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Establishment of Injection Protocol of Test Bolus for Precise Scan Timing in Canine Abdominal Multi-Phase Computed Tomography

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Abstract : This study aimed to establish an injection protocol to determine the precise CT scan timing in canine abdominal multi-phase CT using the test bolus method. Three dynamic scans with different contrast injection parameters were performed using a crossover design in eight normal beagle dogs. A contrast material was administered at a fixed dose of 200 mg iodine/kg as a test bolus for dynamic scans 1 and 2, and 600 mg iodine/kg as a main bolus for dynamic scan 3. The contrast materials were administered with 1 ml/s in dynamic scan 1, and 3 ml/s in dynamic scan 2 and 3. The mean arrival time to the appearance of aortic enhancement in dynamic scan 3 was similar to that in dynamic scan 2, and different significantly to that in dynamic scan 1. The mean arrival time to the peak aortic and pancreatic parenchymal enhancement in dynamic scan 3 was similar to that in dynamic scan 1, and different significantly to that in dynamic scan 2. In multi-phase CT scan, a test bolus should be injected with the same injection duration of a main bolus, to obtain the precise arrival times to peak of arterial or pancreatic parenchymal enhancement.

Key words **:** CT, Dogs, Injection duration, Injection rate, Test bolus.

Introduction

The test bolus method is commonly used to determine the scan timing for multi-phase computed tomography (CT) of the canine abdomen in veterinary medicine (5,12,16). Though bolus tracking technique is a fast and easy method, there are some limitations such as an individual variation by a diagnostic scan delay, an inter-scan interval, and inexact timing for second scanning (10,11). A previous dynamic scan with a small volume of contrast material, referred to as a test bolus, is performed to analyze the contrast enhancement pattern for target vessels and organs and to provide information for the timing of the diagnostic CT scan.

The injection duration, as well as the cardiac output and scan duration, are the most important parameters for determining the CT scan timing (1). As the injection duration increases, the time of the maximum deposition of contrast material is delayed, and subsequently, the time to the peak contrast enhancement increases (4). The effects of injection duration on CT scanning of the canine pulmonary artery, aorta, and hepatic parenchyma have also been reported in the veterinary literature (13,14). It was suggested that contrast materials should be injected with a fixed injection duration to provide reproducible contrast timing (14). In recent studies in the field of human medicine, a fixed injection duration of a test bolus of contrast material has been used to reduce individual variations in coronary CT angiography (8,9).

In this study, we hypothesized that the arrival time to the peak contrast enhancement in a previous dynamic scan will closely approximate that of the diagnostic scan, when a test bolus of contrast material is administered using the injection duration of a main bolus. The purpose of this study was to establish an injection method for the test bolus to determine the precise CT scan timing in canine abdominal multi-phase CT.

Materials and Methods

This study was performed under the guidance of the Chungnam National University Animal Care and Use Committee. Eight normal beagle dogs of 4 intact female and 4 intact male were averaging 3.6 ± 0.7 years (3 to 5 years) and 10.6 ± 1.4 kg (8 to 11 kg). Routine screening examinations such as physical examination, complete blood cell counts, serum chemistry analysis, radiography, and echocardiography were conducted to determine the healthy conditions of the beagle dogs.

Before the general anesthesia for CT examination, the dogs were managed to be the fasting condition for 6 hs. Twenty-gauge needle catheter was placed to the cephalic vein for the anesthetic procedure and the injection of contrast material. The anesthetic drugs of 0.3 mg/kg midazolam (Midacum® inj.; Myungmoon Pharm. Co. Ltd.) for a premedication and 4.0 to 5.0 mg/kg propofol (Provive® inj.; Myungmoon Pharm. Co. Ltd.) for an induction were administered intravenously. After endotracheal intubation, the anesthesia was maintained with isoflurane (Ifran®; Hana Pharm. Co. Ltd.). After the dogs were placed in prone position on the CT table, an

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angiographic power injector of Salient™ (Imaxeon Pty. Ltd.; Australia) was connected. During CT scanning, the breath-holding was conducted with a positive pressure of 15-20 cmH_2O to reduce a motion artifacts due to respiration.

A survey scan of the entire was performed using the Alexion™ (Toshiba; Japan) and the following parameters: 120 kV, 150 mA, 0.75-s rotation time, 1-mm slice thickness, and 0.938 collimation beam pitch. The continued dynamic scan at the level of pancreatic body during 60 s was performed three times with an inter-scan interval of 20 min using different injection parameters for the contrast material. A contrast material, Omnipaque® (GE healthcare; Ireland) of 300 mg iodine (I) /ml, was administered at a fixed dose of 200 mg I/kg as a test bolus for the first (dynamic scan 1) and second (dynamic scan 2) dynamic scans, and 600 mg I/kg as a main bolus for the third (dynamic scan 3) dynamic scan using an angiographic power injector. The injection rates were fixed to 1 ml/s in dynamic scan 1, and 3 ml/s in dynamic scan 2 and 3. Finally, the same injection duration was used in dynamic scan 1 and 3. The scan parameters were 100 kV, 50 mA, 3-mm slices thickness, and 1-s rotation time. All images from the survey and dynamic scans were reconstructed using a standard algorithm for a soft tissue window.

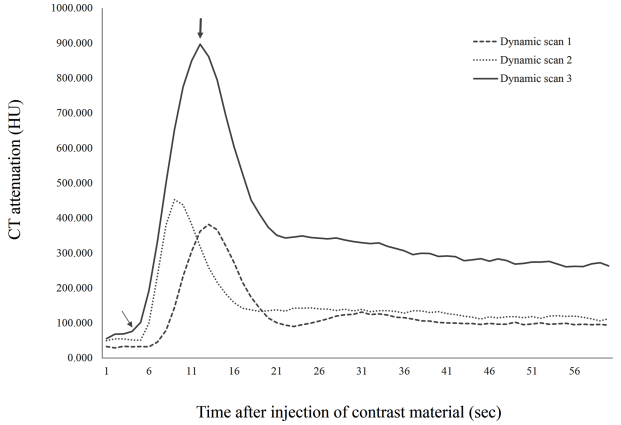

Fig 1. The graph for mean values of aortic enhancement after an injection of contrast material in eight beagle dogs. The point of an aortic appearance of contrast material (thin arrow) in dynamic scan 3 was similar to that in dynamic scan 2, and the point of an aortic enhancement peak (thick arrow) in dynamic scan 3 was closer to that in dynamic scan 1 than that in dynamic scan 2.

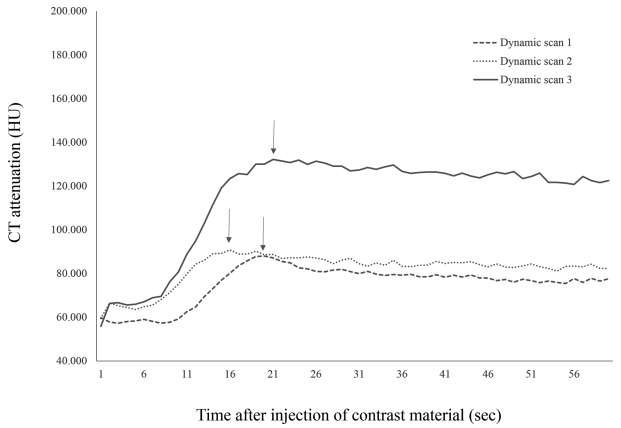

Fig 2. The graph for mean values of contrast enhancement of pancreatic parenchyma after an injection of contrast material in eight beagle dogs. The point of the contrast enhancement peak (arrow) in dynamic scan 3 was similar to that in dynamic scan 1.

The image analysis was conducted using Rapidia® (Infinitt Healthcare Co. Ltd.; Korea). On transverse image of the level of the porta hepatis, four regions of interest (ROIs) with a circle were placed at the aorta, pancreatic body, portal vein and hepatic parenchyma. The time attenuation curves (TAC) for the aortic, pancreatic parenchymal, portal, and hepatic parenchymal enhancement were obtained from the four ROIs. The arrival times to the appearance of aortic enhancement and the peak aortic, pancreatic parenchymal, portal, and hepatic parenchymal enhancement were measured from TAC. The values obtained from TAC on dynamic scans 1 and 2 were compared with those obtained from dynamic scan 3.

All values were expressed as the mean ± SD. Statistical analysis was conducted using SPSS Statistics, V.22 (IBM Corporation; U.S.A.). The arrival times to each point and the differences in the values between the scans were statistically evaluated using the Mann-Whitney test. Values of $p < 0.05$ were considered to be statistically significant.

Results

The arrival time to the appearance of aortic enhancement was significantly slower in dynamic scan 1 than in the other scans, and the arrival times in dynamic scan 2 and 3 were not significantly different from each other. The arrival times to the peak aortic and pancreatic parenchymal enhancement were significantly faster in dynamic scan 2 than in the other dynamic scans, and the arrival times in dynamic scans 1 and 3 did not show a significant difference each other (Fig 1 and 2). The arrival times to the portal vein and hepatic parenchymal peak were not significantly different among the three dynamic scans (Table 1).

Table 1. Arrival times to the aorta, pancreas, portal vein, and liver after injection starting of contrast medium in eight normal beagle dogs

Arrival time (s)	Dynamic Scan		
	1	2	3
Aortic Enhancement Appearance	7.5 ± 0.9*	5.5 ± 0.9	5.5 ± 1.2
Aortic Enhancement Peak	12.0 ± 1.4	8.6 ± 1.5†	11.5 ± 1.9
Pancreatic Parenchymal Peak	19.1 ± 3.0	15.1 ± 3.0‡	18.6 ± 2.8
Portal Vein Peak	31.5 ± 6.8	28.5 ± 4.3	29.0 ± 4.6
Hepatic Parenchymal Peak	40.4 ± 7.0	42.0 ± 9.8	43.7 ± 8.1

Data are expressed as mean ± SD.
*The value was significantly different with the values at dynamic scan 2 ($p = 0.003$) and 3 ($p = 0.006$).
†,‡The values were significantly different with the values at dynamic scan 1 ($p = 0.001$, $p = 0.026$) and 3 ($p = 0.007$, $p = 0.040$).

Discussion

The determination of the exact fixed scan delay is difficult due to individual variations in cardiac output and cardiovascular circulation (3). Decreased cardiac output results in prolonged contrast enhancement, and the contrast enhancement pattern is affected slightly by body weight, size, age, and hepatic pathologic conditions in human medicine (1). In situations affected by those factors, it would be preferable to perform a CT scan using the test bolus method. Furthermore, CT scans have been commonly performed in dogs under general anesthesia using various protocols and with different combinations of anesthetic drugs, which alter the cardiac output (5-7,14,16). The anesthesia protocol should be considered an important patient-related factor for CT scans in veterinary medicine, and the optimal scan delay should be individually determined using the test bolus method or the bolus-tracking technique. However, the bolus-tracking technique cannot also overcome completely the individual variation, because additional scan delays after triggering are influenced by patient-related factors. The CT scan timing determined using the test bolus method may be not influenced by patient-related factors because a previous dynamic and a diagnostic scan are performed in the same patient, although this is a time-consuming and labor-intensive method (10). Therefore, it cannot be emphasized enough that injection-related factors are critical in a multi-phase CT scan using the test bolus method.

The time of the appearance of aortic enhancement indicates the delivery rate for the distance from the injection site to the aorta, and a faster injection rate will increase the delivery rate. As our results showed, the time to the aortic appearance of main bolus was similar to that of test bolus injected using the same injection rate. Because a low-speed CT scanner has a long scan duration relatively, CT scan for arterial phase has been started at the aortic appearance of contrast material (5,16). It means that the time to the aortic appearance may be an important information in determining CT scan timing of arterial phase using a low-speed equipment. To find an exact arrival time to aortic appearance of contrast material, the injection rate of test and main bolus should be same in CT scan using test bolus method.

Unlike the time to the appearance of aortic enhancement, the time to the aortic enhancement peak is determined by the injection duration (1). It was reported that the time to the aortic enhancement peak is the sum of the injection duration and the contrast material bolus transfer time from the injection site to the aorta (2). To obtain an optimal arterial phase, a middle of a scan range should be an aortic enhancement peak (1). Therefore, the exact time to an aortic enhancement peak should be found at the previous dynamic scan using a test bolus to determine the scan range. According to the present study, when the injection duration of test and main bolus is same, the exact time to the aortic enhancement peak of main bolus can be predicted.

The pancreas has a first-pass effect that is influenced directly by a fast delivery of contrast material to the aorta due to the arterial blood supply of the pancreas, and the pancreatic parenchymal enhancement parallels the aorta more closely than that of the portal vein or liver (15). In a veterinary literature, the pancreatic parenchymal peak in dogs was also shown to be closer to the aortic enhancement peak than the portal vein peak, and pancreatic parenchymal enhancement is characterized by a short plateau with fast growth (6). Thus, the pancreatic parenchymal phase in dogs requires a more accurate determination of the scan delay. For the pancreatic parenchymal phase, a test bolus of contrast material should be injected with the same injection duration of a main bolus like the arterial phase.

The arrival times to the portal vein peak and the hepatic parenchymal peak did not show significant difference among the three dynamic scans in this study. While faster delivery of contrast material directly leads to a faster accumulation in the aorta, hepatic enhancement, which is primarily influenced by the portal circulation after the first-pass effect of the fast delivery, increases more gradually than aortic enhancement, which is affected by the long circulation pathway (4). Thus, it is thought that CT images of the portal phase and the hepatic parenchymal phase in multi-phase CT scans obtained using the test bolus method have relatively minor effects related to the injection duration and rate. The portal vein and hepatic parenchyma have a long plateau of peak contrast enhancement in dogs (6), and CT scanning of the portal and hepatic parenchymal phases can be started at any point during the plateau.

A limitation of this study was that the results were obtained from animals with a narrow range of body weights and injection durations. A veterinary study has shown the difference in the peak hepatic enhancement with long injection durations of 30 and 60 s (14). The small volume of contrast material used in toy breeds may result in injection rates that are too slow or injection durations that are too short to produce sufficient contrast enhancement or may lead to undesirable tissue and venous enhancement. The influence of an injection duration and rate of the test bolus should be investigated in dogs with a wide range of the size or body weight.

Based on the results of this study, a test bolus in a previous dynamic scan should be injected with the same injection duration using in a main bolus, to calculate a precise starting point for an arterial phase of abdominal organs or pancreatic parenchymal phase.

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