Comparison of anesthetic induction in cats by use of isoflurane in an anesthetic chamber with a conventional vapor or liquid injection technique

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Objective—To compare 2 techniques for induction of cats by use of isoflurane in an anesthetic chamber.

Design—Prospective, randomized study.

Animals—51 healthy cats.

Procedures—Cats were randomly allocated to 2 induction techniques. Cats were premedicated with acepromazine (0.1 mg/kg [0.045 mg/lb], SC) and buprenorphine (0.01 mg/kg [0.0045 mg/lb], SC) 30 minutes before induction. Cats were then placed into an induction chamber, and anesthetic induction was initiated. One technique involved a conventional flow-through system that used an oxygen flowmeter and an isoflurane vaporizer to flow vapors into the induction chamber. Alternatively, liquid isoflurane was injected into a vaporization tray that was mounted to the interior surface of the chamber lid. Inductions were videotaped for analysis. Five variables (head bobbing, head swinging side to side, paddling, rotating 180° to 360°, and rolling over or flipping) were scored to assess induction quality. Time variables recorded during induction corresponded to the interval until onset of excitatory motion, duration of excitatory motion, interval until recumbency, and interval until complete induction.

Results—Compared with cats anesthetized by use of a conventional vapor chamber technique, cats anesthetized by use of the liquid injection technique had a significantly shorter interval until recumbency and interval until complete induction and lower scores for quality of induction, indicating a smoother induction.

Conclusions and Clinical Relevance—Anesthetic induction in cats by use of a liquid injection technique was more rapid and provided a better quality of induction, compared with results for cats induced by use of a conventional vapor technique. (*J Am Vet Med Assoc* 2008;233:262–266)

Anesthetic chambers are commonly used for anesthetizing fractious and aggressive cats and other small animals. Chambers are usually constructed of clear plastic to allow observation of animals during induction. The conventional method of induction in an anesthetic chamber uses an oxygen flow-through system that delivers oxygen and an inhalant anesthetic into the chamber. Waste gas is vented through an alternate outlet. A few pets may become dysphoric and not have a smooth induction in an anesthetic chamber. Quality of induction and recovery from anesthesia induced with isoflurane or sevoflurane in an anesthetic chamber have been compared.[a] A novel technique of injecting liquid inhalational anesthetic into an anesthetic chamber has been used at our veterinary medical teaching hospital for > 2 years. To our knowledge, there have been no studies conducted to compare conventional vapor induction with isoflurane in an anesthetic chamber and induction by use of liquid isoflurane injected into a vaporization tray. Our clinical impression has been that cats may have a more rapid, smoother induction with the liquid injection technique. The purpose of the study reported here was to compare the 2 techniques for induction of anesthesia in cats by use of isoflurane in an anesthetic chamber.

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Materials and Methods

Animals—Fifty-one healthy domestic cats (27 females and 24 males) undergoing elective ovariohysterectomy or castration were used for the study. Cats ranged from 5 to 14 months of age (mean ± SD, 7.7 ± 1.5 months). Body weight ranged from 2.2 to 4.8 kg (4.84 to 10.56 lb), with a mean of 3.5 ± 0.6 kg (7.70 ± 1.32 lb). All procedures for the study were approved by the Kansas State University Animal Care and Use Committee.

Anesthetic chambers—Two techniques of inductions by use of isoflurane[b] and an anesthetic chamber were evaluated. Two induction chambers were constructed. Inside dimensions of each chamber were 39.9 X

24.9 × 20.3 cm (15.7 × 9.8 × 8.0 inches) with an internal volume of 20,164 mL. A waste gas scavenger interface was attached to each chamber to allow for evacuation of waste gas. Each chamber was configured to ensure that the method of induction could not be discerned on the videotape recording. Each anesthetic chamber was placed in a cardboard container that covered all sides of the chambers, except the front and top. In addition, the cardboard container was constructed such that it prevented the video camera from recording the view of the top of the chamber, which assisted in preventing the investigators from knowledge of the type of induction used for a specific cat. The cardboard container was also used to minimize external visual stimuli to the cats.

Conventional vapor induction—Conventional vapor induction consisted of use of a flow-through system. Oxygen and anesthetic vapor were directed into the induction chamber by use of an oxygen flowmeter[e] and an agent-specific, precision vaporizer.[d] Oxygen and anesthetic vapor entered the top of the chamber at one end and flowed to the bottom of the chamber on the opposite end, where oxygen, air, and isoflurane vapor exited into the anesthetic waste gas scavenger interface. This method of fresh gas cross flow was used to ensure mixing of gases. A new, factory-certified vaporizer was used for all flow-through techniques. The vaporizer dial was set at 5%. The oxygen flowmeter was set at 5 L/min. Vaporizer output was evaluated numerous times throughout the experiments by use of a calibrated gas analyzer[e] and was always within 10% of the indicated dial setting of 5%.

Liquid injection induction—For the liquid injection technique, a custom-made vaporization tray was permanently mounted 3 mm below the interior surface of each chamber lid. Liquid isoflurane was injected into this tray, and the anesthetic was vaporized while the cat was breathing room air in the chamber. Vaporization trays were constructed of 0.6-mm-thick stainless steel. Dimensions (length × width × depth) of the trays were 15 × 2.5 × 0.5 cm (5.9 × 1.0 × 0.2 inches). A liquid injection port that was accessible from the outside of the chamber was centered over the tray (**Figure 1**). Two layers of 5/8-inch tubular cotton material[f] covered the tray and acted as a wick to increase the surface area for vaporization. One layer of size 20, stainless-steel mesh[g] was used to press the wick into the bottom of the tray. A plastic syringe[h] was used to inject the calculated amount of liquid isoflurane into the vaporization tray. The outlet of the waste gas scavenger interface was blocked by an external plug during inductions with injection of liquid isoflurane.

Recording of data—A video camera[i] was placed on a tripod and positioned so that the lens focused on the front of the induction chamber. A dull, nonreflective cardboard shield covered the camera and tripod so that only the camera lens was visible to a cat in the anesthetic chamber. The shield prevented reflection from the front of the chamber and enhanced quality of the videotape recordings. A continuously running digital timer and date stamp[j] were used for the videotape recordings and were visible at the top of the video screen throughout the duration of each induction. Each induction was assigned a unique number for each specific cat and was recorded on the videotape.

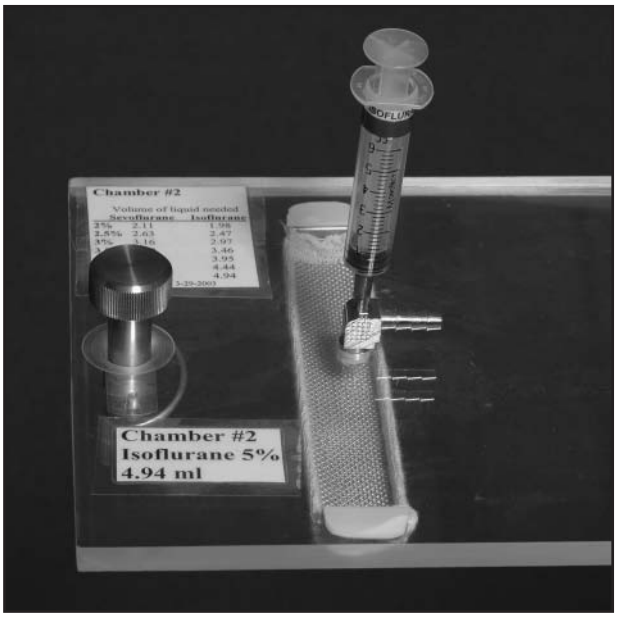

Figure 1—Photograph of components and the complete vaporization tray mounted to the interior surface of an anesthetic chamber lid with the needle-syringe used for injection of liquid isoflurane.

A start sign was placed at the top of the induction chamber to indicate when anesthetic flow through the chamber was initiated or when liquid isoflurane was injected into the tray. A stop sign was placed at the top of the induction chamber to indicate the point at which a cat appeared to be adequately anesthetized. This was determined to be the time when the cat could be removed safely from the induction chamber to continue anesthesia via a face mask until intubation could be performed.

Volume of isoflurane for induction—For the liquid injection technique, a calculated volume of liquid isoflurane was determined that would (with complete vaporization) achieve a maximal target vapor concentration of 5% isoflurane. Thus, the potential maximum isoflurane concentration would be 5% for each method of induction. The amount of liquid isoflurane used for the liquid injection technique was calculated as follows:

Number of mL of liquid isoflurane = (volume of chamber × desired fractional concentration of isoflurane)/(mL of vapor/mL of liquid isoflurane)

The mL of vapor/mL of liquid for isoflurane is 204.[1,2] Therefore, the calculation of the number of milliliters of isoflurane injected into the chamber vaporization tray was (20,164 mL × 0.05)/204 = 4.94 mL of isoflurane. Calculations were performed with the assumption of a room temperature of 24°C (75°F) and barometric pressure of 735 mm Hg.

Procedures—Cats were randomly assigned to be induced by the conventional vapor technique (n = 26) or the liquid injection technique (25). Cats were

premedicated with acepromazine maleate (0.1 mg/kg [0.045 mg/lb], SC) and buprenorphine (0.01 mg/kg [0.0045 mg/lb], SC). At a mean ± SD of 30 ± 10 minutes after administration of premedications, cats were placed into an induction chamber and the lid was secured. Anesthetic induction commenced within 1 or 2 minutes after a cat was placed into a chamber. Lights were dimmed in the room to minimize environmental stimuli. Personnel in the induction room limited movements and conversation during the induction procedure. Room temperature was recorded before each induction; mean ± SD room temperature was 23.6° ± 0.3°C (74.5° ± 0.6°F). The induction chambers, along with the components of the vaporization tray, were alternated and aerated between subsequent cats to ensure elimination of residual isoflurane in the vaporization tray and chamber.

Cats were removed from the induction chamber when an adequate plane of anesthesia was achieved. Cats were judged to be adequately anesthetized on the basis of the rhythm and character of respiration and a lack of spontaneous limb or head movements. All inductions were videotaped. Videotaping was discontinued when cats were removed from the chamber.

Videotaped inductions were subsequently reviewed and scored by an investigator (RDS) who was unaware of the treatment administered to each cat. Inductions were scored on the basis of 5 variables (head bobbing, head swinging side to side, paddling, rotating 180° to 360°, and rolling over or flipping). These variables were chosen on the basis of the authors' clinical experiences with anesthetic induction by use of an anesthetic chamber. Cats maintained an upright posture when rotating 180° to 360°. During roll-over and flips, cats rotated from sternal to dorsal and back to sternal recumbency. The scoring system was developed during this study. Scores assigned in each category ranged from 0 to 4, as determined by the number of times the event was detected during induction (**Appendix**). The scoring system was weighted on the basis of the perceived detrimental effects of each variable and its role on induction quality. The variables chosen were believed to differ in their impact on the evaluation of induction quality on the basis of each cat's response to induction. Head bobbing was considered to be the least detrimental action, whereas rolling over or flipping was considered to be the most detrimental action. Time variables were recorded for the interval until recumbency, interval until onset of excitatory motion, duration of excitatory motion, and interval until complete induction.

After induction, each cat was endotracheally intubated, and anesthesia was maintained by administration of isoflurane in oxygen. Neutering or ovariohysterectomy was performed, and all cats recovered without complications.

Statistical analysis—Statistical analysis was performed by use of statistical software.[k] Scores for quality of induction and induction time variables were compared between groups by use of a standard *t* test. Comparisons of the 2 methods for each of the variables were performed simultaneously. Familywise type I error rate was set at 0.05, and individual type I error rate was set at 0.005 by Bonferroni adjustment for the *t* tests. Box plots of variables were constructed to enable investigators to visually compare effects of the 2 methods and identify possible outliers.

Table 1—Mean ± SD scores for quality of anesthetic induction in cats anesthetized in an anesthetic chamber by use of isoflurane with a conventional vapor or liquid injection induction technique.

Variable	Conventional vapor (n = 26)	Liquid injection (n = 25)
Head bobbing	1.2 ± 0.7	0.9 ± 0.5
Swinging side to side	1.6 ± 0.6	1.5 ± 0.8
Paddling	1.0 ± 0.6	0.9 ± 0.6
Rotating 180° to 360°	2.2 ± 0.7	1.1 ± 0.9*
Rolling over or flipping	2.2 ± 1.5	1.4 ± 1.2
Total score	**8.2 ± 1.9**	**5.8 ± 2.7***

*Within a row, value differs significantly ($P < 0.05$) from value for conventional induction.

Table 2—Mean ± SD time variables for induction-related events in cats anesthetized in an anesthetic chamber by use of isoflurane with a conventional vapor or liquid injection induction technique.

Variable	Conventional vapor (n = 26)	Liquid injection (n = 25)
Interval until onset of excitatory motion (s)	26.4 ± 18.0	38.6 ± 24.0
Duration of excitatory motion (s)	131.4 ± 30.0	79.1 ± 29.0*
Interval until recumbency (s)	165.0 ± 33.0	137.0 ± 19.0*
Interval until complete induction (s)	246.0 ± 30.0	176.0 ± 29.0*

See Table 1 for key.

Results

Age and body weight did not differ significantly between groups. Scores for quality of induction were determined (**Table 1**). The scores for head bobbing, head swinging side to side, paddling, and rolling over or flipping were not significantly different between the 2 groups. However, the score for rotating 180° to 360° for the liquid injection induction was significantly lower, compared with the score for conventional vapor induction. Furthermore, total score for liquid injection induction was significantly lower than the total score for conventional vapor induction.

Mean time variables for both induction techniques were calculated (**Table 2**). Duration of excitatory motion was significantly less for liquid injection induction than for conventional vapor induction. The interval until recumbency was significantly less for liquid injection induction, compared with the interval for conventional vapor induction. Interval until complete induction was also significantly less for the liquid injection induction. Interval until onset of excitatory motion did not differ significantly between the 2 methods.

Discussion

Anesthetic induction by use of a chamber is an important, and sometimes necessary, component for inducing anesthesia in various species of animals. Results of the study reported here indicated that for anesthetic induction of cats, liquid injection induction was a more rapid, smoother method for inducing anesthesia, com-

pared with the results for conventional vapor induction. Overall, there were significant differences between induction techniques for duration of excitatory motion, interval until recumbency, and interval until complete induction, with liquid injection induction being superior for these time variables. Liquid injection induction resulted in a lower total score for quality of induction, which indicated a smoother induction. These results indicated that the liquid injection technique likely caused a more rapid increase in isoflurane anesthetic concentrations, compared with those for the conventional vapor technique. A more rapid induction may provide less time for undesirable behavior during induction.

The chamber for conventional vapor induction was designed such that anesthetic gases flowed through the lid of the chamber on one end to the bottom of the chamber on the other end. We believed this was necessary to establish cross flow for better mixing of gases and more uniformity in isoflurane concentration throughout the chamber. We believe that a more rapid increase in anesthetic concentration may result in a smoother anesthetic induction. The 5% vaporizer setting was selected because that is the maximum setting for many precision isoflurane vaporizers. The oxygen flowmeter was set at 5 L/min because many small anesthetic machine flowmeters are limited to 5 L/min. The amount of isoflurane required for the liquid injection technique was calculated on the basis of the size of the empty chamber. Volume or surface area of each cat was not considered for either induction technique. Placing a cat in a chamber reduces gas volume and would be a factor that could potentially increase the rate of increase of the anesthetic concentration for both techniques. We believe that the differences in size among cats were not sufficient to warrant adjustments in calculations among cats. Furthermore, despite the fact that the size of a cat in the chamber would reduce gas volume and potentially increase the rate of increase of the anesthetic concentration, the cat's tissues would be continuously removing anesthetic gases from the chamber. This factor would decrease the rate of increase of the anesthetic concentration. These factors would likely be similar for both induction techniques.

Although the investigator who reviewed the videotapes was not aware of the induction technique used for each cat, other investigators involved in the induction process did have knowledge of the induction techniques used for each cat. This could have potentially biased the determination of when an induction was considered to be complete. This possible bias could have affected interval until complete induction. However, the differences between duration of excitatory motion and interval until recumbency would not have been influenced by the investigators' awareness of the induction technique. These 2 variables were the major contributors to the interval until complete induction.

Recovery scores were not determined. Regardless of the method of induction used, the amount of time needed for recovery and quality of recovery were likely to be similar between the 2 methods.

Differences between induction and recovery in cats anesthetized by use of isoflurane and sevoflurane in an anesthetic chamber have been reported.[a] Also, induction and recovery characteristics of cats anesthetized by use of desflurane in an isoflurane chamber have been evaluated.[3] To our knowledge, there are no studies in which investigators evaluated the quality of induction in cats by use of isoflurane in an anesthetic chamber with a conventional vapor technique and the liquid injection technique.

In the study[a] in which investigators compared isoflurane and sevoflurane for induction in cats, there was a shortened duration of excitatory motion and a longer interval until recumbency for the isoflurane group, compared with results for the study reported here, despite the fact that vaporizer and oxygen flow settings were the same for both studies. Ages and weights of cats were also similar for both studies. The interval until induction was approximately 281 seconds in the other study,[a] compared with approximately 246 seconds for the conventional vaporization technique in our study. The type of premedication used, if any, was not stated for the other study, and criteria for classifying excitatory motion were not reported. These unknown factors may have contributed to the differences between the 2 studies.

Supplemental oxygen was not delivered into the chambers prior to the liquid injection inductions. Differences in oxygen concentration in the induction chambers between the 2 techniques may have contributed to some of the detected differences. Oxygen consumption and carbon dioxide production of animals during induction in enclosed chambers may be of concern. We calculated theoretic oxygen consumption and carbon dioxide production during induction, and we predicted that oxygen availability and safe carbon dioxide concentrations would be maintained within the chamber during the liquid vaporization inductions. When oxygenation is a concern for compromised patients, the induction chamber may be filled with 100% oxygen prior to starting the liquid injection induction.

Differences in minute ventilation between cats breathing room air and cats breathing 100% oxygen could be a factor that affects the interval until induction. It is possible that cats breathing room air and isoflurane have greater minute ventilation, which would result in more rapid induction than when cats breathe mixtures enriched with oxygen. This is speculative because we did not measure respiratory rate or tidal volume.

To achieve a specific isoflurane concentration in an induction chamber, the rate of increase of isoflurane concentration in an empty chamber can be calculated for the conventional vapor technique by use of the equation $t = (V/F) \times \ln(S/[S - C])$, where t is the time needed to achieve the desired concentration of anesthetic in the chamber, V is the volume of the chamber, F is the rate of flow into the chamber, ln is the natural logarithm, S is the concentration of isoflurane directed into the chamber from the vaporizer, and C is the concentration of anesthetic in the chamber at any specific time point.[4] For example, for the conventional vapor technique, the amount of time needed to achieve an isoflurane concentration of 2.8% (approx twice the minimum alveolar concentration[5,6]) would be 3.3 minutes. Placing a cat in the chamber would reduce gas space and would hasten the increase in the anesthetic

concentration. Because of the measured intervals until complete induction, we predict that the rate of increase in isoflurane concentration for the liquid injection technique is likely to be more rapid than the rate of increase for the conventional vapor technique.

Experiments were not conducted to determine the rate of increase in the anesthetic concentration for the liquid injection technique. Several factors may contribute to the rate of vaporization in the liquid injection inductions. Temperature and surface area of the wick are 2 factors. Surface area of the wick was constant, and although chamber temperature was not measured, room temperatures were similar throughout the study. Thus, these factors were consistent throughout our study and should not have affected results among cats or between groups. Heat radiating from a cat's body could contribute to a slight increase in temperature in the vaporization tray and therefore increase the rate of vaporization.

Analysis of results of the study reported here suggested that there was likely a more rapid increase in isoflurane concentrations when the liquid injection technique was used for induction. We believe that an increase in the rate of rise of the anesthetic concentration may result in a smoother induction for cats. Induction by use of liquid isoflurane and a novel vaporization tray in an anesthetic chamber is a reasonable alternative to the conventional vapor technique for induction. With minor modification of current anesthetic chambers and effective staff training, induction by use of the liquid injection technique should be a cost-effective and efficient method for anesthetizing cats.

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g. Screening stainless-steel type 304, mesh size 20, catalogue No. U-CX-20, Small Parts Inc, Miami Lakes, Fla.
h. Monoject polypropylene syringes, Tyco Healthcare Group LP, Mansfield, Mass.
i. Panasonic AG-455 video camera, Panasonic Corp of North America, Secaucus, NJ.
j. TDG200DT time/date generator, Pelco, Clovis, Calif.
k. SAS software, version 9.1, SAS Institute Inc, Cary, NC.

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Appendix

Criteria used to determine scores for quality of induction in cats induced by use of isoflurane in an anesthetic chamber. Scores were assigned on the basis of the number of times an activity was detected during induction.

Variable	0	1	2	3	4
Head bobbing	Not detected	1–6	7–14	15–22	> 22
Head swinging side to side	Not detected	1–4	5–9	10–14	> 14
Paddling	Not detected	1–6	7–14	15–22	> 22
Rotating 180° to 360°	Not detected	1–3	4–7	7–10	> 10
Rolling over or flipping	Not detected	1	2	3	> 3