NOTE *Internal Medicine*

Sonographic Detection of Small Amounts of Free Peritoneal Gas in Beagle Dogs

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ABSTRACT. The detection of small amounts of free peritoneal gas in the canine patient can pose a diagnostic dilemma. The objective of this study was to determine how much of this free gas could be detected ultrasonographically. Ultrasound examinations were carried out after increments (0.1 m*l*) of air were intraperitoneally injected. Via ultrasonography, 0.4 m*l* of free gas can be reliably detected. The authors concluded that ultrasonography is a very sensitive modality for the detection of small amounts of peritoneal free gas (above 0.4 m*l*).
KEY WORDS: canine, free gas, ultrasound.

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Pneumoperitoneum is a condition in which free gas or air is trapped within the abdominal cavity but not contained in a hollow viscus [16]. Spontaneous pneumoperitoneum can be associated with abdominal wall trauma, gastrointestinal rupture, an extension of pneumothorax, splenic necrosis, bacterial peritonitis, or be idiopathic [6, 16]. Especially, the most common cause of pneumoperitoneum in animals is abdominal surgery [15, 16]. Previous study has reported the duration of iatrogenically introduced pneumopetoneum in animals is approximately 22 days [11].

For many years, abdominal radiography has been established as the definitive method for the diagnosis of pneumoperitoneum in humans and animals [7, 12, 16]. In human medicine, as little as 1–2 m*l* of free intra-peritoneal air can potentially be detected, under ideal circumstances, with upright chest radiographs and left lateral decubitus via abdominal radiography [7].

Computed tomography has been previously reported to be the most sensitive imaging test for the detection of free intra-peritoneal air [18]. However, differentiation of intra-peritoneal air from fat or intra-luminal air may be difficult if the window widths and levels are not appropriately altered [3]. Additionally, the use of CT scanning for the detection of pneumoperitoneum in animals has generally been restricted by limited availability and the need for general anesthesia [2].

Ultrasonography has been broadly employed for the detection of pneumoperitoneum (intra-peritoneal air) in clinical practice [10]. Intra-peritoneal air is recognized by the sonographic appearance of linear enhancement and thickening of the peritoneal stripe sign (EPSS) associated with either dirty shadowing or multiple reflection artifacts at the air-soft tissue interface [9, 13]. This sonographic appearance is observed between the nondependent abdominal wall and intra-abdominal structure such as the liver, stomach, omentum, or intestine. Free gas tends to shift in position with bowel or patient movement [2, 6].

Although several human medical reports have documented the detection of free intraperitoneal air in patients suffering from acute abdominal disorders, the relative sensitivity and specificity of ultrasonography remains to be clearly identified [5, 14].

The principal objective of this study was to determine the smallest amount of free gas that could be detected by ultrasonography and to evaluate the sensitivity of ultrasonography for the detection of free gas in dogs.

Ten clinically healthy adult Beagle dogs (3 male and 7 female) weighing from 6.6 to 10.8 kg (aged between 2–3 years old) were anesthetized with propofol and intubated. Animal care and experiments were carried out adhering to a guide for the care and use of laboratory animals from Gyeongsang National University, Korea. Using sonographic guidance, we inserted a 20-gauge angiocatheter into the peritoneal cavity along the midline at the level of the umbilical region for proper air injection. The air was injected in increments of 0.1 m*l*. Prior to the ultrasonic examinations, abdominal massage was applied for 5 min to properly distribute the gas in standing position. Ultrasonic examination was then carried out, following each increment and 5 min of abdominal massage, to determine whether free air could be detected. A total volume of 0.5 m*l* of air was injected. Images were obtained repeatedly after the injection of each of the five air amounts.

The ultrasound machine (Xario® SSA-660A, TOSHIBA, Otawara, Japan) was used with a 12.0 MHz linear transducer. The abdomen was prepared by clipping the hair over the entire ventral aspect of the abdomen. Coupling gel was applied to the skin. The animals were scanned in dorsal recumbency. The abdomen was divided

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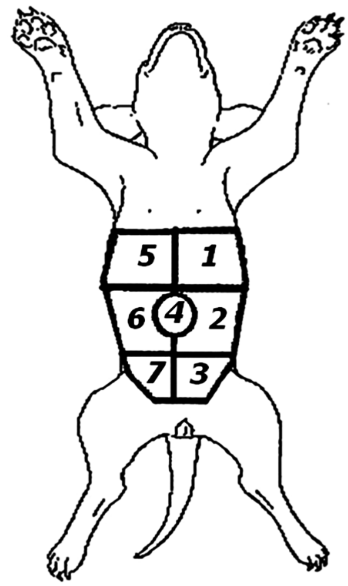

Fig. 1. A diagram of the seven regions using abdominal surface anatomy. 1.LSR; 2.LMA; 3.LIF; 4.UM; 5.RSR; 6.RMA; 7.RIF.

into seven regions using surface anatomy [right subcostal region (RSR), right middle abdomen (RMA), right iliac fossa (RIF), umbilical region (UM), left subcostal region (LSR), left middle abdomen (LMA), and left iliac fossa (LIF)] (Fig 1). Peritoneal free gas was identified as an enhancement of the peritoneal stripe sign (EPSS) during the ultrasound examinations. A systematic search for the EPSS was carried out in all regions. Zoomed images were applied in most cases with appropriate adjustment of the gain, focal point, and other settings.

The results of the ultrasonic examination were classified as either positive or negative (Fig 2). All findings were carried out by the same operator. Statistical analyses were conducted using SPSS version 14.0 software (SPSS Inc., Chicago, IL, U.S.A.).

On examinations, free air was most consistently visualized in the umbilical and the left and right middle abdomen, particularly between the ventral surface of the spleen and the adjacent peritoneal line. On the other hand, air in the right iliac fossa and left iliac fossa regions, pneumoperitoneum was not observed on examination (Table 1). During graded intraperitoneal air injection, the smallest quantity of air that could be detected in the four beagle dogs was 0.1 m*l* (Table 2). As air was added in increments, the accuracy increased from 40% (true positive predictive value) at 0.1 m*l* to 60% at 0.2 m*l* to 70% at 0.3 m*l* and to 100% at 0.4 m*l* and above. At above 0.4 m*l*, the operator has a higher level of accuracy in determining the presence of EPSS (true positive predictive value of 100%) (Table 3).

We evaluated that the smallest amount of free gas could be detected by ultrasonography in experimentally induced pneumoperitoneum. Ultrasound examinations were carried out after increments (0.1 m*l*) of air were intraperitoneally injected. Via ultrasonography, 0.4 m*l* of free gas can be reliablely detected.

The 'Enhancement of the Peritoneal Stripe Sign' (EPSS) has been previously described as a specific ultrasonographic sign of pneumoperitoneum in artificially created pneumoperitoneum in an animal model [13]. EPSS occurred because the acoustic impedance mismatch between the peritoneum and the underlying free air was much greater than the impedance mismatch between the peritoneum and the adjacent peritoneal fluid or bowel, thus generating a brighter echo [1, 19]. With relatively smaller quantities of air, the thickening of the peritoneal stripe without a posterior artifact was indicated, whereas large volumes of air produced enhancement and thickening of the peritoneal stripe associated with either dirty shadowing or multiple reflection artifacts [13].

However, some pitfalls must be avoided during ultrasonographic examination for pneumoperitoneum, including overlying rib reflection, ring-down artifacts from adjacent air-filled lung, and interposition of the colonic gas anterior to the liver [1, 4, 5], thereby resulting in a false-positive di-

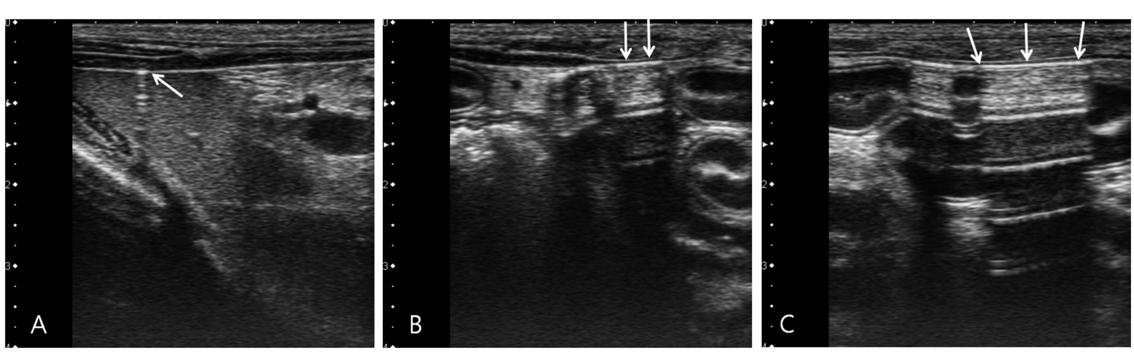

Fig. 2. Ultrasonographic images in sagittal orientation in the left lumbar (A) and umbilical region (B, C) show extraluminal air inducing linear enhancement and thickening of the peritoneal stripe sign (EPSS) associated with either dirty shadowing or reverberation artifacts (arrows). As injected air was added in increments (A: 0.1 m*l*, B: 0.2 m*l*, C: 0.4 m*l*), EPSS size was relatively increased. These results indicate that an increase in the EPSS size reflects an increase in the total extraluminal air within the abdominal cavity.

Table 1. Frequency of EPSS according to abdominal area

	Control	0.1 m*l*	0.2 m*l*	0.3 m*l*	0.4 m*l*	0.5 m*l*
LSR	0	1				3
LMA	0	2	1	2	3	3
LIF	0					
RSR	0	2				3
RMA	0		1	2	6	4
RIF	0					
UM	0		5	7	7	4

LSR, left subcostal region; LMA, left middle abdomen; LIF, left iliac fossa; UM, umbilical region; RSR, right subcostal region; RMA, right middle abdomen; RIF, right iliac fossa.

Table 2. Smallest amount of free air detected using ultrasound

Dog	Volume of free gas detected	Detected area
1	0.4 m*l*	RMA
2	0.2 m*l*	UM
3	0.2 m*l*	UM
4	0.1 m*l*	LMA
5	0.2 m*l*	UM
6	0.2 m*l*	UM
7	0.1 m*l*	LMA
8	0.4 m*l*	LMA
9	0.1 m*l*	RSR
10	0.1 m*l*	LSR & RSR

LSR, left subcostal region; LMA, left middle abdomen; LIF, left iliac fossa; UM, umbilical region; RSR, right subcostal region; RMA, right middle abdomen; RIF, right iliac fossa.

Table 3. Accuracy of ultrasound at detecting abdominal free gas in 0.1 m*l* increments

Gas dose	True positive	True negative	False positive	False negative
0		10/10 (100%)	0/10 (0%)	
0.1	4/10 (40%)			6/10 (60%)
0.2	6/10 (60%)			4/10 (40%)
0.3	7/10 (70%)			3/10 (30%)
0.4	10/10 (100%)			0/10 (0%)
0.5	10/10 (100%)			0/10 (0%)

agnosis. Therefore, in this study, we attempted to differentiate the EPSS from potential artifacts via following ultrasonographic technique. In case of overlying rib reflection, it could be differentiated from a true pneumoperitoneum due to its origin above the peritoneal line and its movement with respiration being asynchrous with the other intra-abdominal structures [4]. As for the ring-down artifacts from adjacent air-filled lung, the pulmonary and pneumoperitoneal reverberation artifacts overlap during inspiration. On the other hand, it seems to be separated at expiration [1, 4, 13]. In terms of interposition of the colonic gas, confusion of peritoneal gas from colonic gas can be prevented by observing of lack of colonic mobility with any changes in the patient's position and the presence of peristalsis on prolonged [4, 13].

EPSS was first demonstrated in the porcine peritoneal cavity after injecting 300 m*l* of degassed water [13]. The presence of fluid-filled structures, free fluid, or fluid collections aids greatly in the diagnosis of pneumoperitoneum, as it provides an anechoic background against which the EPSS can be readily identified [1]. Most cases in which EPSS was identified via ultrasonographic examination tend to produce varying amounts of free fluid in the peritoneal cavity due to a leakage of the intestinal contents or a fluid induced by inflammatory peritoneal fluid [1]. However, due to unintentional injection of gas during degassed water administration, we conducted our experiments without injections of degassed water.

Some authors have concluded that pneumoperitoneum could be diagnosed on ultrasonography by the detection of air between the anterior abdominal wall and the liver in the right upper quadrant [1, 13, 14]. However, our results indicate that the identification of pneumoperitoneum on ultrasonography is not limited to the right upper quadrant. Although we agree that free air can be identified anterior to the surface of the liver, our results also demonstrate that pneumoperitoneum is commonly observed along the midline of the umbilical region and middle abdomen. These results may be yielded as a cause of animal's walking position, shape, and changes in non-dependent side that heavily depend on changes in animal's positions during conducting ultrasonography. Also, we believe this tendency may be affected by the site of injection.

The volume of free air detected in our study was substantially smaller than in previously reported human cases. Chadha *et al.* investigated the ultrasonographic detection of pneumoperitoneum in volunteers subjected to graded infusions of intraperitoneal air. The minimal volume of free air that could be consistently detected via sonography was 5 m*l* [4]. Additionally, according to several investigations, as little as 1 m*l* of free intraperitoneal air can be consistently detected via ultrasonography [8, 17]. Our study results demonstrated that with correct ultrasonographic technique, as little as 0.4 m*l* of free air can be detected consistently. The present study, however, did have some limitations. As our study involved injections of air into the abdomen, gas distribution and volume might differ from that of naturally-occuring pneumoperitoneum. Therefore, additional case studies in ultrasonographic examinations of acute abdomen, and particularly intestinal perforated patients, will be necessary to evaluate the clinical utility of the ultrasonic detection of free gas.

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