Evaluation of the effects of thiopental, propofol, and etomidate on glomerular filtration rate measured by the use of dynamic computed tomography in dogs

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Objective—To evaluate the effects of thiopental, propofol, and etomidate on glomerular filtration rate (GFR) measured by the use of dynamic computed tomography in dogs.

Animals—17 healthy Beagles.

Procedures—Dogs were randomly assigned to receive 2 mg of etomidate/kg (n = 5), 6 mg of propofol/kg (7), or 15 mg of thiopental/kg (5) during induction of anesthesia; anesthesia was subsequently maintained by isoflurane evaporated in 100% oxygen. A 1 mL/kg dosage of a 300 mg/mL solution of iohexol was administered at a rate of 3 mL/s during GFR measurement. Regions of interest of the right kidney were manually drawn to exclude vessels and fatty tissues and highlight the abdominal portion of the aorta. Iohexol clearance per unit volume of the kidney was calculated by use of Patlak plot analysis.

Results—Mean ± SD weight-adjusted GFR of the right kidney after induction of anesthesia with thiopental, propofol, and etomidate was 2.04 ± 0.36 mL/min/kg, 2.06 ± 0.29 mL/min/kg, and 2.14 ± 0.43 mL/min/kg, respectively. However, no significant differences in weight-adjusted GFR were detected among the treatment groups.

Conclusions and Clinical Relevance—Results obtained for the measurement of GFR in anesthetized dogs after anesthetic induction with etomidate, propofol, or thiopental and maintenance with isoflurane did not differ significantly. Therefore, etomidate, propofol, or thiopental can be used in anesthesia-induction protocols that involve the use of isoflurane for maintenance of anesthesia without adversely affecting GFR measurements obtained by the use of dynamic computed tomography in dogs. (Am J Vet Res 2011;72:146–151)

Measurement of GFR via dynamic CT requires 3 serial steps that include a single-slice dynamic scan that is performed only once, a baseline scan that is performed prior to the administration of a contrast agent, and a postcontrast volume scan that is performed after the administration of a contrast agent.1 It is important for a patient that is being scanned to remain motionless for 2 minutes to enable clinicians to acquire accurate data during each of the 3 steps when performing a single-slice dynamic evaluation.1 Therefore, the use of anesthesia is essential for the successful measurement of GFR via dynamic CT in animals. Thus, the relationship between renal function as determined by analysis of GFR and anesthetic effects in animals requires substantial consideration.

The criterion-referenced standard for the measurement of GFR is quantification of the clearance of inulin in urine.2 However, this technique has practical limi-
tations because of the expense of the procedures, the amount of time needed for collection of the appropriate samples, and the time-consuming chemical analysis of the urine samples. Because of the difficulties encountered with the use of inulin, new methods have been evaluated for the measurement of GFR. Plasma clearance of radioactive agents or contrast media and results of renal scintigraphy have been reported as reliable alternatives to the use of renal clearance of inulin for the estimation of GFR.

In particular, renal scintigraphy has been commonly used in veterinary medicine because of its utility as a noninvasive, rapid, and sensitive procedure. Renal scintigraphy requires that an animal be sedated to prevent motion during procedures, and several anesthetic protocols have been investigated to achieve this. However, negative aspects of this procedure include a low spatial resolution and concurrent low image quality, compared with the resolution and image quality of a more advanced imaging modality such as CT. Currently, the use of CT enables researchers to obtain images that simultaneously reveal renal morphology and function; therefore, studies in which investigators evaluated CT-GFR have been reported in veterinary medicine. However, no reports exist describing the effect of anesthesia on results obtained via CT-GFR. In addition, a longer duration and deeper plane of anesthesia are necessary for assessing GFR during CT-GFR than during renal scintigraphy. When there is a need to accurately determine GFR and to evaluate renal morphology at the same time, such as during renal transplantation, preoperative evaluation of cancers of the urinary tract, or planning of a treatment protocol to obtain images that simultaneously reveal renal morphology and function, CT-GFR is useful for the assessment of this combined structural-functional relationship. Therefore, a safe inhalation anesthetic protocol for use in animals would be recommended.

Propofol is widely used in veterinary medicine because it can be administered IV for induction of anesthesia and can be administered as a constant rate infusion for maintenance of anesthesia. Propofol transiently depresses arterial pressure and myocardial contractility, similar to the effects of thiopental. Thiopental is an ultra–short-acting barbiturate that is used for the induction of anesthesia. The administration of thiopental is associated with rapid induction and recovery from anesthesia, but it may increase heart rate and transiently decrease myocardial contractility. Etomidate is another sedative-hypnotic agent that induces minimal changes in cardiopulmonary functions (eg, heart rate, MAP, or myocardial performance). Therefore, etomidate has been used to anesthetize animals for short-duration diagnostic procedures or treatments. Thiopental, propofol, and etomidate are some of the primary anesthesia induction agents used in veterinary medicine. The purpose of the study reported here was to evaluate the effects of thiopental, propofol, and etomidate on GFR by use of dynamic CT during the induction of anesthesia that was followed by maintenance with isoflurane. We hypothesized that there would be significant differences in CT-GFR values among these 3 induction-anesthesia protocols.

**Materials and Methods**

**Animals**—Ten female and 7 male 1- to 3-year-old Beagles weighing 5.5 to 11.8 kg were included in the study. Dogs were housed individually in an Institute of Laboratory Animal Resources–approved facility, fed a commercial diet twice daily, and provided water ad libitum. All dogs were assessed as healthy on the basis of results of physical examinations, CBCs, serum biochemical analyses, urinalyses that included evaluation of the urine protein-to-creatinine ratio, and results of a heartworm antigen test. In all dogs, diagnostic radiographic examinations, such as radiography of the abdomen and thorax, ultrasonography of the abdomen, and echocardiography were performed to rule out abnormalities of the kidneys and confirm the previous assessments of health status. The study and procedures were approved by the Institute of Laboratory Animal Resources at Seoul National University.

**Study design**—Dogs were assigned by random number selection to 1 of 3 treatment groups to be administered thiopental (n = 5 dogs), propofol (7), or etomidate (5), respectively, during the induction of anesthesia; anesthesia was then maintained by administration of isoflurane. Food was withheld from all dogs for approximately 12 hours prior to the induction of anesthesia, but ad libitum access to water was permitted to prevent dehydration. Therefore, IV administration of fluids was not performed during anesthesia because of the hydration status of the dogs. No dog was premedicated with any drug prior to the induction of anesthesia. A 22-gauge catheter was inserted into each cephalic vein for the administration of contrast medium or an induction agent. Anesthesia was induced with 1.5 mg of thiopental/kg, 6 mg of propofol/kg, or 2 mg of etomidate/kg and maintained with isoflurane evaporated in 100% oxygen. Oxygen flow rate was 1 L/min. After the induction of anesthesia, a 22-gauge catheter was placed in a dorsal pedal artery or femoral artery of each dog for the direct measurement of arterial blood pressure by use of a pressure transducer that had been equilibrated to the basal level of the heart while the dogs were positioned in dorsal recumbency on the imaging table of the CT machine. Heart and respiratory rates, arterial blood pressures (ie, SAP, DAP, and MAP), oxygen saturation, and partial pressure of carbon dioxide were monitored continuously by use of a patient monitoring system during dynamic CT in all dogs.

**Dynamic CT and CT-GFR**—Images were obtained approximately 10 minutes after the induction of anesthesia. Hyperventilation procedures were performed 3 times during CT and included an initial renal helical scan for 40 seconds, a single-slice dynamic scan for 2 minutes, and a postcontrast helical scan for 40 seconds. Hyperventilation resulted in the respiratory rate was manually increased to approximately 30 to 40 breaths/min for 1 to 5 minutes to provide enough oxygen and to enable investigators to monitor the condition of each anesthetized dog. Total time spent for each CT-GFR evaluation was approximately 30 minutes from the induction of anesthesia to the conclusion of the postcontrast volume scan. Cardiovascular variables...
were recorded 2 to 3 times/procedure, which included initiation and completion of each of 4 scans (scout, initial precontrast helical-1, dynamic [cine], and postcontrast helical-2 CT). Scout CT scans are survey images obtained prior to dynamic CT. Initial precontrast helical-1 CT scans are images obtained prior to GFR measurement. Cine scans are images obtained during GFR measurement. Postcontrast helical-2 CT scans are images obtained after GFR measurement.

Imaging was performed with a single-detector CT scanner. Image acquisition settings included a helical and single-slice dynamic acquisition, a 512 × 512 matrix, a 25-cm field-of-view display, and a small-scan field of view. Initial precontrast and postcontrast volume scans of both kidneys and the abdominal portion of the aorta were performed by use of helical mode, 120 kVp, 50 mA, 3-mm slice thickness, pitch of 1.3, and 1-mm reconstruction interval for helical images. Single-slice dynamic CT was performed at 1 region with 1-mm-thick slices of the renal hilum of the right kidney at 1.5-second intervals for 2 minutes.

A 1 mL/kg dosage of a 300 mg/mL solution of iohexol was administered at the rate of 3 mL/s by use of a previously inserted 22-gauge catheter and an injector system. The renal hilum of the right kidney was chosen as the region of interest. Regions of interest of the right kidney were manually drawn to exclude vessels and fatty tissues and highlight the abdominal portion of the aorta. Iohexol clearance per unit volume of the kidney was calculated by use of Patlak plot analysis. Patlak plot analyses were performed by use of an in-house computer system that used a commercially available software program to plot ∫h(t)dt/b(t) against c(t)/b(t), where b(t) is the corrected CT number in the aorta at time t and c(t) is the corrected CT number for the kidney at time t. Slope and y-intercept of the line were used to calculate GFR (reported as the number of milliliters per minute at time t. Slope and y-intercept of the line indicate the GFR (number of milliliters per minute) was divided by the weight of the dog to allow for comparisons of a weight-adjusted GFR (reported as the number of milliliters per minute per kilogram).

Statistical analysis—Results of variables among treatment groups were reported as mean ± SD. Results were compared by use of a statistical analysis software program. Because of the small sample size and lack of normal distribution, Kruskal-Wallis tests were used to compare CT-GFR values among treatment groups. A Shapiro-Wilk normality test was used to analyze cardiopulmonary variables to satisfy the hypothesis of normality, and then a 1-way repeated-measures ANOVA was used for statistical analysis of cardiopulmonary data. When significant differences were detected, a Scheffé post hoc analysis was used to compare differences among treatment groups. A contrast test was used to evaluate significant differences in results over time. A value of P < 0.05 was used to indicate significance for all analyses.

Results

Mean ± SD creatinine (0.75 ± 0.13 mg/dL), BUN (12.35 ± 3.67 mg/dL), phosphorus (6.44 ± 1.17 mg/dL), and albumin (2.91 ± 0.22 mg/dL) concentrations and urine protein-to-creatinine ratios (all ratios were < 0.5) were within reference ranges. Abnormal findings were not observed during the diagnostic imaging examinations. Renal function results of the right kidney were recorded 2 to 3 times/procedure, which included initiation and completion of each of 4 scans (scout, initial precontrast helical-1, dynamic [cine], and postcontrast helical-2 CT). Scout CT scans are survey images obtained prior to dynamic CT. Initial precontrast helical-1 CT scans are images obtained prior to GFR measurement. Cine scans are images obtained during GFR measurement. Postcontrast helical-2 CT scans are images obtained after GFR measurement.

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After completion of dynamic CT, a simple postcontrast helical scan was performed to assess the corresponding global renal volume. A kidney was continuously scanned from the cranial to caudal pole (slice thickness, 3 mm). Renal contours were identified within each CT section, and the area within these sections was then summed and multiplied by the slice thickness to calculate a global renal volume. The GFR per unit volume of the kidney (reported as the number of milliliters per minute per unit volume) was multiplied by the renal volume to yield the GFR (number of milliliters per minute) of a single kidney. Iohexol clearance (reported as the number of milliliters per minute per kilogram) was divided by the weight of the dog to allow for comparisons of a weight-adjusted GFR (reported as the number of milliliters per minute per kilogram).

Table 1—Comparison of the effect of anesthesia on results of Patlak plot analysis and CT-GFR variables when anesthesia was induced with etomidate (n = 5 dogs), propofol (7), or thiopental (5) and maintained with isoflurane. Slope and y-intercept of the line indicate the GFR (number of milliliters per minute at time t. Slope and y-intercept of the line indicate the GFR (number of milliliters per minute) was divided by the weight of the dog to allow for comparisons of a weight-adjusted GFR (reported as the number of milliliters per minute per kilogram).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Thiopental</th>
<th>Propofol</th>
<th>Etomidate</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (mL/min)</td>
<td>0.61 ± 0.107</td>
<td>0.72 ± 0.107</td>
<td>0.70 ± 0.127</td>
<td>0.443</td>
</tr>
<tr>
<td>Intercept (mL/min)</td>
<td>0.28 ± 0.079</td>
<td>0.35 ± 0.089</td>
<td>0.42 ± 0.084</td>
<td>0.107</td>
</tr>
<tr>
<td>GFR (mL/min/kg)</td>
<td>15.50 ± 2.67</td>
<td>18.26 ± 5.16</td>
<td>16.72 ± 2.28</td>
<td>0.747</td>
</tr>
<tr>
<td>Weight-adjusted GFR (mL/min/kg)</td>
<td>2.04 ± 0.36</td>
<td>2.06 ± 0.29</td>
<td>2.14 ± 0.43</td>
<td>0.791</td>
</tr>
</tbody>
</table>

Values reported are mean ± SD.
Anesthetic drugs may directly or indirectly affect renal blood flow and thus alter renal function via cardiovascular system changes (such as systemic hypotension and renal vasoconstriction), neuroendocrine activity, or a combination of these. Therefore, all anesthetic drugs have the potential to decrease GFR. Effects on renal function can vary according to the anesthetic, the dose, and the relationship between anesthetic depth and duration of anesthesia. Factors influencing GFR during CT-GFR include the drug used as the induction agent, dose administered, contrast medium, hyperventilation procedure, isoflurane concentration, and total duration of anesthesia required. In the study reported here, effects of 3 anesthetic drugs on GFR were evaluated by use of dynamic CT and Patlak plot analysis; contrary to our hypothesis, remarkable differences in GFR values were not detected among treatment groups when results were combined and analyzed.

When comparisons were made among the 3 anesthetic drugs, etomidate was expected to cause minimal changes to the cardiovascular system and to have the highest CT-GFR values because it does not depress the cardiovascular and respiratory systems. Therefore, all anesthetic drugs have the potential to decrease GFR. Effects on renal function can vary according to the anesthetic, the dose, and the relationship between anesthetic depth and duration of anesthesia. Factors influencing GFR during CT-GFR include the drug used as the induction agent, dose administered, contrast medium, hyperventilation procedure, isoflurane concentration, and total duration of anesthesia required. In the study reported here, effects of 3 anesthetic drugs on GFR were evaluated by use of dynamic CT and Patlak plot analysis; contrary to our hypothesis, remarkable differences in GFR values were not detected among treatment groups when results were combined and analyzed.

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Table 2—Mean ± SD results of cardiovascular and CT-GFR variables measured in dogs when anesthesia was induced with etomidate, propofol, or thiopental and maintained with isoflurane.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Thiopental (n = 5)</th>
<th>Propofol (n = 7)</th>
<th>Etomidate (n = 5)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight-adjusted GFR (mL/min/kg)</td>
<td>2.04 ± 0.36</td>
<td>2.06 ± 0.29</td>
<td>2.14 ± 0.43</td>
<td></td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scout CT scan</td>
<td>127.40 ± 22.27</td>
<td>110.86 ± 12.64</td>
<td>109.60 ± 10.02</td>
<td>0.038</td>
</tr>
<tr>
<td>Precontrast helical-1 CT scan</td>
<td>125.80 ± 20.05</td>
<td>107.57 ± 14.11</td>
<td>107.60 ± 7.37</td>
<td>0.028</td>
</tr>
<tr>
<td>Cine CT scan</td>
<td>116.00 ± 19.45</td>
<td>103.00 ± 14.86</td>
<td>108.60 ± 2.86</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Postcontrast helical-2 CT scan</td>
<td>101.30 ± 17.97</td>
<td>95.14 ± 12.85</td>
<td>106.40 ± 10.53</td>
<td>0.053</td>
</tr>
<tr>
<td>MAP (mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scout CT scan</td>
<td>53.90 ± 5.62</td>
<td>71.57 ± 11.70</td>
<td>66.10 ± 3.78</td>
<td>0.003</td>
</tr>
<tr>
<td>Precontrast helical-1 CT scan</td>
<td>50.30 ± 7.38</td>
<td>57.47 ± 15.24</td>
<td>61.20 ± 4.96</td>
<td>0.082</td>
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<tr>
<td>Cine CT scan</td>
<td>53.20 ± 3.89</td>
<td>58.88 ± 6.30</td>
<td>60.10 ± 7.59</td>
<td>0.002</td>
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<tr>
<td>Postcontrast helical-2 CT scan</td>
<td>53.60 ± 4.51</td>
<td>55.43 ± 8.06</td>
<td>55.00 ± 9.41</td>
<td>0.172</td>
</tr>
<tr>
<td>SAP (mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scout CT scan</td>
<td>79.90 ± 6.64</td>
<td>107.86 ± 18.75</td>
<td>140.80 ± 9.60</td>
<td>0.003</td>
</tr>
<tr>
<td>Precontrast helical-1 CT scan</td>
<td>73.70 ± 9.14</td>
<td>82.14 ± 17.22</td>
<td>94.20 ± 6.87</td>
<td>0.028</td>
</tr>
<tr>
<td>Cine CT scan</td>
<td>78.40 ± 5.24</td>
<td>82.71 ± 8.85</td>
<td>91.10 ± 11.97</td>
<td>0.002</td>
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<tr>
<td>Postcontrast helical-2 CT scan</td>
<td>81.80 ± 8.46</td>
<td>80.43 ± 10.67</td>
<td>88.20 ± 17.92</td>
<td>0.057</td>
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<td>DAP (mm Hg)</td>
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<tr>
<td>Scout CT scan</td>
<td>41.70 ± 5.24</td>
<td>56.86 ± 13.15</td>
<td>50.90 ± 3.05</td>
<td>0.001</td>
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<tr>
<td>Precontrast helical-1 CT scan</td>
<td>39.80 ± 5.89</td>
<td>46.71 ± 14.21</td>
<td>51.20 ± 8.17</td>
<td>0.223</td>
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<tr>
<td>Cine CT scan</td>
<td>45.40 ± 7.70</td>
<td>48.43 ± 7.96</td>
<td>48.20 ± 7.80</td>
<td>0.125</td>
</tr>
<tr>
<td>Postcontrast helical-2 CT scan</td>
<td>43.30 ± 3.03</td>
<td>44.43 ± 7.72</td>
<td>44.80 ± 6.43</td>
<td>0.170</td>
</tr>
<tr>
<td>MAC (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scout CT scan</td>
<td>1.70 ± 0.16</td>
<td>1.81 ± 0.55</td>
<td>1.52 ± 0.08</td>
<td>0.018</td>
</tr>
<tr>
<td>Precontrast helical-1 CT scan</td>
<td>1.85 ± 0.30</td>
<td>1.60 ± 0.20</td>
<td>1.55 ± 0.30</td>
<td>0.486</td>
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<tr>
<td>Cine CT scan</td>
<td>1.81 ± 0.27</td>
<td>1.57 ± 0.18</td>
<td>1.47 ± 0.32</td>
<td>0.824</td>
</tr>
<tr>
<td>Postcontrast helical-2 CT scan</td>
<td>1.54 ± 0.15</td>
<td>1.73 ± 0.26</td>
<td>1.73 ± 0.56</td>
<td>0.239</td>
</tr>
</tbody>
</table>

Scout CT scans are survey images obtained prior to dynamic CT. Initial precontrast helical-1 CT scans are images obtained prior to GFR measurement. Cine scans are images obtained during GFR measurement. Postcontrast helical-2 CT scans are images obtained after GFR measurement.

*Represents the P value for the row; values with different superscript letters differ significantly (P < 0.05).

Within a column within a variable, values with different superscript letters differ significantly (P < 0.05).

Table 2—Mean ± SD results of cardiovascular and CT-GFR variables measured in dogs when anesthesia was induced with etomidate, propofol, or thiopental and maintained with isoflurane.
date was similar to that of dogs administered propofol and thiopental. Mild decreases in heart rate and arterial blood pressures were observed as anticipated in dogs administered propofol, but no significant difference in GFR was detected among treatment groups. An MAP of 55 mm Hg, an SAP < 85 mm Hg, and a heart rate that was initially increased were observed in dogs administered thiopental. Investigators of several studies have reported that thiobarbiturates induce tachycardia in dogs, but marked decreases in MAP were observed in the present study. Thiopental has been reported to maintain or slightly decrease GFR; however, GFR in dogs administered thiopental in the study reported here was within the reference interval. Regardless of the observed differences in systemic hypotension among treatment groups, significant differences in CT-GFR values were not detected. This lack of significant differences could have been the result of autoregulation of blood flow by the kidneys, which reportedly maintains a constant GFR under variable systemic blood pressures (70 to 180 mm Hg) by controlling vasoconstriction or vasodilation of afferent and efferent arterioles of the glomeruli.

Administration of a nephrotoxic contrast medium could influence renal function during anesthesia. Although the pathogenesis of contrast medium–induced nephropathy is not fully understood, this is most likely the result of prolonged vasoconstriction of arterioles and impaired autoregulation of blood flow that predisposes the renal medulla to hypoxia in combination with direct cytotoxic effects. Contrast medium–induced nephropathy has been reported to result in dose-dependent reversible vasoconstriction in dogs. The median effective dose (ie, dose that induces the desired effect in 50% of a population) for vasoconstriction of the renal artery of dogs is 56.2 mg of iohexol/mL. Therefore, the dose of iohexol administered in the present CT-GFR evaluation had the potential to cause contrast medium–induced nephropathy. However, it has been reported that dogs have a lower incidence of contrast medium–induced nephropathy, compared with the incidence of this condition in humans.

Performing a hyperventilation procedure prior to CT-GFR is necessary to prevent motion during the imaging procedure that could lead to the collection of inaccurate data over multiple time points. An artificially increased respiratory rate was expected to alter renal function in combination with secondary effects on the cardiopulmonary system. However, according to the results of another study, passive hyperventilation that leads to a short duration of respiratory alkalosis does not appear sufficient to alter renal hemodynamics, to result in changes of GFR, or to affect renal plasma flow. Three- to 5-minute hyperventilation periods were performed during the present study. However, we believe this short-term hyperventilation period did not directly affect CT-GFR results.

Isoflurane was used for the maintenance of anesthesia during dynamic CT. The inhalation of isoflurane has been reported to cause decreases in renal blood flow and GFR in a dose-dependent manner. Although isoflurane has little effect on renal blood flow, it is reported to decrease GFR and urine output. In the study reported here, a significant decrease in cardiovascular system variables (such as heart rate, MAP, and SAP) over time was detected among treatment groups. Although there was a slight difference in the concentration of isoflurane delivered to the dogs, significant differences in MAC were not detected among treatment groups.

Limitations exist for the measurement of GFR by the use of dynamic CT and Patlak plot analysis. The single-slice CT technique has limitations because it requires the extrapolation of GFR values from a small region to provide the GFR for an entire kidney. Furthermore, thin slice thickness of the CT-GFR dynamic scan was a limitation observed during the study reported here.

In conclusion, analysis revealed that dynamic CT of the kidneys can be a valuable procedure for the evaluation of the effects of anesthetic drugs on renal function in dogs. Therefore, CT could be used widely because of the advantages of its functional application in veterinary medicine and reproducible measurement of GFR. Significant differences in CT-GFR values were not detected among treatment groups in the study reported here. However, thiopental may induce hypotension after administration. Etomidate is recommended for the induction of anesthesia in geriatric patients or patients with cardiovascular disease because it has minimal effects on cardiopulmonary variables. However, the use of etomidate may be associated with a higher number of adverse events during induction and a more difficult recovery from anesthesia. Propofol is recommended for the induction of anesthesia in young healthy dogs undergoing CT-GFR because of its ability to cause smooth and rapid induction and uncomplicated recovery.

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