

가

:

1

. 2 . 2 . 2 . 2 . 3

: 가

: 가

1 10 -5 -10 , 2 10 , 15  
 , 20 가 .

가

: 1 28.1 ± 3.9 mm, 16 ± 1.6 mm .  
 2 20 28.7 ± 6.3 mm, 14.4 ± 3.8 mm  
 . 1  
 가 , 2  
 20 1 .  
 : 20 .

- 가 가 (1). 가 - .
- (cormobidity), , , (6, 11 - 16).  
 (2). 가
- (3). , -40 C°  
 (photodynamic therapy), , -50 C°  
 (brachytherapy), (electrocoagulation), (17).  
 (4 - 6) (percutaneous) 가
- (6 - 13).

mg/mL Ketamine hydrochloride, YUHAN, Seoul, Korea) 0.6 mL/kg (Rompun; Xylazine hydrochloride, Bayer Korea, Ansan, Korea) 0.15 mL/kg

가  
가  
(Somatom Sensation 16; Siemens, Erlangen, Germany)  
(axial image)

: (argon:helium)  
(SeedNet™, Galil Medical, Israel) 17 (1.47 mm)  
(cryoneedle)(IceRod™, Galil Medical, Israel)  
Joule - Thompson  
가 가 , 가 가  
.8 가  
(Thermocouple)

5 - 10 1(n=5) 10  
20 , 2  
2(n=3)  
10 (n=1), 15 (n=1), 20 (n=1) 1  
가 1

가 (PACS;  
Picture Archiving and Communication System, m - view™;  
Marotech, Korea)

72 가  
가  
10%  
Hematoxylin - Eosin  
가

: 가

가 .

10 -70 C° 5 40 C°  
가 가 10 -62 C°  
(Fig. 1A). 2 10 -70  
C° (Fig. 2A).  
: (n=8) (n=8) (Fig. 1B,  
2B). 1(n=5) 28.1 ± 3.9  
mm , 16 ± 1.6 mm  
(n=2) 2(n=3)  
가 가 가  
(Table 1).  
, 가 가 (n=1) 20  
: 가  
1(n=5) 30.8 ± 0.8 mm ,  
16.1 ± 0.5 mm 2(n=3)  
10 28.0 ± 0.3 mm, 12.0 ± 0

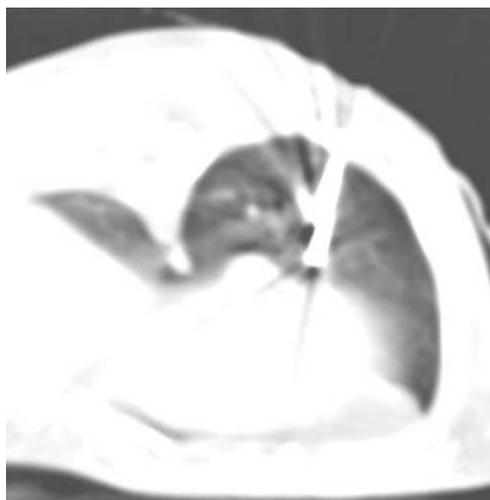


Fig. 1. Cryoneedle was placed through the chest wall and tip of cryoneedle was in the lower lobe of the right lung.

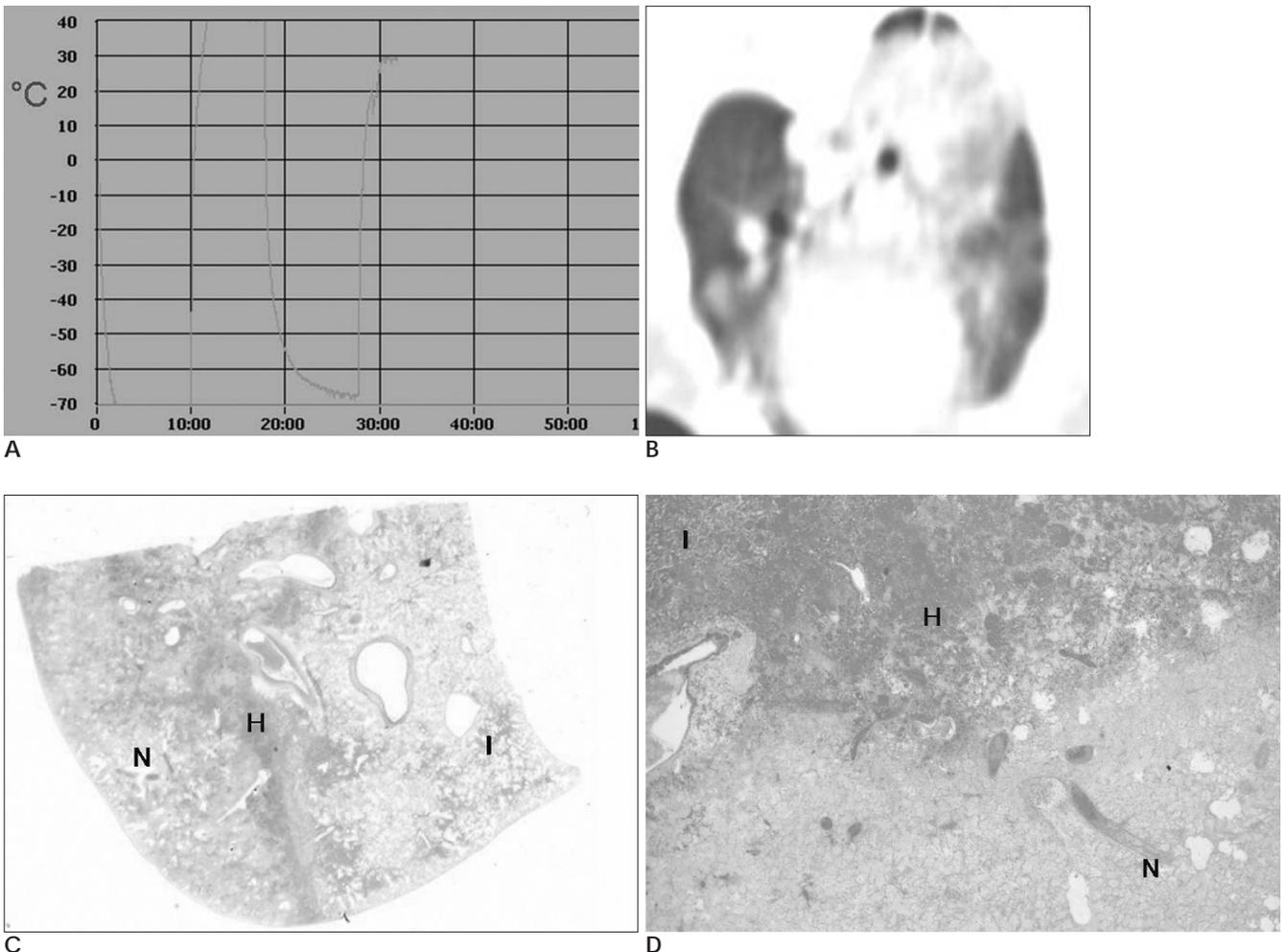
Table 1. The Effects of Cryoablation on Normal Lung in Rabbits

	Group 1 (n=5)	Group 2 <sup>†</sup> (n=3)		
		10 minutes	15 minutes	20 minutes
Dl <sup>‡</sup> [mm]	28.1 ± 3.9	27 ± 3.2	27.4 ± 7.2	28.7 ± 6.3
Ds [mm]	16 ± 1.6	10.9 ± 3.5	12.7 ± 3.1	14.4 ± 3.8
Complication	pneumothorax (n=2)	-	-	pneumothorax

Group 1 : Cryoablation was composed of two freezing-thawing cycles (freezing - thawing - freezing; 10 minutes - 5 minutes - 10 minutes).<sup>†</sup> Group 2 : Cryoablation was composed of 1 freezing - thawing cycle with varying total freezing time. <sup>‡</sup>Dl : Longest Diameter. Ds : Shortest Diameter

mm , 15 29.0 ± 0.1 mm, 12.5 2 10 15  
 ± 0.1 mm , 20 29.0 ± 0 mm, 가  
 15.5 ± 0.2 mm . (n=2) (Fig. 2C). 20  
 1 가 , , 가  
 10 , 15  
 (Fig. 2D).

가  
 (Fig. 1C, D). ( - - ) 가



**Fig. 2.** Group 1. **A.** Change of the temperature during percutaneous cryoablation. Within 10 minutes of first freezing, the temperature dropped below -70 . During second freezing (10 minutes), following thawing (5 minutes), it dropped to -67 .  
**B.** Consolidation on center was surrounded by ground glass opacity on non-contrast CT.  
**C.** Photomicrograph (original magnification, X1; H & E stain). Necrotic (N), hemorrhagic (H), and inflammatory (I) area were well differentiated.  
**D.** Photomicrograph (original magnification, ×400; H & E stain). Necrotic (N), hemorrhagic (H), and inflammatory (I) area were well differentiated.

가 : 가

Hewitt (18) (42 C) 가 가

가 (ice ball) 10 (thermal conductivity) 가

(17). 가 (thermal diffusivity) 가

10 가 -70 C° (n=8)

가 (20, 21).

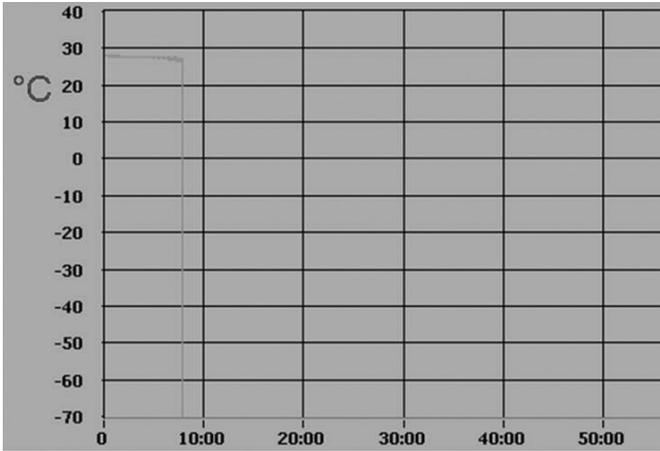
Izumi (19) 15 (n=6)

15 -5 -15 (n=6)

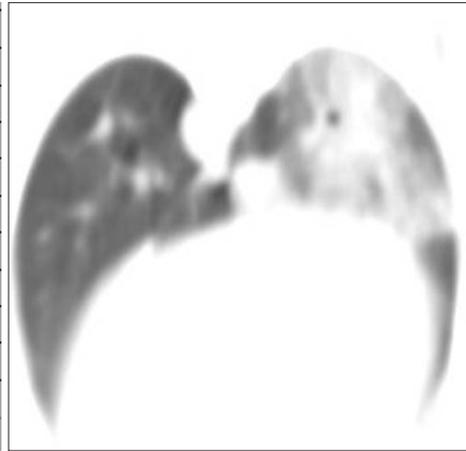
(17). Wang (11) 20 -10 -20

3 가 98.7% , Kawamura

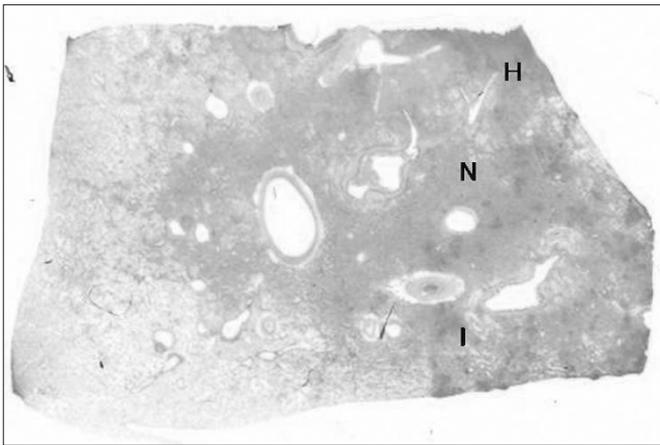
(12) 5 - -5 - -10



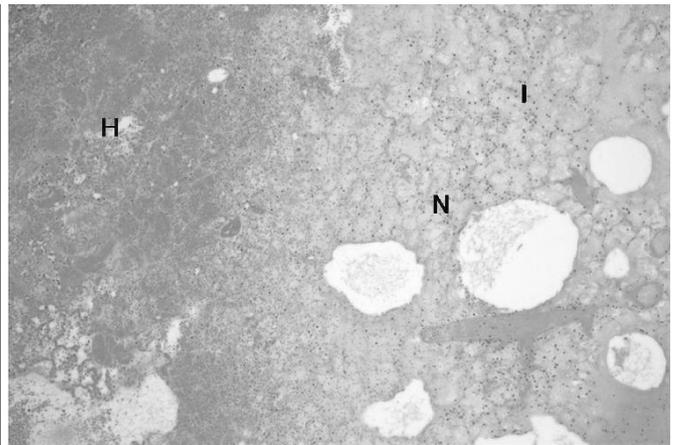
A



B



C



D

**Fig. 3. Group 2. A.** Change of the temperature during percutaneous cryoablation. Within 10 minutes, the temperature dropped below -70  
**B.** Consolidation on center was surrounded by ground glass opacity on non - contrast CT.  
**C.** Photomicrograph (original magnification, X1; H-E stain). Infiltration of inflammatory cell was seen within necrotic area. Positive differentiation between inflammatory and necrotic area was impossible.  
**D.** Photomicrograph (original magnification, ×400; H-E stain). Infiltration of inflammatory cell was seen within necrotic area.



17. Gage AA, Baust J. Mechanism of tissue injury in cryosurgery. *Cryobiology* 1998;37:171-186
18. Hewitt PM, Zhao J, Akhter J, Morris DL. A comparative laboratory study of liquid nitrogen and argon gas cryosurgery system. *Cryobiology* 1995;32:299-305
19. Izumi Y, Oyama T, Ikeda E, Kawamura M, Kobayashi K. The Acute Effects of Transthoracic Cryoablation on Normal Lung Evaluated in a Porcine Model. *Ann Thorac Surg* 2005;79:318-322
20. Poppendiek HF, Randall FR, Breeden JA, Chambers JE, Murphy JR. Thermal conductivity measurements and predictions for biological fluids and tissues. *Cryobiology* 1966;4:318-327
21. Lee CY, Bastacky J. Comparative mathematical analyses of freezing in lung and solid tissue. *Cryobiology* 1995;32:299-305
22. Jin GY, Park SH, Han YM, Chung GH, Kwak HS, Jeon SB, et al. Radio Frequency Ablation in the Rabbit Lung Using Wet Electrodes: comparison of monopolar and dual bipolar electrode mode. *Korean J Radiol* 2006;7:97-105
23. 가 , , , , , . VX2  
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가. 2004;50:343-351

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## Percutaneous Cryoablation for the Normal Lung evaluated in Rabbits: A Radiologic-Pathologic Correlation<sup>1</sup>

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**Purpose:** To assess the CT and histological findings after cryoablation in the normal lung of rabbits.

**Materials and Methods:** After performing chest CT on rabbits, we inserted a cryoneedle toward the lower lobe of the right lung. We performed percutaneous cryoablation that was composed of freeze-thaw-freeze cycles (25 minutes) for group 1 animals and one cycle of variable freezing time (10 - 20 minutes) for group 2 animals. We measured the longest (Dl) and shortest diameter (Ds) of the ablated zones that were determined after cryoablation for all of the CT images. After cryoablation, we performed a pathological examination.

**Results:** The mean Dl and Ds of the ablated zone was  $28.1 \pm 3.9$  mm and  $16 \pm 1.6$  mm, respectively, for group 1 rabbits. For group 2 rabbits, the mean Dl and Ds was  $28.7 \pm 6.3$  mm and  $14.4 \pm 3.8$  mm, respectively, for one cycle of 20 minutes freezing time. Based on the histological findings, the ablated zone was composed of a necrotic, hemorrhagic, and inflammatory area, in order from the center to the outside. Although each area was well differentiated in group 1 rabbits, only freezing for one cycle of 20 minutes for the group 2 rabbits gave the same results as for the group 1 rabbits.

**Conclusion:** A total freezing time of at least 20 minutes and two more freeze-thaw-freeze cycles might be important factors for providing a sufficient area of the ablated zone and uniform necrosis during cryoablation.

**Index words :** Catheter ablation  
Cryotherapy  
Rabbits  
Lung neoplasms

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