FULL PAPER *Surgery*

A Comparison Between Injection Speed and Iodine Delivery Rate in Contrast-Enhanced Computed Tomography (CT) for Normal Beagles

Kosuke TATEISHI[1)], Miori KISHIMOTO[1)], Junichiro SHIMIZU[1)] and Kazutaka YAMADA[1)]

[1)]*Department of Clinical Veterinary Science, Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Hokkaido 080–0555, Japan*

(Received 4 February 2008/Accepted 29 May 2008)

ABSTRACT. The purpose of this study was to compare between the injection speed and iodine delivery rate in order to establish a concept for reproducible contrast timing in contrast-enhanced computed tomography (CT) for small animals. Clinically healthy beagle dogs were administered a nonionic iodinate contrast medium at a dose of 800 mgI/kg; they were divided into 3 groups (n=5, crossover method): in one group, the injection speed was fixed at 1.0 m*l*/sec, and in the second and third groups, the iodine delivery rate was fixed (the injection durations were 30 and 60 sec, respectively). The variation in scatter of the time to aortic and hepatic peak enhancement in the fixed iodine delivery groups was lower than that in the fixed injection speed group. These results suggest that in contrast-enhanced CT for small animals, the contrast medium should be injected at a fixed iodine delivery rate in order to provide reproducible contrast timing.
KEY WORDS: canine, contrast medium, CT, injection speed, iodine delivery rate.

J. Vet. Med. Sci. 70(10): 1027–1030, 2008

Computed tomography (CT) was first introduced in veterinary medicine in the 1980s [3]. The performance of CT improved thereafter, with a shorter scan time and better imaging quality, and CT is now one of the most valuable diagnostic tools, especially for oncological diseases [7]. In abdominal CT, contrast examination is quite important, since it differentiates between abnormal masses and normal tissue by indicating blood flow or vascular permeability, thereby providing diagnostic information. In human medicine, contrast studies with abdominal CT are considered useful in more than 95% cases for the diagnosis of mass lesions [6].

The iodine concentration decreases soon after injection of intravenous contrast medium, because it is diluted in the vessels, distributed in the entire body, and excreted from the kidneys. Thus, the contrast effect is influenced by the time of scanning in that an optimal scan timing provides the greatest contrast enhancement. While a detailed contrast-enhanced CT protocol is well established in human medicine, there are very few standards for the contrast enhancement protocol in small animals. The injection speed (in terms of m*l*/sec) is often standardized, but the iodine delivery rate is rarely set. Different volumes of contrast medium may alter the injection duration, and it may be difficult to set an appropriate scan timing. This study focused on the injection speed and iodine delivery rate in the case of normal beagles in order to establish a concept for reproducible contrast timing in contrast-enhanced CT for small animals.

* CORRESPONDENCE TO: YAMADA, K., Department of Clinical Veterinary Science, Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Hokkaido 080–0555, Japan.
e-mail: kyamada@obihiro.ac.jp

MATERIALS AND METHODS

Five clinically healthy beagle dogs (3–5 years old, 8.9–15.4 kg) were used in a crossover method, and the experiments were performed following the guidelines of the institutional policies for veterinary clinical investigations. The animals were starved for 12 hr before the CT study. A physical examination was conducted, and the complete blood count and serum chemistry profile (blood urea nitrogen, BUN; creatinine, Cre; albumin, Alb; alanine aminotransferase, ALT; aspartate aminotransferase, AST; alkaline phosphatase, ALP; total protein, TP) were assessed; no abnormalities were detected. All the dogs received the nonionic iodinated contrast medium iohexol (300 mgI/m*l*, Omnipaque, Daiichi Pharmaceutical, Tokyo, Japan) at a dose of 800 mgI/kg. The concentration and dosage were determined based on a preliminary experiment.

Three groups were established: a group with a fixed injection speed of 1.0 m*l*/sec and 2 groups with a fixed iodine delivery rate (injection duration of 30 sec in one group, and 60 sec in the other). A fixed injection speed implies that larger dogs are administered a larger volume, and the injection duration consequently increases. Therefore, the injection duration depends on the injection volume (24–42 sec in fixed injection speed group of this study.) On the other hand, a fixed iodine delivery rate implies that larger dogs receive a larger volume at a relatively higher injection speed, while smaller dogs receive a smaller volume at a relatively lower injection speed.

Scanning was performed using multidetector-row CT (Asteion Super 4, Toshiba, Tokyo, Japan), and the CT imaging parameters were 120 kVp, 200 mAs, and a slice thickness of 5.0 mm; the images were reconstructed with a soft tissue algorithm. Propofol (Rapinovet, Schering-Plough Animal Health, Tokyo, Japan) was intravenously adminis-

tered to the dogs, and they were positioned in dorsal recumbency on the CT patient table. The animal status (ECG, SO_2, blood pressure, capnogram) was monitored during examination. The contrast medium was intravenously injected through a 22G catheter placed in the cephalic vein with a power injector (Auto Enhance A-60, Nemoto Kyorindo, Tokyo, Japan). Images were obtained before and after contrast injection at every 5 sec during the 180 sec of observation. From the images, the CT number expressed in Hounsfield units (HU) of the aorta and liver was measured, and time-density curves (TDCs) were obtained for each group. The maximum contrast enhancement (E_{max}, HU) and the time taken to achieve it (T_{max}, sec) were determined for the aorta and liver. As an indicator of scattering of T_{max} in each group, we compared the coefficient of variation (CV; SD/mean × 100%) for each group. The duration for which hepatic contrast enhancement persisted (at greater than 60 HU) was measured [9]. Statistic analysis was performed using the paired *t*-test.

RESULTS

The T_{max} and E_{max} of the aorta and liver in each group are shown in Table 1. The T_{max} of the aorta (mean ± SD) was 29.0 ± 6.5 in the fixed injection speed group, 32.0 ± 2.7 in one of the fixed iodine delivery rate groups (injection duration of 30 sec), and 58.0 ± 5.7 in the other fixed iodine delivery rate group (injection duration of 60 sec). In the fixed iodine delivery rate groups, the T_{max} of the aorta was similar to the time at which contrast medium injection was completed. The CV of T_{max} of the aorta in the 3 groups was 22.5%, 8.6%, and 9.8%, respectively.

The E_{max} of the aorta was 379.5 ± 43.4 in the fixed injection speed group, 387.2 ± 49.5 in one fixed iodine delivery rate group (injection duration of 30 sec), and 274.1 ± 18.8 in the other fixed iodine delivery rate group (injection duration of 60 sec). There were no significant differences observed in the E_{max} of the aorta among these groups.

The T_{max} of the liver was 53.0 ± 7.6 in the fixed injection speed group, 57.0 ± 2.7 in one fixed iodine delivery rate group (injection duration of 30 sec), and 81.0 ± 7.4 in the other fixed iodine delivery rate group (injection duration of 60 sec). The CV of T_{max} of the liver was 14.3%, 4.8%, and 9.2%, respectively.

The E_{max} of the liver was 99.0 ± 12.1 in the fixed injection speed group, 93.6 ± 11.5 in one fixed iodine delivery rate group (injection duration of 30 sec), and 89.3 ± 7.8 in the other fixed iodine delivery rate group (injection duration of 60 sec). There were no significant differences in the E_{max} of the liver among these groups.

The TDCs of the fixed iodine delivery rate groups are shown in Fig. 1. The duration for which hepatic contrast enhancement persisted (at > 60 HU) for the fixed iodine delivery rate group with an injection duration of 60 sec (83.0 ± 5.7) was longer than that for the group with an injection duration of 30 sec (74.0 ± 25.4), but there were no significant differences between the groups.

DISCUSSION

The contrast effect may vary depending on technical factors, including the iodine dose, concentration, volume, injection speed, and iodine delivery rate as well as patient-related factors such as body size, age, and cardiac output [9].

The variation in scattering of the aortic and hepatic T_{max} in the case of the fixed iodine delivery rate groups was lower than that of the T_{max} in the case of the fixed injection speed group. Therefore, a fixed iodine delivery rate might yield reproducible contrast timing.

The literature on human medicine mentions that a fixed iodine delivery rate could minimize not only the scattering of the aortic T_{max} but also that of the aortic E_{max} [5]. In this study, however, there was no significant difference observed in the aortic E_{max}. The underlying reason is considered to be the differences in body weight; which varied within the beagles in this study; however, these weights were less varied than those in the human study. In veterinary clinical cases, the body size of patients varies widely, from a 3 kg Chihuahua to a larger than 60 kg Saint Bernard. Further, clinical studies are required to prove that a fixed iodine delivery rate provides reproducible contrast timing.

To determine the optimal injection duration, we compared the 30 and 60 sec injection durations. No significant differences in the aortic and hepatic E_{max} were observed

Table 1. T_{max} (sec) and E_{max} (HU) of aorta and liver in each group (n=5)

Group		T_{max} of aorta (sec)	E_{max} of aorta (HU)	T_{max} of liver (sec)	E_{max} of liver (HU)
injection speed 1.0 ml/sec	mean ± SD	29.0 ± 6.5	379.5 ± 43.4	53.0 ± 7.6	99.0 ± 12.1
	coefficient of variation (%)	22.5		14.3	
injection duration 30 sec	mean ± SD	32.0 ± 2.7	387.2 ± 49.5	57.0 ± 2.7	93.6 ± 11.5
	coefficient of variation (%)	8.6		4.8	
injection duration 60 sec	mean ± SD	58.0 ± 5.7	274.1 ± 18.8	81.0 ± 7.4	89.3 ± 7.8
	coefficient of variation (%)	9.8		9.2	

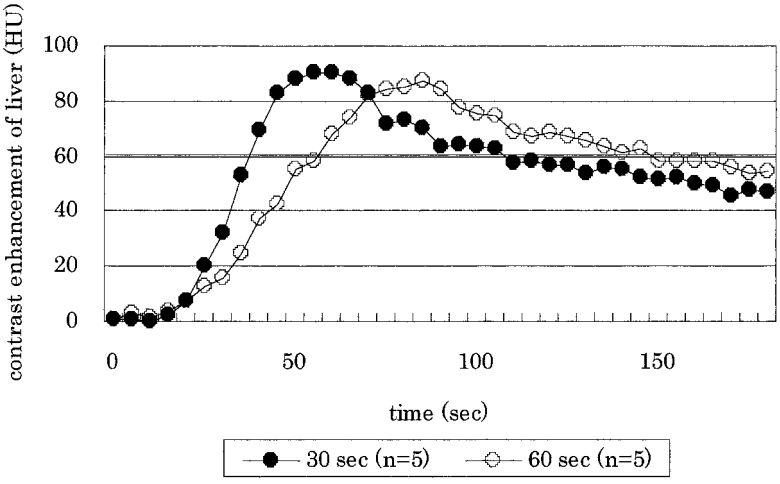

Fig. 1. Time density curves of the fixed injection duration of 30 and 60 seconds (mean, n=5).

between these groups. The hepatic enhancement persisted for a longer duration in the fixed iodine delivery rate group with an injection duration of 60 sec than in that with an injection duration of 30 sec, but this difference was not significant. Thus, it was surmised that both iodine delivery rates could be applied. A higher iodine delivery rate might be advantageous for detecting hepatocellular carcinoma (HCC), which receives blood supply from the hepatic artery during the arterial phase and cannot be detected in the portal/delay phase in which the contrast medium is distributed in both the HCC and normal hepatic parenchyma. It has been reported that faster injection is better to distinguish between arterial and portal/delay phases [1, 4]. Therefore, a high iodine delivery rate might be more suitable for the detection of HCC. On the other hand, a lower iodine delivery rate obtained by slow injection of the contrast medium might be considered less invasive for patients and therefore advantageous. Further, it has been reported that a slower injection rate would result in increased persistence of enhancement [4]. Some CT units still require a long scanning time, and do not scan at an adequate scanning speed within the duration of contrast enhancement. With regard to the scanning speed, a lower fixed iodine delivery rate should be selected. Thus, both iodine delivery rates have individual advantages, and the iodine delivery rate should therefore be selected depending on the purpose of the examination or the performance of the CT.

In veterinary medicine, the usefulness of dynamic study (scanning in the arterial phase) mentioned above has not yet been discussed widely. The concept of contrast medium injection in this paper was not for a specific disease but for the general abdominal organs. Further, these injection durations do not apply CT angiography, a vessel depiction study such as portosystemic shunt CT angiography. It may therefore require another protocol [2, 8, 10, 11]. In addition, test bolus injection for detecting contrast in the aorta, which is widely used in human medicine, is another option for contrast study; however, in our experience, it is difficult to fix the region of interest in the aorta of small animals. Nonetheless, it can be expected that optimal injection protocols will be established for specific purposes in veterinary clinics in the future.

Our results suggest the concept that in contrast-enhanced CT for small animals, the contrast medium should be injected at a fixed iodine delivery rate in order to provide reproducible contrast timing.

REFERENCES

1. Bae, K. T., Heiken, J. P. and Brink, J. A. 1998. Aortic and hepatic peak enhancement at CT: effect of contrast medium injection rate--pharmacokinetic analysis and experimental porcine model. *Radiology* **206**: 455–464.
2. Bertolini, G., Rolla, E. C., Zotti, A. and Caldin, M. 2006. Three-dimensional multislice helical computed tomography techniques for canine extra-hepatic portosystemic shunt assessment. *Vet. Radiol. Ultrasound* **47**: 439–443.
3. Fike, J. R., LeCouteur, R. A., Cann, C. E. and Pflugfelder, C. M. 1981. Computerized tomography of brain tumors of the rostral and middle fossas in the dog. *Am. J. Vet. Res.* **42**: 275–281.
4. Frank, P., Mahaffey, M., Egger, C. and Cornall, K. K. 2003. Helical computed tomographic portography in ten normal dogs and ten dogs with a portosystemic shunt. *Vet. Radiol. Ultrasound* **44**: 392–400.
5. Ichikawa, T., Erturk. S. M. and Araki, T. 2006. Multiphasic contrast-enhanced multidetector-row CT of liver: contrast-enhancement theory and practical scan protocol with a combination of fixed injection duration and patients' body-weight-tailored dose of contrast material. *Eur. J. Radiol.* **58**: 165–176.
6. Ito, K., Ono, C., Kohno, A., Sumi, Y., Honda, M., Uchimura, F. Ogawa, K. and Ohtaki, M. 2003. Is intravenous contrast enhancement effective in improving CT diagnosis of hepatic disease? *Nippon Igaku Housyasen Gakkai Zasshi* **63**: 160–170 (in Japanese).
7. Ohlerth, S. and Scharf, G. 2007. Computed tomography in

small animals - Basic principles and state of the art applications. *Vet. J.* **173**: 254–271.
8. Winter, M. D., Kinney, L. M. and Kleine, L. J. 2005. Three-dimensional helical computed tomographic angiography of the liver in five dogs. *Vet. Radiol. Ultrasound* **46**: 494–499.
9. Yamashita, Y., Komohara, Y., Takahashi, M., Uchida, M., Hayabuchi, N., Shimizu, T. and Narabayashi, I. 2000. Abdominal helical CT: evaluation of optimal doses of intravenous contrast material--a prospective randomized study. *Radiology* **216**: 718–723.
10. Zwingenberger, A. L., McLear, R. C. and Weisse, C. 2005. Diagnosis of arterioportal fistulae in four dogs using computed tomographic angiography. *Vet. Radiol. Ultrasound* **46**: 472–477.
11. Zwingenberger, A. L. and Schwarz, T. 2004. Dual-phase CT angiography of the normal canine portal and hepatic vasculature. *Vet. Radiol. Ultrasound* **45**: 117–124.