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Short Communication

Radiographic and computed tomographic evaluation of experimentally induced lung aspiration sites in dogs

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This study was performed to radiographically examine the prevalence of aspiration sites and to evaluate their atomical correlation with the bronchial pattens. Ten healthy beagle dogs were repeatedly radiographed, at weekly intervals, in the left and right lateral, ventrodorsal (VD) and dorsoventral (DV) positions. Three mililiters of iohexol distilled with same volume of saline was infused into the tracheal inlet. Which lung lobe was aspirated was decided upon by the presence of a significant alveolar pattern due to the contrast medium. Alveolar patterns were identified at the left (100%) and right cranial lung lobes (77%) with the dogs in dependant lateral recumbency, at the right caudal lung lobe (71%) with the dogs in VD recumbency and at the right middle lung lobe (59%) with the dogs in DV recumbency, respectively. The anatomical correlation was evaluated by performing computed tomography. The right principal bronchus (165.8 ± 1.6°) was more straightly bifurcated than was the left principal bronchus (142.7 ± 1.8°, $p < 0.01$). In VD position, the right side lung had a greater opertunity to become aspirated. The ventrally positioned right middle lobar bronchial origin was more easily to be aspirated the other laterally positioned ones. We think that these anatomical characteristics can be one of the causes for aspiration pneumonia to occur more frequently in the right side lung.

Key words: aspiration pneumonia, computed tomography, dog, iohexol, lung

Aspiration pneumonia can occur as an acute fulminant illness or as a chronic, insidious process. Esophageal disease, an autonomic defect, pharyngeal dysfunction, vomiting, iatrogenic causes and decreased consciousness are known to predispose people to aspiration [3,6,7]. The radiographic signs in the clinical cases, including alveolar opacities and consolidated regions, are common in the cranioventral and middle lung lobes [1,2,4,6,8] but the reasons for these sites to be more easily aspirated are not yet known.

This study was performed to radiographically examine the aspiration sites as they depend on patient positioning after iohexol infusion into the trachea, and to evaluate the anatomical relationship among the lobar bronchi with using the computed tomographic (CT) findings in dogs.

Ten healthy beagle dogs (6 males and 4 females) weighing 8.5 to 11 kg each were selected based on clinical, laboratory and thoracic radiographic examinations.

Under general anesthesia with using a combination of diazepam (Samjin Pharm, Korea) plus ketamine HCl (Yuhan, Korea), 3 ml of iohexol (Omnipaque; Nycomed Imaging, Norway) mixed with the same volume of saline was infused into the distal lobe to the thyroid cartilage level via a tracheal tube. All the dogs were restrained and then radiographed in the left and right lateral, ventrodorsal (VD) and dorsoventral (DV) positions at 1 min after iohexol infusion; this was done at weekly intervals. The lung lobe that showed an obvious alveolar pattern with contrast medium was decided upon as a main aspirated lung lobe. Cefazolin sodium (Dongwha Pham, Korea) was given for anti-inflammation.

Transverse CT examinations were performed to verify the radiographic results and to describe the anatomical characteristics and variations of the principal bronchus, along with the lobar bronchial ramifications, with using 5 randomly selected dogs that were put in the same positions as those in the radiographic study. The left and right principal bronchial bifurcations were compared for the angle they made with the trachea by using 3 dimensional reconstructed images (Fig. 1).

The CT images were obtained using a helical CT scanner (GE CT/e; General Electric Medical System, Japan). The scan settings were 50 mA, 120 kVp, a pitch of 1.3, a slice thickness of 2 mm and an image interval of 2 mm from the 3rd to the 10th thoracic vertebra. The images were recorded with using a lung tissue window (L500-700, W1000-2000). The retro-reconstruction settings were done with a slice

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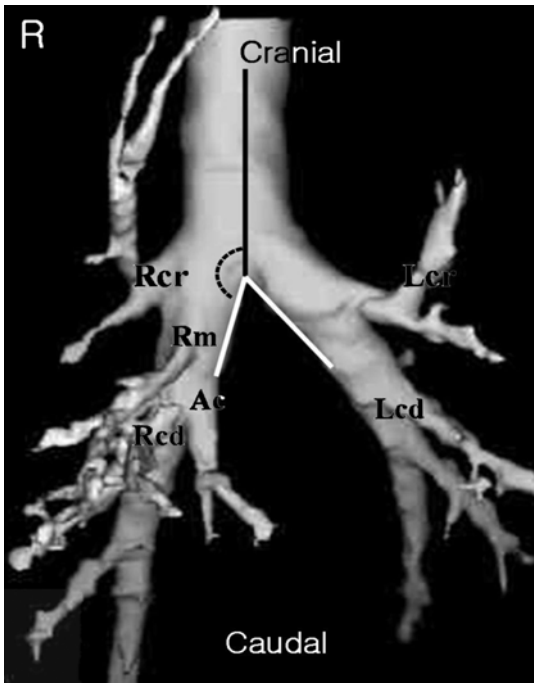

Fig. 1. Ventral aspect view of the three-dimensional reconstruction CT images. The right cranial (Rcr), middle (Rm), caudal (Rcd) and accessory (Ac) lobar bronchi in the right side and the cranial (Lcr) and caudal (Lcd) lobar bronchi in the left side are seen. The middle lobar bronchus originates from the ventral side of the right principal bronchus. The angle (black dotted curved line) was measured between the principal bronchial (white line) and the tracheal (black line) extension.

thickness and image interval of 1 mm.

The six dogs in this study showed intermittent mild coughing after 2 days of iohexol infusion. The infiltrated iohexol was identified radiographycally at 24 h, but it was not seen at 48 h after infusion, and there were no other side effect [5].

Alveolar patterns induced by the contrast medium were identified in 2/14 (14%) right cranial lung lobes, 2/14 (14%), left caudal lung lobes and 10/14 (72%) right caudal lung lobes following VD recumbency; they were identified in 4/17 (24%) right cranial lung lobes, 10/17 (59%) right middle lung lobes and 3/17 (18%) left cranial lung lobes following DV recumbency; they were identified in 10/13 (77%) right cranial ling lobes, and in 3/10 right caudal lung lobes following right lateral recumbency. In left lateral recumbency, alveolar patterns were identified only in the left cranial lung lobe (Table 1). The prevalence rate was 72% (39 of the 54 lung lobes) in the right lung and 28% in the left side lung.

On the CT examinations, the right principal bronchus (165.8 ± 1.6^{o}) was more straightly bifurcated ($p < 0.01$) in comparison with the left principal bronchus (142.7 ± 1.8^{o}) (Fig. 1). With the dogs in VD recumbency, both the left and right cranial lobar bronchial openings were located more or less on the ventrolateral side, but the middle lobar bronchial opening arouse from the ventral midline of the right principal bronchus (Fig. 2).

In DV recumbency, the right cranial bronchial opening was positioned at the side of the concave basal surface of the right principal bronchus. The middle lobar bronchial opening was located at almost the ventral midline of the right principal bronchus. The left cranial bronchial opening was imaged with a full diameter at the same plane as the end portion of the cranial lobar bronchus (Fig. 2&3). These results were also identified on the 3 dimensional retroreconstructed images (Fig. 1).

Table 1. Prevalence of the alveolar patterns induced by iohexol instillation

Position	Right (Number of lung lobes)			Left	
	Cr	M	Cd	Cr	Cd
VD	2		10		2
DV	4	10		3	
Right lateral	10		3		
Left lateral				10	

Cr: cranial lobe, M; middle lobe, Cd; caudal lobe, VD: ventrodorsal, DV: dorsoventral.

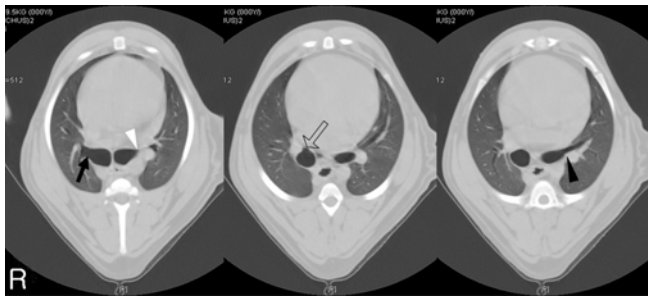

Fig. 2. CT images of the canine thorax in ventrodorsal recumbency. The right cranial (black arrow), middle (open arrow), the beginning (white arrow head) and the full sliced diameter (black arrow head) of the left cranial bronchial opening are visualized.

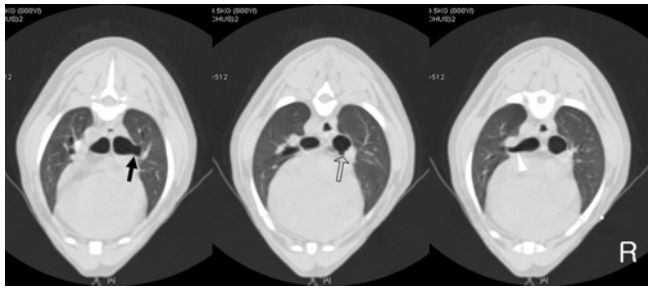

Fig. 3. CT images of the canine thorax in dorsoventral recumbency. The right cranial (black arrow), middle (open arrow) and left cranial (white arrow head) bronchial openings are seen.

The right principal bronchus travels straighter towards the trachea than does the left principal bronchus [1,3]. These characteristics could be a reason for the prevalence of aspiration pneumonia in the cranial and middle lobes [1] and this was verified in this study. With the dog in VD and DV recumbency, the infiltration rate of contrast medium was high at 84% of the right side lung lobes (26 of the 31 lung lobes). We thought that the obtuse angle the right principal bronchus made with the trachea was one of the factors to facilitate aspiration to the right-side lung [2-4]. Accordingly, these anatomical characteristics could be factors for a greater opportunity for aspiration to occur in the right side lung, with the dog in VD and DV recumbency, as compared to the left side lung.

The cranial and middle lobar bronchial openings were deviated dorsolaterally from the contrast flow in VD recumbency. So, the right cranial and middle lung lobes were difficult to become aspirated, but the caudal lung lobe was readily reached. However, the right middle bronchial opening arose almost from the ventral midline of the right principal bronchus in DV recumbency, and there was a more significant alveolar pattern in the middle lung lobe. Of course, these patterns were identified in the right and left cranial lung lobes in 4 dogs, but the degree of opacity was lower than that of the middle lung lobe. These results can be explained that the right middle lung lobe is the commonest and most easily aspirated lobe, and aspiration pneumonia usually develops when aspiration occurs with the subject conscience and in the standing position.

The right cranial lung lobe is known to be most susceptible lobe to passive aspiration [1,4,8], but this was noted in as low as 19% of right cranial lung lobes (4 of the 31 lung lobes) with the subject in a neutral position, including VD and DV recumbency. In right lateral recumbency, the cranial lobar bronchial opening is positioned in the direction of the flow of the infused contrast medium compared to the swerved middle lobar bronchial opening. Therefore, the middle lung lobe can stay free from aspiration; the prevalence of aspiration was high in the right cranial lung lobe rather than the middle and caudal lung lobes. It can be inferred from these results that the right cranial lung lobe is especially sensitive to aspiration the right lateral recumbency. The left cranial lobar bronchial opening extends in a gravity dependent manner and it is positioned ventral to the contrast flow [6,7,9]. Under these conditions, the left cranial lung lobe is prone to aspiration.

In conclusion, the alveolar patterns may be simultaneously presented in various lung lobes when a large volume of fluid is aspirated. However, experimentally induced aspiration with a small volume of contrast medium is useful to determine the primary aspiration lung sites without hampering the researcher differentiating the results. The retro-reconstructed CT images could help create a numeric measurement scale for the angle between the principal bronchus and trachea; this could help identify bronchial relationships that can affect the aspiration pattern. Finally, the anatomical characteristics of the right lung might be correlated with a high prevalence of aspiration.

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