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Fluid Accumulation in Canine Tympanic Bulla: Radiography, CT and MRI Examinations

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Abstract : Fluid accumulation within the tympanic bulla is an important diagnostic indicator of canine otitis media although its identification can be a challenge using currently available imaging techniques. The purpose of this study was to compare radiography, computed tomography (CT) and magnetic resonance imaging (MRI) in the identification of fluid accumulation within canine tympanic bulla. Unilateral tympanic bulla in 10 beagles were experimentally filled with blood or saline. Quantitative analysis of CT images were obtained by using Hounsfield unit (HU). MR signal intensity was obtained by using region of interesting (ROI) and compared with those of gray matter. On the CT image, the presence of blood or saline produced a fluid opacity occupying the tympanic bulla. On the MR image, the appearance of blood in the tympanic bulla was isointense in T1-weighted images and hyperintense in T2-weighted images. However, the appearance of saline in the tympanic bulla was hypointense in T1-weighted images and hyperintense in T2-weighted images. This study suggest that CT and MR imaging are useful methods for detection and differentiation of fluid in canine tympanic bulla.

Key words **:** Tympanic bulla, Radiography, CT, MRI, Dog.

Introduction

Otitis media, an inflammatory disease in the middle ear cavity, is a common disease process that goes unrecognized in most veterinary practices (11). Otitis media in dogs is much more prevalent than previous thoughts. In dogs, secondary otitis media occurs in approximately 16% of acute otitis externa cases and in as many as 50% to 80% of chronic otitis externa cases (11,12). Otitis media should also be considered when the veterinarian is presented with a patient showing any neurologic diseases affecting the head, including vestibular diseases, Horner's syndrome, or facial nerve damages.

The presence of fluid within the lumen of the tympanic bulla is one of the most consistent changes associated with the presence of otitis media in the dog. In acute cases, it may be the only abnormality present prior to the development of more chronic secondary changes. However, fluid within the tympanic bulla has also been observed as an incidental finding in dogs undergoing CT or MRI examination of the head(2) and so may not be a specific indicator. The material could be granulation tissue, blood, exudate, or cerebrospinal fluid.

The ear canal and tympanic bulla can be evaluated otoscopically, surgically, and radiographically. Ultrasound is also being evaluated as an inexpensive and noninvasive imaging modality for diagnosing otitis media (11). Additionally, advanced imaging techniques like CT and MRI are becoming increasingly available for imaging the ear. Although general anesthesia is required, imaging is a noninvasive method of evaluating the ear canal and tympanic bulla. Radiographs, CT, and MRI may help to diagnose congenital deformities of the ear, otic neoplasia, otitis media, and vestibular disease. Diagnostic imaging of the canine tympanic bulla has been historically centered on the use of radiography. However, the complex nature of the canine skull results in superimposition of the tympanic bulla and the radiographic changes associated with otitis media can be subtle making interpretation a challenge. False negative findings appear to be more common than false positives (14,20). Advanced imaging techniques such as CT and MRI are becoming more widely available in veterinary medicine. CT provides excellent evaluation of bone structures while MRI is extremely sensitive to alterations in soft tissue (9) of ear structures.

The aim of this study was to appreciate whether CT and MRI could be useful methods for detection and differentiation of fluid in canine tympanic bulla.

Materials and Methods

1. Experimental animals

Ten clinically normal adult Beagle dogs were used for this study. Each dog weighed between 8-10 kg, and all dogs were sexually intact. CBC, serum biochemical analysis, and thoracic radiography were taken to evaluate the health of each dog. The external ear canal had a normal apperance on the otoscopic examination and there was no previous history of otitis.

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Survey skull radiography using dorsoventral lateral and open-mouth views and CT examination were available in all dogs.

1) Experimental group

Saline was injected in 5 dogs (group A), and Blood in the other 5 dogs (group B)

2) Experimental fluid accumulation in tympanic bulla

The dogs were premedicated with atropine (0.04 mg/kg, SC, Atropine sulfate inj.®, Jeil, Korea) and sedated with midazolam (0.1 mg/kg, IM, Domicum®, Roche, Switzerland) and medetomidin (0.04 mg/kg, IV, Domitor®, Orion, Finland), and positioned in lateral recumbency. One tympanic bulla in each dog was filled by the following method. The spinal needle (Spinocan®, 22Gx3½, B.Braun, Germany) was advanced along the external ear canal using otoscopy, through the tympanic membrane and into the dorsal compartment of the tympanic bulla. Then air was removed in tympanic bulla using syringe suction. One-to-two milliliter of saline (Sterile Saline Inj.®, Daehan, Korea) was then injected into the tympanic bulla in Group A and the same volume of blood in Group B. The blood was used without anticoaguant.

2. Diagnostic imaging

All the obtained images were evaluated in order of radiography, CT, and MRI without any preliminary knowledge about the each other image studies.

1) Radiography

The X-Omat® regular film (Kodak Co., USA) was used with intensifying screen. The radiographic examination consisted of dorsoventral (DV), left to right lateral, left 20° ventral-right dorsal oblique, right 20° ventral-left dorsal oblique and rostral 30° ventral-caudodorsal open mouth (RCdOM) projections.

2) CT

CT was performed immediately after radiography. The CT images were obtained with a third-generation whole body scanner (CTmax®, GE, USA). The dog was positioned in ventral recumbency and the head introduced in the CT unit. Contiguous transverse 5mm thickness images of the skull were obtained beginning immediately rostral to the tympanic bulla and continuing caudally to a level just caudal to the petrous temporal bones. Quantitative analysis of CT images were obtained by using Hounsfield unit (HU), centered on the fluid filled tympanic bulla.

3) MRI

Images were obtained with a 0.2 tesla permanent magnet (VetMR®, Esaote, Italy) using a standard small animal coil. Similar to CT, the dog was positioned in ventral recumbency with the head positioned in the radiofrequency (RF) coil with the front limbs pulled caudally. Turbo T2 sequence (TR 3800, TE 90, slice thickness 5 mm) and T1 sequence (TR 540, TE 26, slice thickness 5 mm) were performed on the transverse plane. Statistic data of signal within fluid filled tympanic bulla were analyzed using ROI and compared with those in gray matter.

3. Image evaluation & statistical analysis

The radiographs, CT and MR images were respectively evaluated without knowledge of the other images, and the CT images were then evaluated without knowledge of the radiographic findings. The MR images were evaluated without knowledge of the radiographic and CT findings. After all image evaluations were complete, the corresponding MRI, CT and radiographic evaluations were compared. Data were evaluated using t-test.

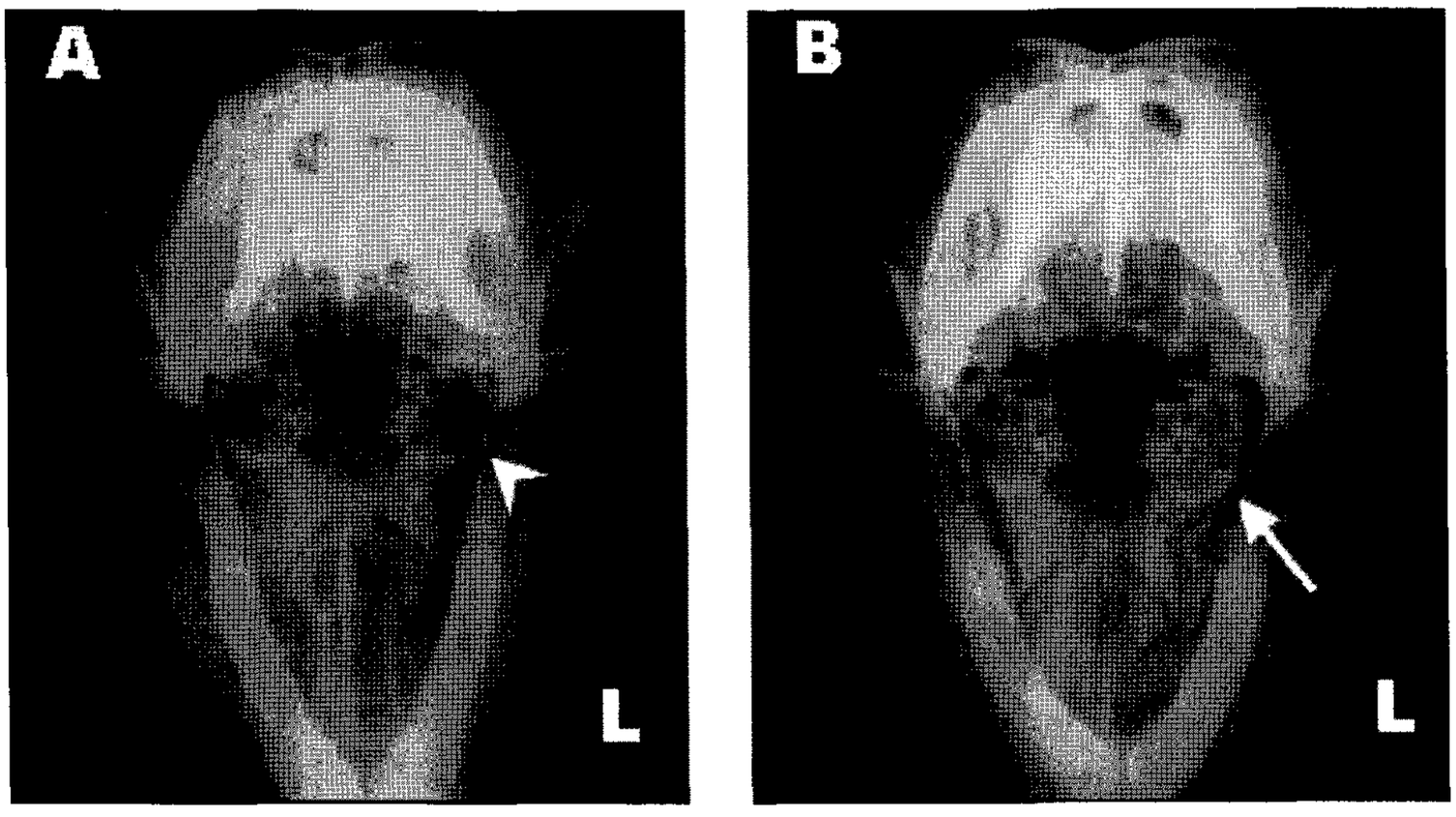

Fig 1. Rostrocaudal open mouth radiographs. Saline (A) and blood (B) are injected within left tympanic bulla. However, the soft tissue opacity seems to increase in both tympanic bullae due to tongue overlapping.

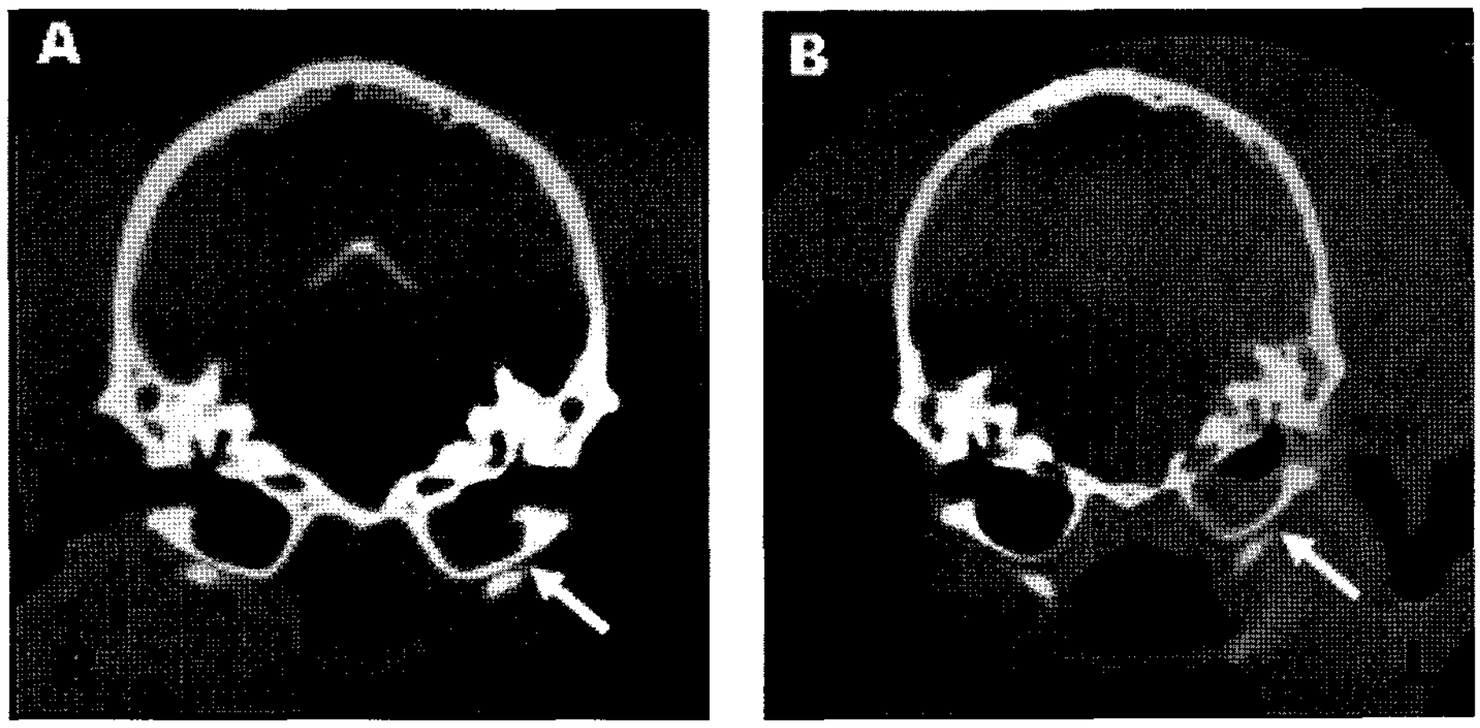

Fig 2. CT images. Injected materials are saline (A) and blood (B). There are soft tissue density in tympanic bulla (arrow). It is difficult to grossly differentiate whether fluid is saline or blood.

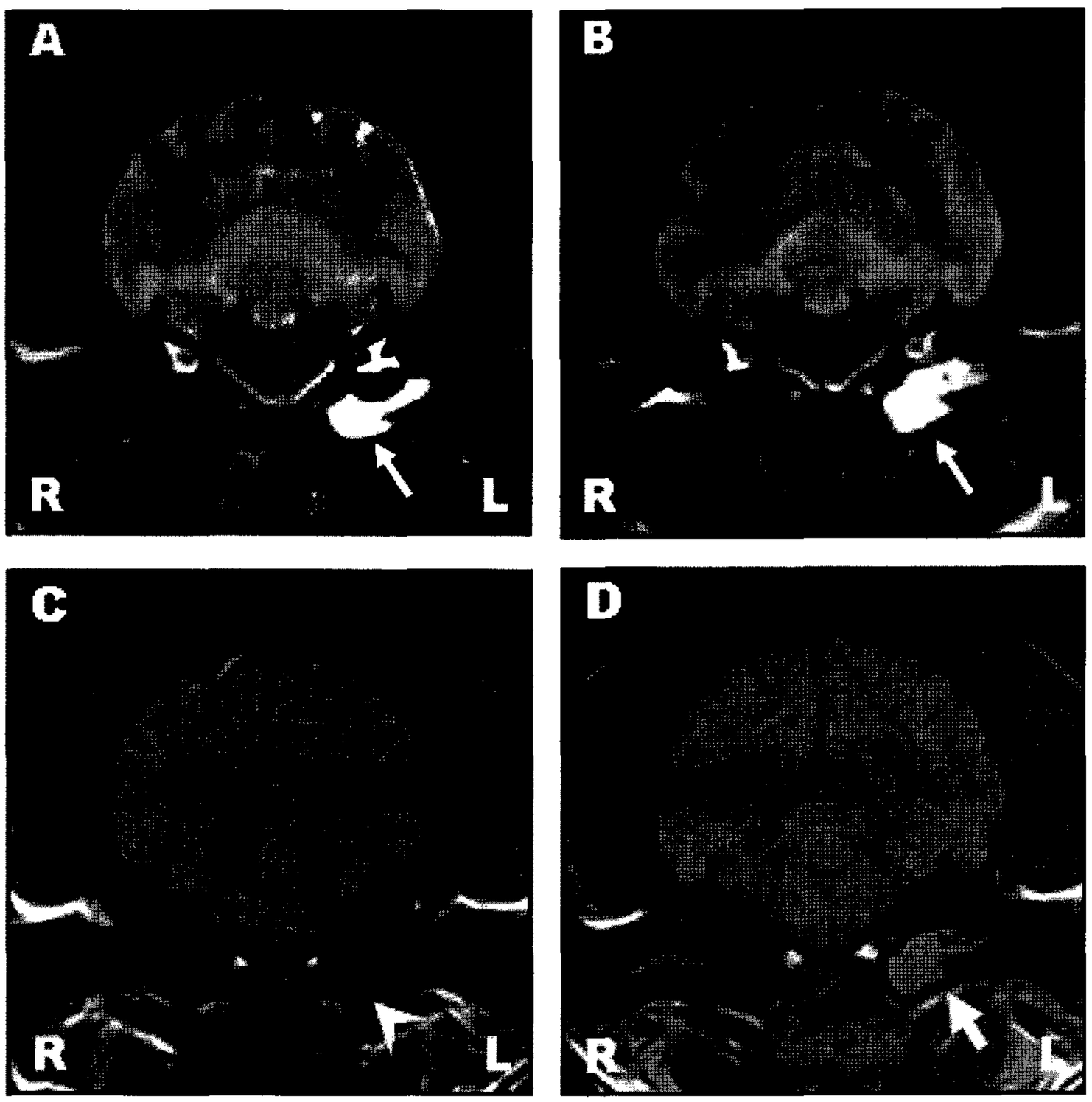

Fig 3. Injected materials are saline (A,C) and blood (B,D). On transverse T2-weighted images (A,B), the contents of the bulla are hyperintense (arrow) compared to cerebral gray matter. On transverse T1-weighted images (C,D), the contents of the bulla are hypointense (arrow head) and isointense (bold arrow) compared to cerebral gray matter.

Result

1. Gross evaluation

The radiography, CT and MR images obtained are shown in Fig 1~3 and demonstrate the appearance of saline or blood filled tympanic bulla.

On the rostrocaudal open mouth radiographs, the normal air filled tympanic bulla appeared as a hemispherical structure with a smooth, thin, complete bone wall and a radiolucent lumen projecting from the ventral surface of the temporal

bone and overlying the soft tissue of the pharynx. The presence of fluid produced a diffuse increase in soft tissue opacity throughout the lumen (Fig 1).

On the CT images, the normal gas filled tympanic bulla lumen appeared black and is surrounded by a smooth, well defined thin hyperdense bone wall. The presence of fluid produced a fluid density occupying the lumen (Fig 2).

On the MR images, the saline filled tympanic bulla lumen appeared hypointense compared to cerebral gray matter on T1-weighted images, hyperintense on T2-weighted images. However, the blood filled tympanic bulla lumen appears isointense compared to cerebral cortex on T1-weighted images, and hyperintense on T2-weighted images (Fig 3).

2. Quantitative analysis

On CT and MR images, there was apparent correlation between the signal characteristics of the material and statistic data. Results were considered statistically significant when the p value was less than 0.05.

On the profile of CT numbers, a difference was seen between the blood filled (44.64 ± 4.79 CT numbers) and the saline filled (13.45 ± 8.30 CT numbers) tympanic bulla (Fig 4).

On the profile of number of functions on T1 and T2-weighted images, there was a significant difference between the saline filled tympanic bulla and gray matter, and between the blood filled tympanic bulla and gray matter. Also, significant difference was seen on the number of functions between blood and saline filled tympanic bulla on T1 and T2-weighted images (Table 1 and Fig 5).

Discussion

There are many conditions that result in accumulation of tissue or fluid in the middle ear in humans. The most important ones are complications of otitis media (4,15,16) and abnormal Eustachian tube function (17) secondary to nasopharyngeal carcinoma (8) or cleft palate (10). Less common causes include congenital anomalies (18), such as an abnormal large facial nerve canal (19), which allows accumulation of cerebrospinal fluid in the middle ear.

The diagnosis of otitis media in dogs can be quite difficult to make because of the long, bent, funnel-shaped conformation of the dog's ear canal, which makes it hard to see the tympanic membrane. In addition, many patients with otitis media have an intact tympanic membrane, giving the clinician the impression that there is nothing wrong in the middle ear. Most canine patients with otitis media also have chronic otitis externa with

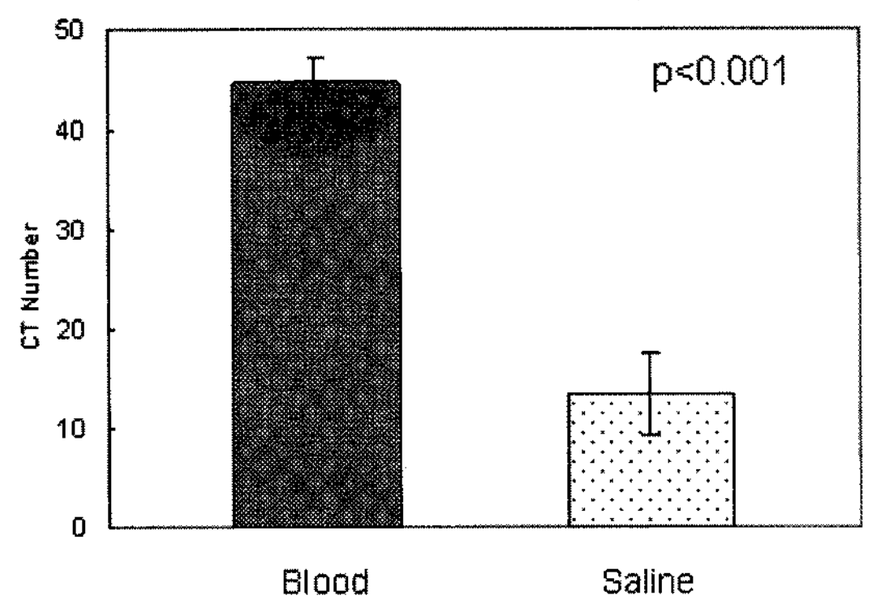

Fig 4. Comparison of CT number in the blood filled tympanic bulla and the saline filled tympanic bulla. A significant difference was seen between the blood filled and the saline filled tympanic bulla.

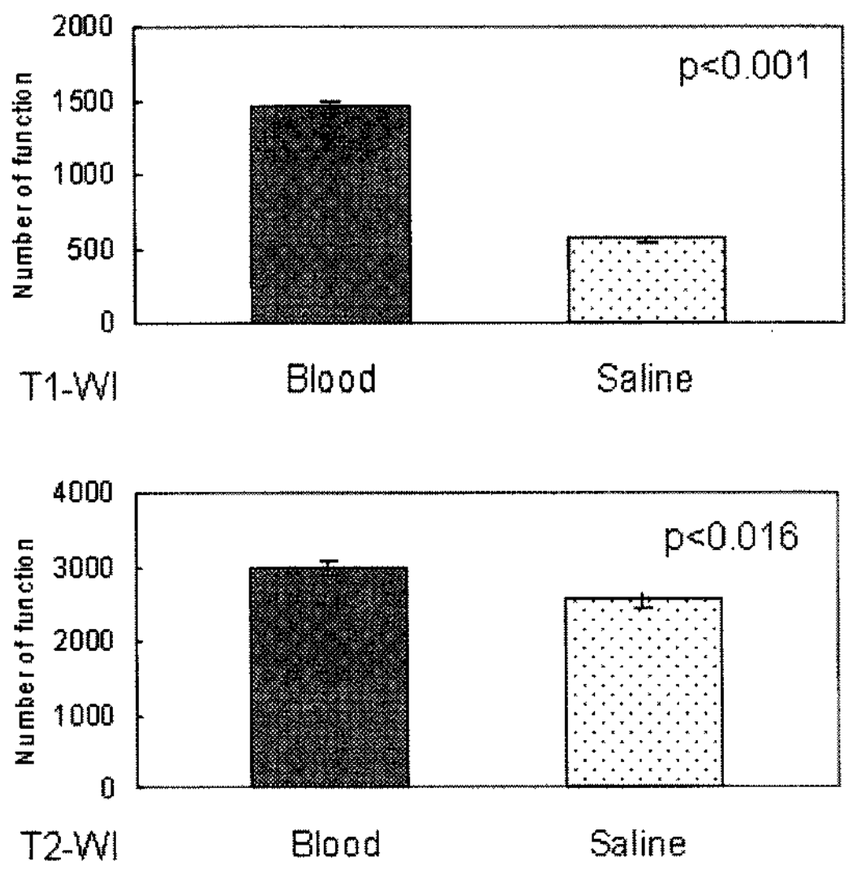

Fig 5. Comparison of number of function in the blood filled tympanic bulla and the saline filled tympanic bulla. Significant difference was seen between the blood filled and the saline filled tympanic bulla on T1-weighted images ($p < 0.001$) and T2-weighted images ($p < 0.05$).

Table 1. Results of number of function

	Group A		Group B	
	Saline	Gray matter	Blood	Gray matter
T2	2560.43 ± 248.85	1289.28 ± 36.23	2982.14 ± 183.53	1288.09 ± 62.88
	($p < 0.001$)		($p < 0.001$)	
T1	553.95 ± 26.50	1441.75 ± 53.16	1448.41 ± 73.95	1436.59 ± 62.52
	($p < 0.001$)		($p < 0.001$)	

pathologic changes to the ear canal that cause stenosis, making visual examination of the tympanic membrane impossible.

Radiography has been used extensively in the diagnosis of otitis media. Dorsoventral, lateral, oblique lateral and rostrocaudal open mouth views have been recommended for investigation of the bulla (12,21). However, radiographic evaluation of the tympanic bulla is limited. Improper obliquity or angulation of the skull for radiographs or malpositioning of the tongue can result in an inadequate study (20). Additionally, because of the complex anatomy of the canine skull, with superimposition of multiple osseous structures, radiography can result in false-negative examinations or underestimation of the disease present (7). When compared with surgical findings of 19 clinical cases of presumptive middle ear disease, false-negative radiographic findings were found in 25% of the surgically comfirmed cases of otitis media (20). Therefore, radiographs are not considered to be a highly sensitive mode of diagnosing otitis media. Radiographs may be helpful in determining lysis associated with neoplasia; however, the extent of involvement is still underestimated(14).

Advanced imaging techniques such as CT and MRI are becoming more widely available in veterinary medicine. CT provides excellent evaluation of bone structures while MRI is extremely sensitive to alterations in soft tissue (9). Both techniques produce individual slices through the head allowing each tympanic bulla to be examined freely from superimposition and a series of slices is required in order to image the entire structure. The use of CT and MRI to image the tympanic bulla, and in the diagnosis of otitis media have been reported (5-7,14). The sensitivity of CT in diagnosis of otitis media was reported to be greater than for radiography but the specificity was less (14). It has been suggested that MRI provides information not available using either radiography or CT (5). Both techniques require general anaesthesia to allow accurate, symmetrical positioning and to prevent patient movement during the examination.

MRI is a sensitive technique for detection of material in the middle ear (15,16). In humans with otitis media and its complications MR images obtained after administration of gadolinium enable granulation tissue (which consistently enhanced) to be distinguished from cholesteatoma, cholestrol granuloma, and herniation of the brain into the middle ear cavities (15,16). Lesions resulting from intracranial extension of inflammation originating in the middle ear, such as meningitis, brain abscess, facial neuritis, or venous thrombosis may also be identified by MR imaging (4,15,16). Studies in cats and dogs with otitis media have recorded similar MR imaging findings as those described in humans (1,5,6). Animals with otitis media usually have material within the affected tympanic bulla that appears isointense compared to cerebral gray matter on T1-weighted images, hyperintense on T2-weighted images (1,6). In dogs with neoplasia affecting the middle ear, destruction of the tympanic bulla and petrous temporal bone may be observed on MR imaging (6). Material in the middle ear may be observed in dogs undergoing MR imaging for investigation of neurologic signs that appear to be unrelated to otitis media. In this scenario, the material could be granulation tissue, blood, exudate, or cerebrospinal fluid (17).

In summary, it appears that CT and MRI were more reliable than radiography in detecting and differenciating of fluid in canine tympanic bulla. Especially, MRI allowed superior differentiation of fluid for gross evaluation.

These results suggest that CT and MRI examination of the tympanic bulla have abilities to assess the fluid accumulation and the differentiation of the fluid of the tympanic bulla. Thus, these techniques may aid in differential diagnosis of otitis media.

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