

# A Comparison of the Use of Contrast Media with Different Iodine Concentrations for Multidetector CT of the Kidney

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**Objective:** To determine the optimal iodine concentration of contrast media for kidney multidetector computed tomography (MDCT) by comparing the degree of renal parenchymal enhancement and the severity of the renal streak artifact with contrast media of different iodine concentrations.

**Materials and Methods:** A 16-row MDCT was performed in 15 sedated rabbits by injection of 2 mL contrast media/kg body weight at a rate of 0.3 mL/sec. Monomeric nonionic contrast media of 250, 300, and 370 mg iodine/mL were injected at 1-week intervals. Mean attenuation values were measured in each renal structure with attenuation differences among the structures. The artifact was evaluated by CT window width/level and three grading methods. The values were compared with iodine concentrations.

**Results:** The 370 mg iodine/mL concentration showed significantly higher cortical enhancement than 250 mg iodine/mL in all phases ( $p < 0.05$ ). There was however no significant difference in the degree of enhancement between the 300 mg iodine/mL and 370 mg iodine/mL concentrations in all phases. There is a significant difference in attenuation for the cortex-outer medulla between 250 mg iodine/mL and 300 mg iodine/mL ( $p < 0.05$ ). The artifact was more severe with a medium of 370 mg iodine/mL than with 250 mg iodine/mL by all grading methods ( $p < 0.05$ ).

**Conclusion:** The 300 mg iodine/mL is considered to be the most appropriate iodine concentration in an aspect of the enhancement and artifact on a kidney MDCT scan.

**Index terms:** Kidney; CT; Contrast media; Iodine concentration

## INTRODUCTION

Many investigators have described comparisons of contrast media with different iodine concentrations in the enhancement of multiple organs and vessels on CT scans with contrast media of various iodine concentrations (1-7).

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However, to the best of our knowledge, there have been no reports of descriptions of renal parenchymal enhancement in previous studies. There is however a study about the parenchymal enhancement according to contrast media with different doses on MR renography (8). Contrary to other solid organs, the kidney excretes waste products, including contrast media, via the cortex, medulla, and pelvocalyceal system. For the kidney, there are characteristic enhancing techniques such as the use of the corticomedullary phase and the excretory phase for CT imaging. Therefore, results from studies with other solid organs cannot be directly applied to the kidney. In addition, most previous reports did not perform studies in the same patient (3-7, 9), and only a few reports have described CT imaging in the same patient (10-12). Considering radiation and contrast media exposure,

an intra-individual comparison study has many limitations. In particular, CT enhancement with contrast media depends on various interacting factors such as the nature, volume and concentration of the contrast media, the injection technique, tissue characteristics, and patient characteristics such as sex, age, weight, height, cardiovascular status and renal function (2, 3, 13-16). Therefore, an appropriate correction of patient characteristics is important for a successful comparison study of different iodine concentrations of contrast media. A study with an animal model is considered to be an appropriate solution in these studies.

The renal streak artifact from the characteristic structure of the kidney can interfere with the interpretation of CT images. The artifact was evaluated according to osmolarity degrees of the contrast media with grading systems used in a previous study (17). Coincidentally, the artifact is also thought to be influenced by the iodine concentration of the contrast media.

Therefore, it is important to find an appropriate iodine concentration for the contrast media, while keeping a balance between the degree of renal parenchymal enhancement and the severity of the renal streak artifact on multidetector CT (MDCT). We compared the degree of renal parenchymal enhancement and the severity of the renal streak artifact on MDCT at three different iodine concentrations--250, 300, and 370 mg iodine/mL--in the contrast media.

## MATERIALS AND METHODS

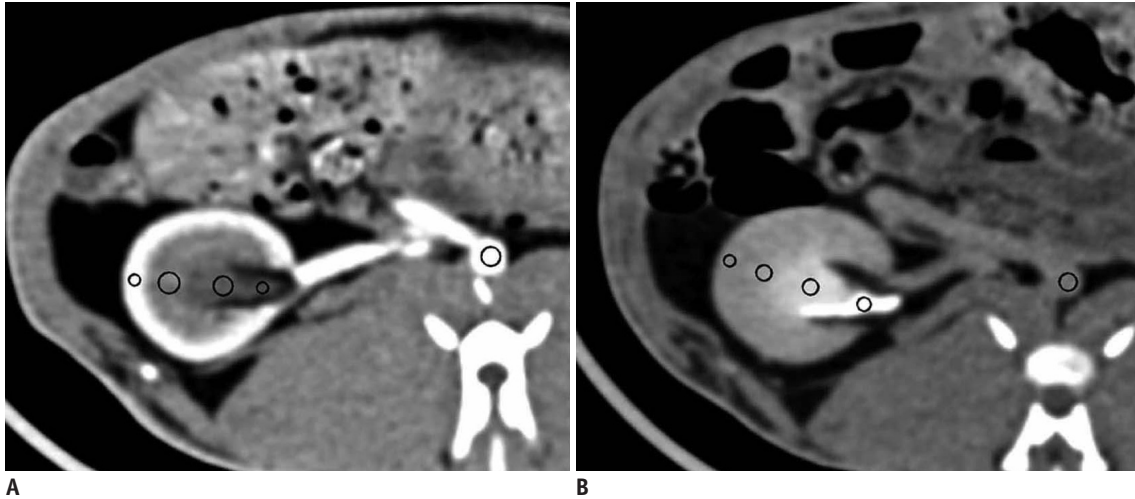
The protocol for the current investigation was approved by the Institutional Animal Care and Use Committee of the Clinical Research Institute, Seoul National University Hospital. Fifteen New Zealand White rabbits (weight range, 2.8-3.3 kg) were evaluated with contrast-enhanced dynamic MDCT using the three concentrations of CT contrast media. The rabbits were intramuscularly injected with a mixture of tiletamine/zolazepam (Zoletil 50, Virbac Laboratories, Carros, France) and xylazine (Rompun, Mobay, Shawnee, KS) for sedation. A 22 G intravenous catheter was inserted via a marginal ear vein for the infusion of contrast media.

Each rabbit (n = 15) underwent three CT examinations at one-week intervals on a 16-row MDCT scanner (Somatom Sensation 16; Siemens Medical Solutions, Malvern, PA) using contrast media at three different iodine concentrations. We did not control feeding and hydration of the rabbits

before and after the CT examinations. Contrast media at a concentration of 250 mg iodine/mL was used in the first week, while contrast media of 300 mg iodine/mL and 370 mg iodine/mL were used in week 2 and 3, respectively. CT scans consisted of a pre-contrast phase and five post-contrast phases. The first post-contrast scan started 5 seconds after the attenuation value reached 100 Hounsfield units (HUs) in the thoracic aorta using the bolus tracking technique. After a 15-second delay, 35-second delay, 65-second delay, and 115-second delay, additional scans were performed. A total of 2 mL/kg of body weight of nonionic contrast media (nonionic monomeric iodine contrast media, Iopamidol; Pamiray 250, 300, and 370; Dongkook Pharmaceutical, Seoul, Korea) was administered with a power injector (Envision CT; Medrad, Indianola, PA) at a rate of 0.3 mL/sec. Total iodine loads were respectively 1.5-1.75 g (250 mg iodine/mL), 1.8-2.1 g (300 mg iodine/mL), and 2.22-2.59 g (370 mg iodine/mL), respectively. Scanning parameters were as follows: 0.75 x 16 mm detector, 5 mm slice thickness, 5 mm interval, rotation time of 0.5 seconds, reconstruction interval of 1 mm, X-ray tube voltage of 120 kVp, and an effective tube current of 160 mAs.

## Image Analysis

CT scans of 30 kidneys in 15 rabbits were evaluated based on the consensus of two experienced genitourinary radiologists using a picture archiving and communications system (PACS) workstation (Marotech, Seoul, Korea). We considered the right and left kidneys in one rabbit separately in the image analysis. We compared the attenuation values, the attenuation differences, and the severity of the renal streak artifact with contrast media at three different iodine concentrations. The attenuation values were measured in the aorta, cortex, outer medulla, inner medulla and pelvis using the mean value of the HUs of all the pixels in a region of interest (ROI) circle. The ROI circles were located in the aorta and each sub-renal structure (cortex, outer medulla, inner medulla and pelvis) with the largest diameter and no extension into the adjacent structures (Fig. 1). The attenuation differences were calculated for the cortex, outer medulla, inner medulla, and pelvis (cortex-outer, medulla, outer-inner medulla and medulla-pelvis). The renal streak artifact was defined as the interference due to concentrated contrast media and degradation of the CT image with beam hardening. The window width and level were used to determine the degree



**Fig. 1.** Axial contrast enhanced CT images show five region-of-interest circles at 5-second delay (A) and 115-second delay (B) for 370 mg iodine/mL. Attenuation values were measured using region-of-interest circles. Region-of-interest circles were located in cortex, outer medulla, inner medulla, pelvis and aorta as depicted on PACS workstation.

of severity of the renal streak artifact. Two investigators separately controlled the window width and level to acquire an image with the most appropriate contrast with minimal renal streak artifact for interpretation of the CT images on the PACS workstation. The differences between the base value (width: 300, level: 35) and the controlled value in the window width and level were defined as the degree of the renal streak artifact. The differences were calculated by subtracting the base value from the controlled value. We considered that an increase in the difference of the window width and level, which particularly means a wider window width and higher window level, indicates increased severity of the artifact. In addition, three grading methods for determining the degree of severity of the renal streak artifact were performed by two investigators in consensus. For the first method, each CT image was assigned a score of 0 or 1. A score of 0 indicated no artifact and a score of 1 indicated the presence of artifact. The sum of scores for each iodine concentration (250, 300 and 370 mg iodine/mL) for each rabbit ( $n = 15$ ) was considered the degree of severity of the artifact. For the second method, each CT image was assigned a score of 1, 2 or 3. A score of 1 indicated no interference in CT interpretation. A score of 2 indicated only interference due to degradation of the renal structure, including the detection of concentrated contrast media. A score of 3 indicated the conditions required for a score of 2 as well as interference due to image degradation of structures around the presence of contrast media. For the third grading method, scores from 1 to 3 were assigned to the CT images in which different iodine concentrations

were used. A score of 1 indicated the most severe degree of artifact. A score of 2 indicated a moderate degree of severity and a score of 3 indicated the least degree of severity. Sums were determined as described above for the first grading method.

### Statistical Analysis

We analyzed the attenuation values, the attenuation differences and the degree of severity of the renal streak artifact according to the CT scan phase and iodine concentration of the contrast media in a mixed model using the SAS software (version 9.1; SAS Institute, Cary, NC). A multiple comparison study was performed with Bonferroni correction. For comparison of the degree of severity of the renal streak artifact according to the three grading methods, the Wilcoxon matched-pairs signed rank test was used with Bonferroni correction. A  $p$  value less than 0.05 indicated statistical significance.

### RESULTS

There were significant differences in the attenuation values for the aorta and cortex with contrast media at the three iodine concentrations ( $p < 0.05$ ). Also, there were significant differences between the 250 mg iodine/mL and 300 mg iodine/mL media ( $p < 0.01$ ), and between the 250 mg iodine/mL and 370 mg iodine/mL media ( $p < 0.05$ ) with respect to attenuation values of the aorta. The attenuation values of the cortex only showed a significant difference between the 250 mg iodine/mL and 370 mg iodine/mL

**Table 1. Attenuation Values of Aorta and Cortex According to Iodine Concentration of Contrast Media and Post-Contrast Phase**

	Aorta <sup>a</sup>			Cortex <sup>b</sup>			Outer Medulla			Inner Medulla			Pelvis		
	250 <sup>c</sup>	370 <sup>c,d</sup>	300 <sup>c,d</sup>	250 <sup>c</sup>	300 <sup>c,d</sup>	370 <sup>c,d</sup>	250	300 <sup>d</sup>	370 <sup>d</sup>	250	300 <sup>d</sup>	370 <sup>d</sup>	250	300 <sup>d</sup>	370 <sup>d</sup>
1	312.9 ± 70.5	391.1 ± 54.4	208.3 ± 27.0	220.1 ± 31.9	223.5 ± 55.0	74.9 ± 16.2	71.5 ± 21.0	82.5 ± 52.2	39.2 ± 12.3	38.3 ± 12.2	40.7 ± 15.8	17.3 ± 8.9	17.3 ± 8.9	9.3 ± 5.2	13.0 ± 10.7
2	148.7 ± 23.7	179.4 ± 17.9	155.4 ± 20	182.7 ± 23.5	183.3 ± 46.3	154.6 ± 44.9	161.9 ± 60.3	171.2 ± 63.4	56.2 ± 18.5	46.5 ± 16.2	62.4 ± 57.1	21.5 ± 10.6	21.5 ± 10.6	14.5 ± 6.9	16.4 ± 12.7
3	131.4 ± 16.7	148.4 ± 15.8	121.4 ± 23.4	133.4 ± 22.5	149.3 ± 37.3	190.3 ± 31.8	219.3 ± 36.5	227.7 ± 57.6	182.0 ± 74.3	118.0 ± 73.1	161.1 ± 122.4	26.4 ± 13.7	26.4 ± 13.7	24.0 ± 26.4	32.8 ± 45.1
4	117.5 ± 14.6	128.9 ± 15.6	153.4 ± 21.5	169.4 ± 26.3	173.7 ± 35.8	182.0 ± 27.1	204.2 ± 33	206.9 ± 46.1	349.0 ± 82.5	376.2 ± 114.5	382.6 ± 141.8	555.9 ± 318.6	555.9 ± 318.6	501.8 ± 292.7	685.8 ± 376.5
5	101.4 ± 13.1	110.3 ± 11.3	119.6 ± 14.6	132.4 ± 14.7	136.6 ± 24.2	147.2 ± 20.5	160.2 ± 20	161.1 ± 32.5	299.9 ± 69.9	339.2 ± 119.1	296.8 ± 100.5	632.8 ± 341.0	632.8 ± 341.0	632.8 ± 371.7	681.5 ± 373.4

**Note.**— Values represent means ± standard deviation in Hounsfield units (HU) and numbers in first column indicate different phases.

<sup>a</sup>Attenuation values of aorta associated with iodine concentrations are significantly higher at 300 mg iodine/mL than at 250 mg iodine/mL ( $p < 0.0001$ ) and value for 370 mg iodine/mL is higher than for 250 mg iodine/mL ( $p < 0.05$ ). <sup>b</sup>Attenuation values of cortex indicate that 370 mg iodine/mL concentration is higher than values for 250 mg iodine/mL ( $p < 0.05$ ). <sup>c</sup>These values indicate that mean iodine concentrations of contrast media expressed as mg iodine/mL. <sup>d</sup>CT imaging with 300 mg iodine/mL shows no significant difference in attenuation values compared to 370 mg iodine/mL concentration in all phases and all sub-renal structures ( $p > 0.05$ ).

**Table 2. Differences in Attenuation Values of Cortex-Outer Medulla, Outer-Inner Medulla, and Inner Medulla-Pelvis According to Iodine Concentration of Contrast Media and Post-Contrast Phase**

	Cortex-Outer Medulla			Outer-Inner Medulla			Inner Medulla-Pelvis		
	250 <sup>a,b</sup>	300 <sup>a,b,c</sup>	370 <sup>b,c</sup>	250	300 <sup>c</sup>	370 <sup>c</sup>	250	300 <sup>c</sup>	370 <sup>c</sup>
Phase 1	133.4 ± 29.7	148.6 ± 30.2	148.0 ± 51.7	35.7 ± 18.5	34.5 ± 23.1	41.8 ± 40.7	22.4 ± 15.3	28.9 ± 13.5	27.7 ± 14.3
Phase 2	31.8 ± 27.6	48.1 ± 40.1	49.6 ± 37.9	98.8 ± 45.8	115.4 ± 67.1	112.8 ± 55.0	34.7 ± 19.1	32.0 ± 15.2	47.0 ± 54.3
Phase 3	69.2 ± 25.0	85.9 ± 35.5	78.4 ± 30.8	64.4 ± 49.5	115.4 ± 51.2	106.1 ± 69.6	155.6 ± 71.4	94.0 ± 63.3	128.3 ± 88.1
Phase 4	28.6 ± 12.7	35.4 ± 26.4	33.5 ± 21.2	167.2 ± 65.7	174.3 ± 93.3	177.1 ± 109.8	294.3 ± 170.1	217.7 ± 144.1	342.1 ± 242.7
Phase 5	27.7 ± 16.1	29.2 ± 15.5	24.7 ± 16.1	152.8 ± 60.7	179.0 ± 112.6	135.7 ± 82.9	349.0 ± 283.4	338.5 ± 257.0	384.7 ± 295.0

**Note.**— Values represent means ± standard deviation in Hounsfield units (HU).

<sup>a</sup>Value for 300 mg iodine/mL is significantly higher than for 250 mg iodine/mL ( $p < 0.05$ ). <sup>b</sup>These values indicate mean iodine concentrations of contrast media in mg iodine/mL. <sup>c</sup>CT imaging using 300 mg iodine/mL shows no significant difference in attenuation among sub-renal structures compared to 370 mg iodine/mL concentration in all phases ( $p > 0.05$ ).

media ( $p < 0.05$ ). CT imaging with 300 mg iodine/mL showed no significant difference in enhancement degree compared to the 370 mg iodine/mL concentration in all phases and all sub-renal structures ( $p > 0.05$ ). There was no significant difference in the attenuation values of the outer medulla, inner medulla, and pelvis ( $p > 0.05$ ) (Table 1).

There was only a significant difference between the 250 mg iodine/mL and 300 mg iodine/mL media for the attenuation difference of the cortex-outer medulla ( $p < 0.05$ ). CT imaging with 300 mg iodine/mL showed no significant difference for the attenuation differences among the sub-renal structures compared to the 370 mg iodine/mL concentration in all phases ( $p > 0.05$ ). Other attenuation differences, including those between the outer-inner medulla and inner medulla-pelvis, were not significantly different (Table 2).

A comparison study of the degree of severity of the renal streak artifact as determined by the window width and level did not reveal a significant difference ( $p > 0.05$ ) (Table 3). However, according to all grading methods, CT images with the 370 mg iodine/mL media showed a renal streak artifact with a higher degree of severity than CT images with 250 mg iodine/mL media ( $p < 0.05$ ). The artifact with 300 mg iodine/mL media showed a higher degree of severity than that with the 250 mg iodine/mL media only by the third grading method ( $p < 0.05$ ). None of the grading methods

showed a significant difference between the 300 mg iodine/mL and 370 mg iodine/mL media ( $p > 0.05$ ) (Table 4) (Fig. 2A-C).

## DISCUSSION

Many studies concluded that the use of a higher iodine concentration results in greater enhancement on CT images (4, 10, 18-22). However, Behrendt et al. (11) presented a study in which contrast media with a lower iodine concentration resulted in better contrast enhancement than a higher iodine concentration (370 mg iodine/mL versus 300 mg iodine/mL) for equivalent iodine load and delivery rate as seen in the early phase of chest MDCT scans. These investigators suggested that the viscosity of the contrast media plays an important role in contrast enhancement. A fluid with a lower viscosity can be injected at a lower pressure and may be distributed more easily and more evenly in the vessels. The investigators further explained that contrast media with a lower iodine concentration and the advantage of lower viscosity results in greater contrast enhancement in the early phase. Sandstede et al. (6) described that the use of contrast media of a high iodine concentration (370 mg iodine/mL versus 240 mg iodine/mL and 300 mg iodine/mL) showed higher contrast enhancement on arterial phase MDCT images with a constant

**Table 3. Differences between Controlled Values and Base Values in Window Width and Level, According to Phase and Iodine Concentration for Two Observers**

	250 <sup>b</sup>		300 <sup>b</sup>		370 <sup>b</sup>	
	Width	Level	Width	Level	Width	Level
Observer 1						
Phase 1 - Base <sup>a</sup>	124.4 ± 61.7	30.7 ± 24	91.7 ± 63.6	16.2 ± 11.4	135.9 ± 73.8	23.9 ± 19
Phase 2 - Base <sup>a</sup>	133.1 ± 66.7	27.5 ± 13.9	132 ± 69.6	18.4 ± 16	197.9 ± 153.8	36.2 ± 28.6
Phase 3 - Base <sup>a</sup>	278.8 ± 107.8	91.1 ± 34.1	280.4 ± 126.9	63.7 ± 34.8	305.3 ± 187.9	75.9 ± 65.9
Phase 4 - Base <sup>a</sup>	366.5 ± 141.6	107.7 ± 47.9	408 ± 199.7	102.5 ± 78.8	408.4 ± 247.7	99.7 ± 60.3
Phase 5 - Base <sup>a</sup>	324 ± 123.6	87.4 ± 41.1	355.9 ± 198.1	78.7 ± 70.5	343.3 ± 237.1	50.1 ± 31.8
Observer 2						
Phase 1 - Base <sup>a</sup>	128.4 ± 59.8	7.6 ± 9.7	106.7 ± 65.5	17.5 ± 18	116.5 ± 92.9	17.2 ± 19.9
Phase 2 - Base <sup>a</sup>	104.4 ± 60.7	12.4 ± 10.5	148.8 ± 79.6	30.1 ± 25.7	177.9 ± 171.5	36 ± 47.3
Phase 3 - Base <sup>a</sup>	274.1 ± 98.1	40.9 ± 26.4	293.9 ± 131.9	56.2 ± 30.1	299.3 ± 263.1	71 ± 54.9
Phase 4 - Base <sup>a</sup>	348.3 ± 100.8	68.7 ± 39.8	396.4 ± 191.5	69.1 ± 58.6	387.7 ± 249.1	91.1 ± 59.9
Phase 5 - Base <sup>a</sup>	300.8 ± 114.9	61.1 ± 27.5	322.5 ± 207.1	69.7 ± 44.3	270.1 ± 204.2	52.1 ± 40.5

**Note.**— Values represent means ± standard deviation for window width and level. No observer showed statistically significant difference of subtracted values (controlled value-base value) in window width and level among contrast media for three different iodine concentrations ( $p > 0.05$ ).

<sup>a</sup>Base values subtracted from controlled values in window width and level on each phase. <sup>b</sup>Iodine concentrations in contrast media expressed as mg iodine/mL.

**Table 4. Three Grading Methods for Determining Degree of Severity of Renal Streak Artifact**

Rabbit	1st grading			2nd grading			3rd grading		
	250 <sup>a,d</sup>	300 <sup>c,d</sup>	370 <sup>a,c,d</sup>	250 <sup>a,d</sup>	300 <sup>c,d</sup>	370 <sup>a,c,d</sup>	250 <sup>a,b,d</sup>	300 <sup>b,c,d</sup>	370 <sup>a,c,d</sup>
1	3	4	4	11	12	12	1	2	3
2	3	4	4	9	11	11	1	3	3
3	3	5	5	11	14	13	1	2	3
4	3	4	3	10	12	9	2	3	1
5	5	5	5	12	13	13	1	3	3
6	4	4	4	12	13	12	1	3	2
7	3	3	4	8	9	12	1	2	3
8	3	5	5	9	14	13	1	3	2
9	3	3	3	9	10	9	1	3	2
10	5	4	5	13	12	14	2	1	3
11	4	4	5	12	11	15	1	2	3
12	3	4	5	10	12	14	1	2	3
13	5	4	5	12	10	13	2	1	3
14	3	3	3	10	10	11	1	1	3
15	3	4	5	10	12	14	1	2	3

**Note.**— Values are scored by each grading method.

<sup>a</sup>According to all grading methods, scores of 370 mg iodine/mL contrast media is significantly higher for 250 mg iodine/mL ( $p < 0.05$ ). <sup>b</sup>According to 3rd grading method, scores of 300 mg iodine/mL of contrast media is significantly higher than for 250 mg iodine/mL ( $p < 0.05$ ). <sup>c</sup>Regardless of three grading methods, there is no significant difference between 300 mg iodine/mL and 370 mg iodine/mL media ( $p > 0.05$ ). <sup>d</sup>Iodine concentrations in contrast media expressed as mg iodine/mL.

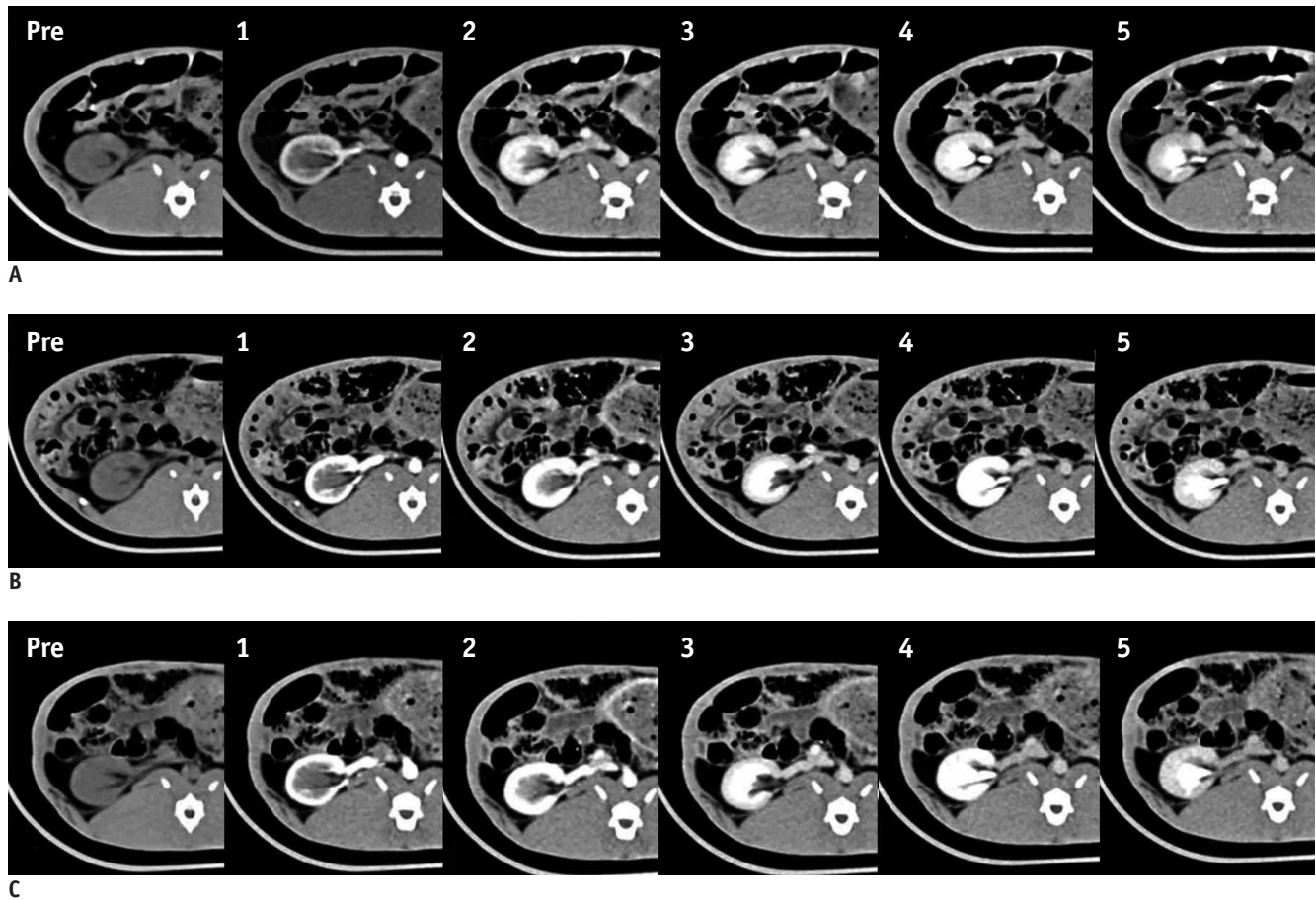
iodine load and injection rate. This result was discordant with the findings of Behrendt et al. (11). However, there are no significant effects of different iodine concentrations on delay phase images (6, 11). In most studies of solid organs, a higher iodine concentration results in higher CT enhancement only on early phase images (3, 6, 11).

In our study, the use of 370 mg iodine/mL contrast media provided higher enhancement than the 250 mg iodine/mL contrast media for the cortex in all phases ( $p < 0.05$ ). However, there were no significant differences in the enhancement degree in each sub-renal structure or attenuation among the sub-renal structures between the 300 mg iodine/mL and 370 mg iodine/mL concentrations in all phases. The attenuation values of the medulla and pelvis were not significantly different according to the iodine concentrations employed in all phases, including the early phase. This result may represent a unique characteristic of kidney where contrast media travels from the cortex to the pelvis. Two explanatory factors for this result are: 1) the contrast media does not yet reach the medulla and pelvis on early phase CT scans and consequently, the attenuation values do not show significant differences in the medulla and pelvis; 2) although only a small amount of the contrast media arrives in the medulla and pelvis on early phases,

it is too difficult to detect a difference in enhancement among the sub-renal structures on CT scans. Contrary to the findings for the medulla and pelvis, the cortex had a definite early phase on CT images. Therefore, even though the kidney has a characteristic structure as an excretory organ, the degree of enhancement had a similar pattern to other organs.

The beam hardening streak artifact arises from uneven absorption of the energy produced by the X-ray beam. Lower energy components of the polychromatic X-ray beam are preferentially absorbed within materials of high attenuation, such as concentrated iodinated contrast media or a surgical prosthesis. This beam hardening phenomenon contributes to the underestimation of attenuation coefficients and misinformation with regards to the CT reconstruction algorithms (17, 23). The pelvocalyceal system in the kidney increases the streak artifact due to the beam hardening phenomenon with concentrated iodinated contrast media in urine.

Sussman et al. (17) have described that a contrast media of low osmolarity results in a higher incidence in the renal streak artifact than a high osmolar agent. These investigators explained that a low osmolar contrast media with less osmotic diuresis results in a higher concentration



**Fig. 2.** Axial contrast enhanced CT images in rabbit show various CT enhancement patterns according to six phases and use of contrast media with three iodine concentrations. CT images show prominent differences of enhancement according to iodine concentration of contrast media in renal cortex regardless of phase, with most severe renal streak artifact produced with concentration of 370 mg iodine/mL. Three rows indicate iodine concentrations: **A.** 250 mg iodine/mL, **B.** 300 mg iodine/mL, **C.** 370 mg iodine/mL. Six columns indicate each phase as function of time: pre (pre-contrast), phase 1 (5-second delay), phase 2 (15-second delay), phase 3 (35-second delay), phase 4 (65-second delay), and phase 5 (115-second delay).

of urinary iodine. Low osmolar contrast media is widely used in CT examinations due to a lower incidence of contrast-induced nephropathy (19, 24). In our study, low osmolar contrast media was also used. Sussman et al. (17) evaluated the degree of severity for the renal streak artifact using a grading system in which observers characterized images with no artifact, minimal artifact, and marked artifact. In our study, a new measurement method using the window width and level as determined on the PACS workstation was evaluated. The method did not show a statistically significant difference according to contrast media of different iodine concentrations because of limitations with the grading method due to deficient control and inter-observer variance on images with appropriate contrast. However, there was a tendency for observers to interpret images with a wider window width on CT scans with a higher iodine concentration (Table 3). In contrast, we also

used three grading systems that could easily discern the degree of severity of the artifact according to the three iodine concentrations, as seen on the PACS workstation.

This current study has limitations related to the use of an animal model. However, the evaluation of the characteristic renal CT enhancement provides details that will be useful for future studies. In this study, the injection volume of contrast media could not be controlled beyond the unit level because of the use of the power injector like that used in a clinical setting. We performed the study with using a constant injection protocol based on a renal CT protocol in use at our institute. Therefore, various protocols examining factors such as injection rate, injection volume or constant iodine load will be necessary in a future study.

In conclusion, CT imaging with contrast media at a concentration of 370 mg iodine/mL showed better enhancement for the renal cortex than at 250 mg iodine/

mL and, no significant difference in the attenuation values was found compared to 300 mg iodine/mL. The renal streak artifact was more severe for contrast media at 370 mg iodine/mL contrast than at 250 mg iodine/mL on MDCT images. Therefore, the 300 mg iodine/mL was considered to be the most appropriate iodine concentration in an aspect of the enhancement and artifact on the kidney MDCT scan.

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