NOTE *Surgery*

Sound Signature for Identification of Tracheal Collapse and Laryngeal Paralysis in Dogs

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ABSTRACT. The aims of this study were to investigate whether upper airway sounds of dogs with laryngeal paralysis and tracheal collapse have distinct sound characteristics, compared with unaffected dogs. The sounds of 5 dogs with laryngeal paralysis and 5 dogs with tracheal collapse were recorded. Honking sound appeared as predominant clinical signs in dogs with tracheal collapse. Laryngeal stridors appeared as predominant clinical signs in dogs with experimentally produced laryngeal paralysis by resection of laryngeal nerve, in which two types of stridor, I and II, were recorded. All these sounds were analyzed using sound spectrogam analysis. There were significant differences in duration (sec), intensity (dB), pitch (Hz), first formant (Hz), second formant (Hz), third formant (Hz), fourth formant (Hz) of sounds between the normal bark and two types of stridor or honking sound, indicating that the sound analysis might be a useful diagnostic modality for dogs with tracheal collapse and laryngeal paralysis.

KEY WORDS: honking sound, laryngeal stridor, sound spectrogam analysis.

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Laryngeal paralysis occurs when the normal innervation of the laryngeal muscles is interrupted [15]. Hereditary transmission, trauma, diffuse polyneuropathy, and hypothyroidism have been reported as causes of laryngeal paralysis [6, 13, 22, 23, 25, 31]. Laryngeal paralysis occurs predominantly in older male large and giant breed dogs, but it can be occurred in any breed dogs and cats [24, 33]. Clinical signs include laryngeal stridor, exercise intolerance, dyspnea, voice change, cyanosis, and collapse [4, 12]. Recognition of laryngeal stridor and dyspnea is important in the diagnosis of this disease [32]. Endoscopy was used as a definitive technique to diagnose laryngeal paralysis and ultrasound investigation accurately indicated the presence of the paralysis and confirmed the uni- or bilateral nature of the disorder [27].

Tracheal collapse is a problem of small, middle-aged dogs characterized as dorsoventral flattening of the cartilaginous tracheal rings and laxity of the dorsal tracheal membrane that result in partial or complete obstruction of the airway [2]. A distinctive goose honk sound is often observed.

The sound spectrogram is a permanent visual record showing the distribution of energy in both frequency and time. Spectrogram has been used in many clinical investigations to specify acoustic clues to specific speech-language disorders in human [1, 16]. It has also served to verify the outcome of various types of therapy. There have been few reports about the effect of spectrogram on upper respiratory disease in dogs.

The purpose of this study was to investigate whether upper airway sounds of dogs with laryngeal paralysis and tracheal collapse have distinct sound characteristics, compared with unaffected normal dogs.

Five male healthy mongrel dogs were used for laryngeal paralysis. Their mean age was 18.5 (range, 14 to 28) months and mean body weight was 5.12 (range 5 to 7) kg. Following experiments were conducted according to the guidelines for Animal Experiment Committee, College of Veterinary Medicine, Gyeongsang National University. Five dogs were subjected to experimentally produced laryngeal paralysis according to the previously described method with resection of the recurrent laryngeal nerve [3, 14, 26]. Also, 5 male dog patients with the signs of clinical tracheal collapse were included in this study. Their mean age was 9.5 (range, 6 to 11) years and mean body weight was 4.97 (range 1.8 to 9.4) kg. Fluoroscopic examination of the trachea and primary bronchi was conducted for definitive diagnosis.

Before the experimental induction of laryngeal paralysis, normal barks were recorded and analyzed (Fig. 1). Normal bark, honking sounds of the patients with tracheal collapse, and stridors of dogs experimental laryngeal paralysis were recorded by a digital audio tape-corder (DAT, Sony TCD-D8, Japan) with a unidirectional microphone(Audio-technica, Japan) and a digital camcorder (Panasonic PV-DV400D, Matsushita Electronic Ltd, Japan). When each sound was recorded, the dog was placed within a meter distance from the microphone or camcorder. After connecting the DAT or camcorder to a computer, we collected sounds by using Cool Edit® (Adobe, San Jose, CA) program, and grasped types of sounds. Also we measured the parameters of the sounds using Praat (P. Boersma & D. Weenink, University of Amsterdam, The Netherlands) with wide band (300 Hz) filter. Duration of sound (sec), intensity (dB), pitch (Hz), first formant, second formant, third formant, fourth formant (Hz) were analyzed. In these parameters, duration of call is duration of sound, intensity is degree of strength of sound, the pitch is as a relative concept of frequency, an auditory feature of sound aiming the high and low of the sound, and each formant is the convergence

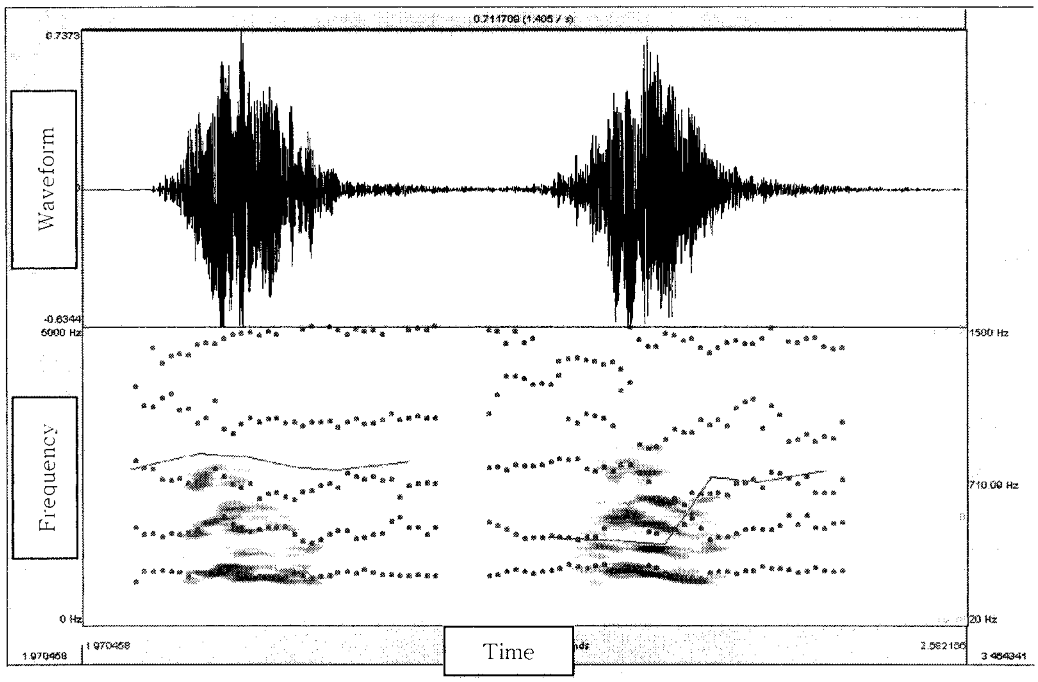

Fig. 1. Spectrogram of normal bark of the dog(two barks).

degree of sound energy in special frequency of stridor or honking sound [19]. Statistical analysis was carried out with SPSS (SPSS, Inc., Chicago, IL) and comparison of the difference in values of stridor's types and honking sound was conducted by General Linear Model.

Honking sounds recorded in dogs with tracheal collapse were shown in Fig. 2. The fundamental frequency(pitch) was lower than that of normal bark. Honking sound was characteristic for the repeated sounds during short periods. Two types of stridor, I and II, were recorded in dogs with experimental laryngeal paralysis. Type I was listened when the dog with severe clinical signs inspired (Fig. 3), whereas type II was listened when the dog with mild clinical signs inspired and expired (Fig. 4), and especially anterior note (AN) and posterior note (PN) were repeated during short periods. There were significant differences in duration (sec), intensity (dB), pitch (Hz), first formant (Hz), second formant (Hz), third formant (Hz), fourth formant (Hz) of sounds between the normal bark and two types of stridor or honking sound, indicating the acoustic characteristics of the sounds were different (Table 1).

The method used in the present study appeared to be practical and easy to apply in the clinical setting; the sound of the patient was just recorded using a pamcorder.

In the present study, the diagnosis of tracheal collapse with grade 2 or the worse stage was confirmed by fluoroscopy. When compared to that of normal barking, the spectrogram of honking sounds had similar waveform, however, the pitchs between two sounds were much different. Dogs younger than 6 years old had more severe tracheal collapse but had better prognosis after surgery than dogs over 6 years old [2]. This suggests that dogs at risk for tracheal collapse should be evaluated as young as possible, and that surgery, if indicated, should be performed when dogs are younger, so that importance of the identification of respiratory or cough sounds should be emphasized through the client education.

Bilateral laryngeal paralysis is a common cause of upper airway obstruction in older large breed dogs but it can also affect small breed dogs [24, 33]. The diagnosis of this disease is usually done by gross or laryngoscopic examination under short-acting barbiturate anesthesia. Dogs should be maintained under a light plane of anesthesia to gag intermittently during laryngeal examination [15], however, it may be difficult to define the diagnosis for the inexperienced clinician. Spontaneous laryngeal paralysis may be acquired as a result of damage to the recurrent laryngeal nerves or intrinsic laryngeal muscles associated with polyneuropathy, polymyopathy, iatrogenic trauma or intrathoracic or extrathoracic masses [20]. Laryngeal paralysis typically does not cause clinical signs in dogs unless it is bilateral [20], so that in the present study, bilateral laryngeal paralysis was experimentally produced.

The stridor caused by partial functional obstruction in the upper airway [32] is an audible sound synchronous with respiration. This stridor could be analysed by sound spectrogram and could be a objective diagnostic tool. Two types of stridor were recorded depending on the severity of clinical signs which were related to dyspnea. Type I was more related to severe clinical signs. Type I stridor was thought to indicate almost complete obstruction of the airway pas-

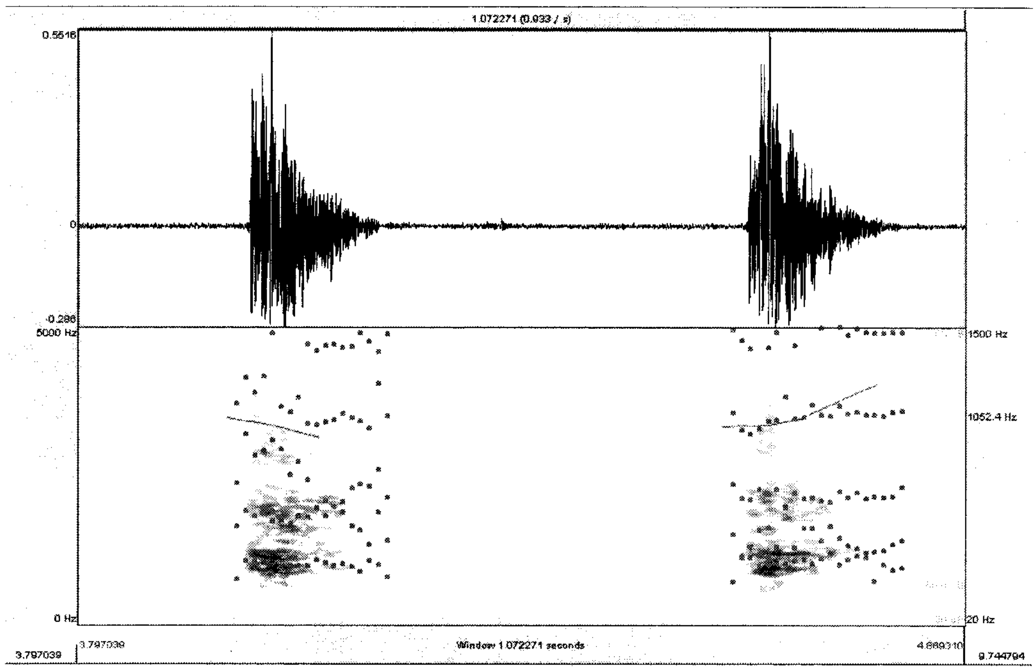

Fig. 2. Spectrogram of honking sound (two sounds) caused by tracheal collapse.

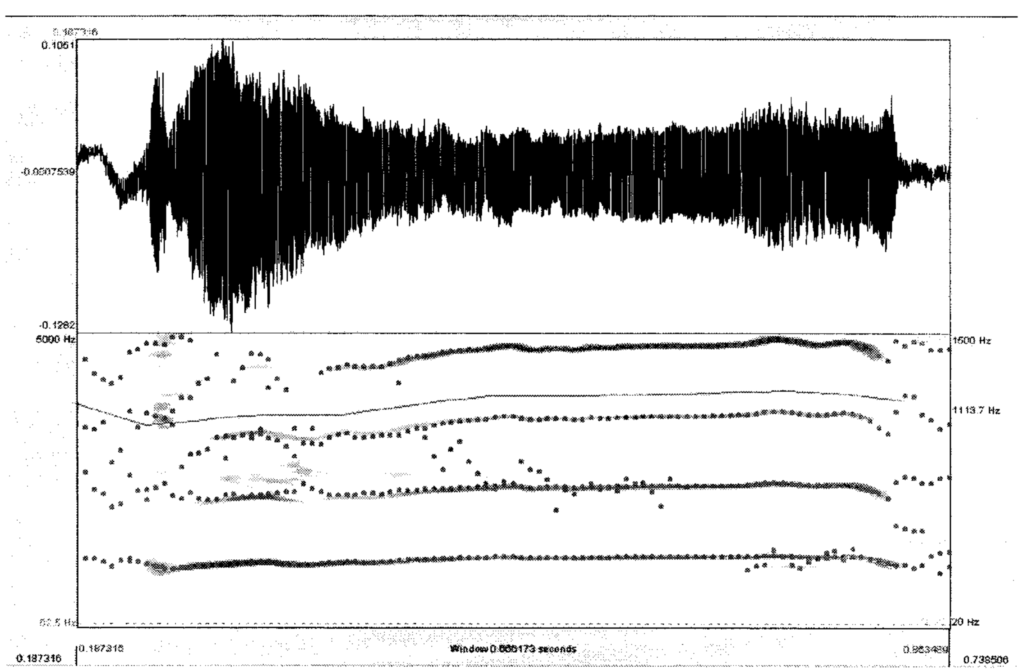

Fig. 3. Spectrogram of laryngeal stridor (type I) caused by experimentally produced laryngeal paralysis.

sage of the dog, while type II stridor may indicate rather milder obstruction. In this study, spectrogram analysis indicated that the parameters of these sounds showed an easily recognizable pattern, suggesting that it would be possible to determine whether these sounds were caused by tracheal collapse or laryngeal paralysis in dogs.

In this study, we could get the objective records of honking sound and laryngeal stridor using sound spectrogram analysis. The technique used to recorded upper airway sounds in the present study was easy, inexpensive, and non-

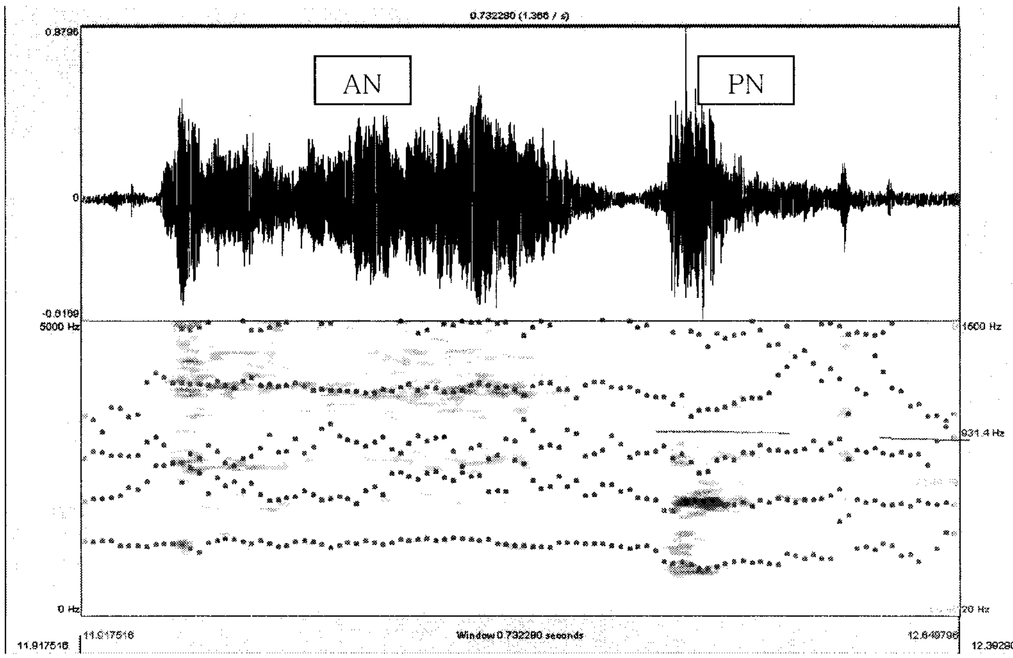

Fig. 4. Spectrogram of laryngeal stridor (type II) caused by experimentally produced laryngeal paralysis.

Table 1. Results of spectrogram analysis of upper airway sounds recorded from dogs with tracheal collapse or laryngeal paralysis

Parameter / Sound type	Pitch (Hz)	F1 formant (Hz)	F2 formant (Hz)	F3 formant (Hz)	F4 formant (Hz)	Duration (sec)	Sound intensity (dB)
Normal bark	816 ± 148 a)	946 ± 85 a,b)	1758 ± 189 a)	2485 ± 281 a)	3384 ± 401 a)	0.25 ± 0.01 a)	76 ± 4 a)
Honking sound with tracheal collapse	145 ± 72 b)	881 ± 160 a)	1636 ± 313 a)	2672 ± 336 a)	3817 ± 331 b)	0.41 ± 0.14 a)	64 ± 6 b)
Stridor with laryngeal paralysis type 1	1087 ± 77 c)	1098 ± 60 b)	2149 ± 156 b)	3042 ± 333 b)	4083 ± 403 b,c)	0.98 ± 0.36 b)	59 ± 10 b,c)
Stridor with laryngeal paralysis type 2	1001 ± 42 c)	1072 ± 202 b)	2012 ± 160 b)	2939 ± 234 a,b)	3809 ± 412 b,d)	0.72 ± 0.33 c)	61 ± 3 b,d)

Data are given as mean ± SD.
Values within variety columns with different superscript letters are significantly different among the sounds.
a-d): $p<0.05$.

invasive method. Therefore, this technique should be a potential diagnostic modality for the differential diagnosis of upper airway diseases.

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