Inhalation anesthetics such as isoflurane and halothane have traditionally been used to maintain anesthesia in calves undergoing prolonged surgical procedures in both clinical and research settings. In general, the advantages of administering inhalant anesthetics for maintenance of anesthesia in any species include ease of administration, rapidity with which depth of anesthesia can be adjusted, and quick recovery from anesthesia after termination of drug administration.

The cardiopulmonary effects of the currently available inhalant anesthetics, including isoflurane, have been thoroughly evaluated in horses, dogs, and goats, both with and without surgical intervention. Overall, in most species, a moderate decrease in arterial blood pressure and cardiac index, mild increase in heart rate, and hypocapnia are consistently observed at surgical planes of anesthesia resulting from isoflurane.\(^1\)\(^2\) Although it is anticipated that the cardiopulmonary effects of isoflurane administration will be similar in bovids, a detailed evaluation of the cardiopulmonary effects of isoflurane when administered to newborn calves has not been reported, to the authors’ knowledge.

Despite the advantages associated with administration of inhalant anesthetics, use of these agents for...
anesthetic maintenance may be limited in some circumstances by equipment requirements, including the need to scavenge the volatile agents and prevent personnel exposure and environmental pollution. In addition, use of an inhalant agent as the sole anesthetic may result in greater hemodynamic depression than that produced with injectable anesthetics.\(^5\) In certain research investigations, administration of inhalant agents may be contraindicated and an alternative must be used. Several injectable anesthetic agents or combinations of agents have been investigated for inducing and maintaining anesthesia in large animal species. Although repeated administration of bolus doses of various agents can be used, an infusion of agents is generally considered to result in more consistent anesthesia with a lower overall quantity of each drug being administered. One of the most commonly used protocols for maintaining general anesthesia in large animals for a prolonged duration is continuous infusion of a mixture of XGK. The quality of anesthesia resulting from this combination of agents has been reported as comparable to that resulting from use of inhalant agents when used for short-duration anesthesia in numerous large and small animal species.\(^6,7\)

Unfortunately, in few studies have direct comparisons between this type of injectable regimen with inhalant anesthetics been made in animals undergoing surgery. In 1 investigation,\(^7\) the cardiopulmonary effects of administration of a combination of romifidine, guaifenesin, and ketamine were compared with those associated with administration of halothane for anesthetic maintenance in spontaneously breathing horses. Although cardiac output was similar when horses were anesthetized with either regimen, significantly higher and more desirable blood pressures were detected in horses receiving the injectable anesthetic, compared with those receiving halothane. In the latter study,\(^1\) differences in arterial oxygen and carbon dioxide concentrations between groups were of no clinical importance. In sheep, calves, and adult cows, the hemodynamic changes associated with XGK infusions are similar to those reported in horses.\(^1,6,7\)

However, substantial degrees of hypoxemia and hypercapnia have been reported in ruminants spontaneously breathing room air while anesthetized with injectable anesthetic combinations.\(^7,8\) The objective of the study reported here was to evaluate and compare the cardiopulmonary effects of anesthesia resulting from IV infusion of XGK or inhaled isoflurane in calves undergoing abdominal laparoscopy with oxygen supplementation and controlled ventilation.

**Materials and Methods**

Thirteen male Holstein-Freisen calves with a mean SD age of 12 ± 7.81 days and mean ± SD weight of 49.9 ± 6.06 kg were included in the study. Prior to entry into the study, calves were determined to be healthy on the basis of physical examination, CBC, and serum biochemistry results. Calves were housed individually at the University of Guelph Veterinary Teaching Hospital and fed a commercial milk replacer; feed was withheld for 4 hours prior to the study period. The University of Guelph's Animal Care Committee approved the experimental protocol, and guidelines of the Canadian Council on Animal Care were followed during the study.

Calves were randomly assigned to the XGK (n = 7) or isoflurane (6) groups. On the day of the study, anesthesia was induced and maintained in all calves with isoflurane\(^1\) in oxygen, delivered via a face mask and circle breathing system attached to an anesthesia machine.\(^5\) Calves underwent instrumentation with ECG leads placed in a base-apex configuration; a 20-gauge, 2.5-cm catheter\(^1\) in the auricular artery; a 16-gauge, 8.3-cm catheter\(^1\) in the jugular vein; and a rectal temperature probe. The ECG leads were connected to a multiparameter monitor\(^1\) that displayed heart rate. A disposable pressure transducer\(^1\) connected to the multiparameter monitor measured SABP, MABP, and DABP from the auricular arterial catheter. The manubrium was used as the zero reference point for all arterial blood pressure measurements. A sampling line for measuring gases was inserted between the face mask or endotracheal tube and the circle breathing system to measure (ET\(_{CO2}\) and ET\(_{O2}\)) with an infrared absorption spectrophotometer.\(^1\) Calibration of the pressure recording system and the spectrophotometer component of the multiparameter unit was performed at the start of each experimental period by use of a mercury manometer and standard gases,\(^6\) respectively. After instrumentation, calves received celtifur\(^4\) (dose, 2.0 mg/kg) and ketoprofen\(^3\) (3.0 mg/kg) administered IV through the jugular venous catheter and were allowed to recover from anesthesia.

Thirty minutes after extubation, calves were gently restrained in right lateral recumbency, and baseline measurements of heart rate and respiratory rate were obtained by observation of thoracic wall excursion. Values of SABP, MABP, DABP, and CO were recorded, and arterial blood samples were collected anaerobically from the auricular artery into heparinized plastic syringes. Arterial blood gases were determined,\(^7\) and electrolyte\(^k\) and hemoglobin\(^i\) measurements were performed within 10 minutes after collection. Samples were corrected for body temperature, which was obtained from the rectal temperature probe. Cardiac output was measured by use of the lithium dilution technique.\(^10,11\) In brief, the sensor\(^a\) and lithium dilution CO cardiac computer\(^b\) were prepared as described by the operations manual. The most recent serum sodium and hemoglobin concentrations were entered immediately prior to performing CO measurements. The inlet port of the sensor was attached to the auricular artery catheter 3-way valve, and the outlet port was attached via tubing to a collection bottle with the tubing passing through the flow regulator pump. When the pump was activated, blood was withdrawn from the auricular artery and forced across the sensor at a constant rate of 4 mL/min. An injectate volume (0.005 mL/kg) of a commercial lithium chloride solution (concentration, 0.15 mmol/mL)\(^a\) was administered via the catheter in the jugular vein and used for each CO determination. A single lithium dilution CO determination was obtained at each sampling interval and used for subsequent analysis.

After baseline measurements were obtained, anesthesia was induced and maintained with a solution containing xylazine\(^1\) (0.1 mg/mL), guaifenesin\(^i\) (50 mg/mL), and ketamine\(^1\) (1 mg/mL) in 5% dextrose
placed at 1 site, and laparoscopic instruments were in laparoscopic equipment placement. A laparoscope was inserted as an initial bolus. If the depth of anesthesia was inadequate to permit endotracheal intubation via the direct visualization technique, a second 0.5 mL/kg bolus of the mixture was administered IV over 20 seconds. Induction of anesthesia and intubation were performed in all calves by 1 author (CLK). Immediately after intubation, an IV administered infusion of XGK was started at a rate of 2.5 mL/kg/h, resulting in delivery of 0.25 mg of xylazine/kg/h, 125 mg of guaifenesin/kg/h, and 2.5 mg of ketamine/kg/h. Calves were connected to a circle breathing system attached to an anesthetic machine with an oxygen flow rate of 60 to 100 mL/kg/min. If the plane of anesthesia was deemed insufficient as assessed by muscle relaxation, eye movement, and eye reflexes, a bolus dose of 0.5 mL/kg was administered IV, and the infusion rate was increased by 0.5 mL/kg/h if necessary. If the plane of anesthesia was considered to be excessively deep as indicated by muscle relaxation and ocular reflexes, the infusion rate was decreased by 0.5 mL/kg/h.

Anesthesia was induced in calves in the isoflurane group with isoflurane delivered in oxygen via a face mask with a circle system attached to an anesthetic machine. In brief, calves received oxygen at 60 to 100 mL/kg/min. The isoflurane vaporizer was initially set at 4%. Once calves reached a suitable depth of anesthesia as assessed by muscle relaxation, eye position, and eye reflexes, they were intubated by use of the direct visualization technique. As with the previous group, induction and intubation were performed in all calves by 1 author (CLK). Immediately after intubation, the vaporizer was adjusted to achieve a suitable depth of anesthesia as assessed by muscle relaxation, eye position, and eye reflexes.

In both treatment groups, intermittent positive-pressure ventilation was initiated immediately after intubation with a tidal volume of 10 mL/kg, with the rate adjusted to maintain ET CO2 from 35 to 50 mm Hg as measured by the side stream gas analyzer. Induction was scored as excellent, moderate, or poor. An excellent score was assigned if induction was smooth with no muscle twitching or muscle rigidity, whereas a moderate score was assigned if induction was smooth but some muscle twitching or rigidity was observed. A calf received a poor induction score if induction of anesthesia was associated with considerable muscle twitching, muscle rigidity, or excitement. Calves were placed in dorsal recumbency and aseptically prepared for an abdominal surgical procedure.

Hemodynamic measurements were repeated at 5 and 15 minutes after induction (ie, presurgery measurements). After the 15-minute recording, calves were tilted to a 10° head-down position and underwent laparoscopic cystostomy via a caudal abdominal approach as part of a second investigation. In brief, a small volume of lidocaine was injected at 3 sites for laparoscopic equipment placement. A laparoscope was placed at 1 site, and laparoscopic instruments were introduced at the other 2 sites. An arterial blood sample was obtained for blood gas analysis at 30 minutes, and hemodynamic measurements were repeated at 30, 45, and 60 minutes (eg, surgery measurements). After the 60-minute recordings, the abdomen was insufflated with an initial 12 mm Hg by use of an automatic high-flow carbon dioxide insufflator connected to the laparoscope cannula. The abdomen remained insufflated for the remainder of the experimental period. Hemodynamic recordings were repeated at 75 and 90 minutes (eg, postinsufflation measurements). An arterial blood gas sample was obtained for analysis prior to the 90-minute hemodynamic measurements.

At the end of the experimental period, 3 calves in the XGK group and 3 calves in the isoflurane group were euthanatized with pentobarbital sodium. Recovery times were not recorded in calves that were not euthanatized because surgery continued for variable times following the 90-minute data collection period.

Statistical analysis—All variables that were measured over time were analyzed with 2-way repeated-measures ANOVA. The main effects of treatment and time and the treatment-by-time interaction were included in the model with appropriate covariance structure to account for making repeated measures on the same animal. The data were also examined by event (eg, awake, presurgery, surgery, and postinsufflation measurements). A significant F ratio was further analyzed via Dunnett post hoc analysis, and a t test was performed to compare surgical times between groups. For all comparisons, values of P < 0.05 were considered significant. Data were expressed as mean ± SE. A Shapiro-Wilk test was used to check the residuals for normality.

Results

The quality of induction was assessed as excellent in all calves in both treatment groups. Six calves required a dose of 0.5 mL/kg, IV, and 1 calf required a...
Table 1—Mean ± SD values for hemodynamic variables in healthy calves at baseline and after induction and maintenance of anesthesia with intravenously administered XGK solution (n = 7) or inhaled isoflurane (6). Measurements were obtained prior to surgery (5 and 15 minutes after induction), during surgery (30, 45, and 60 minutes after induction), and during surgery with the abdomen insufflated (75 and 90 minutes after induction).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>BL</th>
<th>5 minutes</th>
<th>15 minutes</th>
<th>30 minutes</th>
<th>45 minutes</th>
<th>60 minutes</th>
<th>75 minutes</th>
<th>90 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SABP (mm Hg)</td>
<td>XGK</td>
<td>126.6 ± 18.3</td>
<td>110.9 ± 16.5*</td>
<td>108.4 ± 13.4*</td>
<td>111.1 ± 16.4*</td>
<td>113.3 ± 16.0*</td>
<td>113.1 ± 13.7*</td>
<td>114 ± 13.5*</td>
<td>105.9 ± 16.6*</td>
</tr>
<tr>
<td></td>
<td>ISO</td>
<td>92.2 ± 20.7</td>
<td>95.5 ± 22.0*</td>
<td>98.3 ± 20.0*</td>
<td>101.8 ± 10.71</td>
<td>103.8 ± 11.81</td>
<td>101.6 ± 15.71</td>
<td>103.8 ± 15.71</td>
<td>99.2 ± 15.71</td>
</tr>
<tr>
<td>DAPB (mm Hg)</td>
<td>XGK</td>
<td>82.7 ± 20.5</td>
<td>68.3 ± 10.5*</td>
<td>57.1 ± 11.3</td>
<td>50.6 ± 13.8</td>
<td>61.4 ± 14.5</td>
<td>63.3 ± 15.7</td>
<td>71.3 ± 13.7</td>
<td>66.0 ± 8.2</td>
</tr>
<tr>
<td></td>
<td>ISO</td>
<td>76.8 ± 9.9</td>
<td>50.8 ± 9.7</td>
<td>49.0 ± 18.7</td>
<td>62.8 ± 22.0</td>
<td>59.7 ± 23.2</td>
<td>76.5 ± 10.8</td>
<td>70.8 ± 7.7</td>
<td>68.2 ± 9.8</td>
</tr>
<tr>
<td>SI (mL/kg/beat)</td>
<td>ISO</td>
<td>1.65 ± 0.33</td>
<td>1.27 ± 0.41</td>
<td>1.44 ± 0.51</td>
<td>1.25 ± 0.60</td>
<td>1.29 ± 0.51</td>
<td>1.37 ± 0.58</td>
<td>1.48 ± 0.58</td>
<td>1.46 ± 0.57</td>
</tr>
<tr>
<td></td>
<td>XGK</td>
<td>1.89 ± 0.26</td>
<td>1.46 ± 0.24</td>
<td>1.60 ± 0.17</td>
<td>1.61 ± 0.2</td>
<td>1.58 ± 0.29</td>
<td>1.54 ± 0.23</td>
<td>1.48 ± 0.27</td>
<td>1.47 ± 0.26</td>
</tr>
</tbody>
</table>

BL = Baseline, ISO = Isoflurane.
*Significant (P < 0.05) difference from value at BL. †Significant (P < 0.05) difference from value for ISO group at this time interval.

dose of 1.0 mL/kg, IV, of the XGK mixture to achieve adequate anesthetic depth to permit endotracheal intubation. The infusion rate of XGK was not changed during the maintenance phase of anesthesia in 5 calves. One calf received an additional 0.5 mL/kg bolus of XGK 37 minutes after induction, but the rate was not adjusted; another calf received bolus doses at 30 and 36 minutes after induction. The infusion rate in the latter calf was increased after each bolus dose to 3.0 mL/kg and 3.5 mL/kg, respectively. Mean ET was 1.34% (range, 0.9% to 1.6%) prior to surgery (5 and 15 minutes) and 1.59% (range, 1.3% to 1.8%) throughout surgery (30 to 90 minutes).

During the experimental period, mean heart rate values ranged from 98.0 to 116.0 beats/min in the isoflurane group and from 88.0 to 97.0 beats/min in the XGK group (Figure 1). Heart rate was significantly lower than baseline at 5 to 90 minutes after induction. In the isoflurane group, heart rate was significantly greater than baseline at 5 minutes after induction. Although calves in the XGK group had a significantly lower heart rate than calves in the isoflurane group at 5 minutes after induction, there was no significant difference in heart rate between treatment groups for the remainder of the study period.

Systolic arterial blood pressure was significantly lower in the isoflurane group than in the XGK group from 5 to 90 minutes (Table 1). Mean arterial blood pressures for the isoflurane and XGK groups ranged from 63.2 to 90.2 mm Hg and 75.7 to 88.7 mm Hg, respectively. There was no significant difference between groups in MABP at any time during the study. Mean arterial blood pressure was, however, significantly less than baseline for both groups at 5 to 45 minutes after induction (Figure 2). In calves in the XGK group, DAPB was significantly higher than that in calves that received isoflurane 5 minutes after induction. In calves that received XGK, DAPB was significantly less than baseline 5 to 45 minutes after induction, whereas DAPB in calves that received isoflurane was significantly less than baseline at 5, 10, and 45 minutes after induction. No significant differences in CI or SI over time were detected within a group or between treatment groups at any time point (Table 1). Mean CI ranged from 134.0 to 151.2 mL/kg/min and 133.95 to 149.6 mL/kg/min for the isoflurane and XGK treatment groups, respectively (Figure 3). In the isoflurane group, mean SI ranged from 1.27 to 1.48 mL/kg/beat, and in the XGK group, mean SI ranged from 1.40 to 1.61 mL/kg/beat. When SI was examined by event (awake, presurgery, surgery, and postsufflation measurements), a significant difference between treatments was revealed, with calves in the XGK group having a higher mean SI than calves in the isoflurane group. There were no significant differences between groups at any time period in arterial oxygen partial pressure, arterial carbon dioxide partial pressure, or arterial blood pH (Table 2).

Discussion

Compared with isoflurane, the combination of XGK evaluated in this study resulted in an equivalent quality of anesthesia with overall similar cardiopulmonary alterations when administered to mechanically ventilated calves undergoing surgery. The described injectable anesthetic regimen has potential for use in situations when administration of inhalant anesthetics is contraindicated or restricted because of equipment availability.

Various methods have been used to induce general anesthesia when anesthesia is to be maintained by XGK infusion, including administration of a bolus of the XGK solution at various doses or administration of sedatives followed by initiation of a slow infusion of the solution. In the present study, a bolus of a mixture containing 0.05 mg of xylazine/kg, 25 mg of guaifenesin/kg, and 0.5 mg of ketamine/kg was sufficient to...
induce general anesthesia in 6 of 7 calves. This dose is in accordance with recommendations by Thurmon for calves, but it is less than half the dose of XGK required to induce anesthesia in adult sheep. In another study performed in calves, authors did not use a bolus dose to induce anesthesia, but rather calves were sedated with xylazine (0.1 mg/kg) 15 minutes before XGK infusion was started. Although medication of calves with xylazine may facilitate handling, this regimen is associated with greater cardiopulmonary depression than we observed when no sedation was administered prior to induction. The present study reveals that, by combining guaifenesin and ketamine with a low dose of xylazine, anesthesia can consistently be induced in calves without medication.

Various rates of infusion of different combinations of XGK for the purpose of maintaining anesthesia have been described in several large animal species, including horses, sheep, and cattle. In the present study, an infusion of guaifenesin, xylazine, and ketamine at 2.5 mL/kg/h was sufficient to maintain a surgical plane of anesthesia in most calves. This rate of infusion was comparable to the 2.6 mL/kg/h for XGK used to maintain anesthesia in sheep subjected to a cutaneous electrical stimulus as a model of surgical stimulation. Conversely, the rate used in the present study was much higher than the 1.1 mL/kg/h for the identical mixture of XGK, which was used to maintain anesthesia in sedated calves in an earlier study. In that study, calves received an epidural injection, but no other stimuli were applied. The lower dose requirements may therefore reflect different target anesthetic depths among the studies. Although it is possible that a lower dose of an XGK combination could be used if a sedative agent is administered prior to induction, the negative cardiopulmonary effects of prior administration of an α2-adrenergic receptor agonist may outweigh the benefits of the lower XGK dose.

In the present investigation, heart rate decreased after induction of anesthesia and remained below baseline for the entire study period in calves that received XGK. This finding was in contrast to those from other studies in which it was reported that this combination had minimal effect on heart rate or caused an increase in heart rate. Administration of xylazine alone in calves results in bradycardia, and the decrease in heart rate detected in the present study was likely a result of inclusion of this agent in our anesthetic combination. Despite the decrease in heart rate, values for heart rate were still within the reference range throughout the study, and it is likely that baseline values were mildly high because of mild excitement prior to induction of anesthesia. Heart rates in calves assigned to the isoflurane group in the present study were similar to rates measured in yearling steers by Greene et al when the cardiopulmonary effects of several inhalants, including isoflurane, were evaluated. The transient increase in heart rate detected immediately after induction in the present study was likely secondary to sympathetic nervous stimulation associated with mask induction. Although the differences in heart rate between groups in this study were not substantial, they are consistent with findings of Young et al who reported significantly lower heart rates in horses in which general anesthesia was maintained with an infusion of XGK, compared with the control group anesthetized with halothane.

At the doses administered in the present study, use of XGK for induction and maintenance of anesthesia did not negatively impact systemic arterial blood pressures. This is in accordance with findings reported in a study of sheep anesthetized with XGK. However, hypotension has been reported in calves sedated with xylazine prior to XGK infusion and in sheep anesthetized with xylazine and ketamine. In both of those investigations, it was concluded that xylazine was respons...
sible for the decrease in blood pressure. In the present study, the decrease in blood pressure was minor, suggesting that by minimizing the dose of xylazine administered with the addition of guaifenesin and ketamine, hemodynamic stability was improved. Although values were not substantially different from those in calves in the XGK group, calves in the isoflurane group had arterial blood pressures that were mildly hypotensive. The moderate decrease in systemic arterial pressures in calves receiving isoflurane is similar to values reported in mechanically ventilated goats anesthetized with isoflurane. In that study, MABP decreased to hypoten-sive values as ET\text{\textsubscript{\text{aw}}}, was increased from 1.0 to 1.5 times the minimum alveolar concentration of isoflurane. In a study of yearling steers,\textsuperscript{2} MABP remained within the reference range throughout anesthesia with isoflurane; however, the steers in that study developed severe hypercapnia, which likely had a positive influence on systemic arterial pressures because of sympathetic nervous system stimulation.\textsuperscript{9}

Cardiac index was not significantly different between calves maintained with either anesthetic regimen in the current study, although there was a decrease relative to awake baseline values in both groups. In a study by Picavet et al., administration of XGK resulted in an increase in CI in calves from postsedation values. This change, however, resulted from a significant decrease in CI after sedation with xylazine, and when compared with values in awake calves, CI during XGK anesthesia was below baseline values. A decrease in CI has also been described in sheep anesthetized with xylazine and ketamine and after anesthetic induction with a bolus of XGK in ponies.\textsuperscript{16,17} Likewise, McMurphy et al.\textsuperscript{8} detected no difference in CO values between horses anesthetized with halothane and those anesthetized with infusion of an \(\alpha\)-adrenergic agonist, guaifenesin, and ketamine.

The SI of calves in the XGK group was greater than that of the isoflurane group, but neither regimen caused a significant change from values obtained while calves were awake. The difference between groups is likely attributable to the lower heart rates detected in calves anesthetized with XGK. The increased filling time associated with sedation with xylazine and after anesthetic induction with a bolus of XGK in ponies.\textsuperscript{16,17} Likewise, McMurphy et al.\textsuperscript{8} detected no difference in CO values between horses anesthetized with halothane and those anesthetized with infusion of an \(\alpha\)-adrenergic agonist, guaifenesin, and ketamine.

Sedation of most ruminants, including calves, with an \(\alpha\)-adrenergic agonist results in substantial reductions in arterial oxygen partial pressures.\textsuperscript{8} In sheep, primary alterations to pulmonary vascular permeability with secondary pulmonary edema and microthrombi formation, in addition to an increase in intrapulmonary shunting, likely contributed to the hypoxemia typically observed with \(\alpha\)-adrenergic agonist administration.\textsuperscript{18,19}

To avoid the risk of hypoxemia, \(\alpha\)-adrenergic agonists are often not included in anesthetic protocols for ruminants, particularly if oxygen supplementation is not available. On the basis of previous studies of xylazine in calves and cattle, we elected to intubate and provide oxygen supplementation and ventilatory support for calves in the present study. Interestingly, as used in the present study, the XGK regimen did not have a negative impact on oxygenation. The lack of adverse effects on pulmonary function was likely a result of the fact that the calves were intubated and mechanically ventilated with 100% oxygen.

Results of the present study indicated that cardiovascular effects are minimal when calves receive oxygen supplementation and ventilatory support while anesthetized with an IV-administered mixture of XGK, during a surgical procedure 90 minutes in duration. This regimen offers an alternative to inhalant anesthesia and could potentially be used to anesthetize calves, with oxygen supplementation, under field conditions. It was not possible to evaluate quality of recovery from anesthesia in the present study, but recoveries in calves that received tolazoline after termination of XGK administration were reported as uncomplicated in a study by Picavet et al.\textsuperscript{5} However, in that study, details of anesthetic recovery were not reported. Similar findings have been reported in sheep and steers that did not receive an \(\alpha\)-adrenergic receptor antagonist after XGK administration, although the recovery times in the sheep were long and variable.\textsuperscript{7,9} Further studies in which recovery characteristics are evaluated, with and without use of an \(\alpha\)-adrenergic receptor antagonist, are warranted.\textsuperscript{2}

Xylazine, guaifenesin, and ketamine are not licensed for use in cattle in most countries, as is true for isoflurane. Appropriate regulatory agencies should be consulted for recommendations on tissue withdrawal times when anesthetic protocols including these agents are used in food-producing animals.

References

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