ± 0.0
1	98.5 ± 2.0	99.1 ± 1.3	36 ± 4	36 ± 4	4.1 ± 1.0	4.1 ± 1.1
30	98.2 ± 2.2	99.1 ± 1.2	35 ± 2	36 ± 2	7.3 ± 1.0	7.5 ± 0.8
60	98.4 ± 2.5	99.8 ± 0.4	35 ± 2	36 ± 1	8.1 ± 0.6	7.8 ± 0.5
90	98.9 ± 1.4	99.8 ± 0.6	35 ± 2	35 ± 1	8.3 ± 0.7	8.0 ± 0.5
120	98.9 ± 1.1	99.8 ± 0.6	34 ± 2	35 ± 2	8.1 ± 0.2	8.0 ± 0.6
150	98.7 ± 1.6	99.2 ± 1.4	34 ± 2	35 ± 1	8.2 ± 0.2	8.0 ± 0.5
180	98.7 ± 1.5	99.8 ± 0.6	35 ± 1	34 ± 2	8.2 ± 0.2	8.0 ± 0.5
210	98.9 ± 1.3	99.7 ± 0.7	34 ± 2	34 ± 2	8.2 ± 0.2	8.1 ± 0.6
Final	98.9 ± 1.5	99.9 ± 0.3	35 ± 2	35 ± 2	8.2 ± 0.2	8.1 ± 0.6

See Table 1 for key.

Table 3—Recovery times in dogs anesthetized with desflurane and fentanyl and undergoing laparotomy or abdominal laparoscopy

	Recovery time (min)	
Recovery indicator	Laparotomy	Laparoscopy
First movement	4.5 ± 2.6	5.3 ± 3.1
Extubation	4.5 ± 2.6	5.1 ± 2.4
Sternal recumbency	8.1 ± 2.6	10.3 ± 2.4*
Standing	13.6 ± 2.4	12.5 ± 2.9

Data are expressed as mean ± SD.
*Significantly ($P < 0.05$) different from value for dogs undergoing laparotomy.

laparoscopy than for dogs undergoing laparotomy (**Table 2**).

During anesthesia, none of the animals responded to external stimuli; good muscular relaxation was observed, and analgesia was good. The first signs of recovery from anesthesia were tail movement and head lift. No excitement or other complications were observed during this period. All dogs appeared friendly, curious, and interested in their surroundings. No significant differences were observed between groups in regard to recovery times (**Table 3**). All dogs managed to stand up on the first attempt.

Discussion

Results of the present study suggested that induction of anesthesia with propofol and maintenance with desflurane and fentanyl is safe in dogs undergoing abdominal surgery, resulting in only mild cardiovascular alterations. Recovery from anesthesia was rapid and uncomplicated, without evidence of ataxia, excitement, or sudden movements. Results for dogs undergoing laparotomy were similar to those for dogs undergoing abdominal laparoscopy.

Studies[6-8] of the pharmacokinetics of propofol confirm that it is rapidly distributed and eliminated. It is a useful agent for induction of anesthesia, followed by maintenance with inhalation or injectable agents. Other authors have reported an induction dose for propofol of 6.6 mg/kg (3 mg/lb) in dogs that have not been premedicated.[7,9] Apnea is the most common adverse effect of propofol administration; the incidence of apnea depends on the dose administered and the speed of administration. If propofol is administered too quickly, it may cause apnea or vomiting.[10] However, if it is administered too slowly, it may not cause adequate induction of anesthesia because of its rapid redistribution and metabolism. In this study, dogs were given propofol at a mean dose of 5.2 ± 2.3 mg/kg over 60 seconds; this dose ensured adequate induction of anesthesia with no evidence of apnea or excitement.

Previous studies[2,3] have determined that the MAC of desflurane in dogs ranges from 7.2 to 10.3%. In the present study, mean expired desflurane concentration was 8.0 ± 0.6% (1.1 × MAC), with no significant difference between dogs undergoing laparotomy and dogs undergoing laparoscopy. Normally the concentration of an inhalant anesthetic needed to maintain a surgical plane of anesthesia is 1.5 × MAC; the concentration we used was lower because of the concomitant administration of boluses of fentanyl every 30 minutes.

The cardiovascular effects of desflurane in dogs have been determined previously.[11] This agent induces tachycardia and a decrease in arterial pressure regardless of the type of ventilation (spontaneous or controlled) and concentration used.[4] Results of the present study confirm these findings, insofar as anesthesia prompted a decrease in arterial blood pressure, although heart rate did not vary significantly during anesthesia, because desflurane was not administered at high concentrations. Previous studies[11,12] of the effects of desflurane in dogs suggest that with doses > 1 × MAC, heart rate increases significantly even if tachycardia is not dose-dependent. In the present study, administration of fentanyl as an analgesic prevented any possible episodes of tachycardia.[12] Intermittent positive-pressure ventilation does not modify changes in arterial pressure.[11] Pagel et al[13] and Merin et al[14] reported an increase in heart rate and a decrease in arterial blood pressure, compared with baseline values, in dogs anesthetized with desflurane, regardless of the concentration administered. The lowest mean arterial blood pressure recorded in the present study was 66 mm Hg at a desflurane concentration of 8.2% in dogs undergoing laparotomy. This value was similar to that reported by Pagel et al[13] and Merin et al,[14] who recorded an expired desflurane concentration of 12.6%. The decrease in arterial blood pressure in the present study at expired desflurane concentrations less than those reported in these previous studies was attributed to the

longer duration of anesthesia; to our knowledge, no studies have previously been published on the effects of prolonged anesthesia with desflurane in dogs.

Hypotension in the present study may also have been associated with the administration of propofol for induction of anesthesia, because propofol is a vasodilator. In humans, the initial administration of desflurane prompts a transitory but substantial increase in heart rate and arterial blood pressure[12] that is associated with sympathetic stimulation. In the present study, this did not occur, suggesting that administration of desflurane in dogs does not induce sympathetic stimulation. The cardiovascular responses observed by Clarke et al[11] suggest that the decrease in arterial blood pressure in dogs anesthetized with desflurane is mediated by a decrease in cardiac output, whereas in humans, hypotension is a result of a decrease in peripheral vascular resistance.

In the present study, hypotension was more severe in dogs undergoing laparotomy than in dogs undergoing laparoscopy. Generally speaking, a higher arterial blood pressure can be observed during laparoscopy, probably because the pneumoperitoneum created during surgery increases intra-abdominal pressure, giving rise to increased systemic vascular resistance and arterial blood pressure and compensating for the decrease in cardiac output resulting from a decrease in venous return.[15] However, this occurs only when very high intra-abdominal pressures are used, which was not the case in the present study. It has been reported that neither the increase in intra-abdominal pressure nor the carbon dioxide accumulation in plasma influences cardiac output,[16,17] and we agree with the suggestions of others that hypertension in dogs undergoing abdominal laparoscopy may be caused by any of 3 factors: mechanical compression of the splanchnic vascular bed, a sympathetic reflex from the splanchnic regions, and release of humoral vasoconstriction mediators such as renin or vasopresin.[17-19] Systemic arterial hypertension has consistently been found during inflation of the peritoneum with CO_2, but Huang et al[20] reported that hypercarbia may not be the major determinant factor of it. We can conclude that although CO_2 insufflation does not greatly affect cardiovascular function in dogs, the hemodynamic consequences of laparoscopy must be carefully monitored so that possibly severe changes in arterial blood pressure can be detected and managed.

In the present study, Spo_2 remained within reference limits at all times. Nevertheless, Spo_2 was significantly higher in dogs undergoing laparoscopy, although we could not find a clear reason for this. It is known that if correct ventilatory support is provided, Spo_2 can easily be maintained > 90% during laparoscopy.

Carbon dioxide pneumoperitoneum causes absorption of this gas, and if lung ventilation is insufficient to eliminate the carbon dioxide absorbed during pneumoperitoneum, hypercapnia will develop, which may cause acidosis, depress myocardial function, and induce arrhythmias and cardiovascular collapse.[15] In view of this possibility, controlled ventilation was used to prevent hypercapnia in the present study. No significant differences were observed with respect to the ventilatory parameters measured during anesthesia, and none of the dogs developed any cardiac arrhythmias.

Although $Paco_2$ would have been a better way to assess ventilation than $Petco_2$, we were unable to monitor $Paco_2$ in the present study. There is, however, a study[16] that reports that insufflation of the peritoneal cavity with CO_2 to an intra-abdominal pressure < 15 mm Hg does not interfere significantly with pulmonary gas exchange in patients without preexisting cardiopulmonary diseases. Other authors reported a statistically significant correlation between $Paco_2$ and $Petco_2$ during 60 minutes of CO_2 insufflation.[21] Puri and Singh,[22] in a study of human patients undergoing laparoscopy, found an increase in physiologic dead-space and arterial to end-tidal difference in partial pressure of CO_2, but these differences were not significant. In the present study, a substantial but variable increase in minute ventilation was needed to compensate for absorption of CO_2 from the peritoneal cavity, as has been reported previously.[23]

Recovery was swift in the present study, and all dogs managed to stand on the first attempt. Mean time to standing was < 14 minutes, and recovery times were not significantly different between groups (laparotomy vs laparoscopy). Rapid recovery times were also reported by Song and White[24] in a study of the effects of desflurane and remifentanyl in humans and by Jakobsson et al[25] in a study of the effects of anesthesia with desflurane administered in 67% nitrous oxide (anesthesia was induced with propofol, and fentanyl was administered before anesthetic induction) in humans undergoing gynecologic laparoscopic surgery. Clarke[26] reported a recovery time of 6 minutes after desflurane anesthesia in dogs.

[a]Sims Portex Inc, Keene, NH.
[b]Ohmeda, Madrid, Spain.
[c]Suprane, Baxter, Valencia, Spain.
[d]Fentanest, Roche, Madrid, Spain.
[e]Hewlett Packard model 86S, Geneva, Switzerland.

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