



Triolein Oleic Acid CT

16 8 Triolein 0.2 mL (I), 8 Oleic Acid  
 0.2 mL (II) 30, 24, 48, 72 CT  
 : I 24 CT 2-3 mm 가  
 100% (n=8/8)가 가  
 75% (n=6/8) 4 CT 100% (n=7/7)  
 가 48 CT 100% (n=6/6) 가  
 . 72 CT 가  
 : Triolein Oleic Acid CT 가  
 , Triolein Oleic acid 가  
 . CT

(1-3). 24 72 24 72 (lipase)  
 (latent time) 가  
 (petechia) 3가 가  
 (triad)가 , Triolein (8, 9). 가 Oleic Acid 가  
 가 (4-7). 가 (10). 가  
 48 가 Triolein Triolein 가  
 CT Oleic Acid CT  
 Triolein Oleic Acid  
 CT

1  
2  
3

: Triolein Oleic Acid CT

( ), ( , , , , , )  
, , )  
, (liver)

1.8 kg 2.2 kg

( 2.0 kg) 16

CT

. Triolein Oleic Acid 99.9%  
. 1 8 , 0.2 mL Triolein (1,2,3 - tri(cis - 9 - octadecanoyl)glycerol, Sigma, St. Louis, MO, U.S.A., Triolein 1 mL = 0.8988g, Triolein)  
30 . 2 8 , Oleic Acid (cis - 9 - octadecanoic acid, Sigma, St. Louis, MO, U.S.A., Oleic Acid 1 cc=0.891 g, Oleic Acid) 0.2 mL

100% 16 32

가

5 (0%, 10% , 11 - 30%, 31 - 50%, 50 % ).

Triolein Oleic Acid 30 , 24 , 48 , 72 CT

(ketamine hydrochloride; , , , ketamine 1 mL=50 mg)  
(xylazine hydrochloride; Bayer Korea, , , xylocaine 1 mL= 23.32 mg) 0.3 mL/Kg

CT (succinyl choline; , , ) 50 mg 0.5 mL

가

10%

(ceftazidime sodium, , , ) 20 mg/Kg 2 12

CT 2 (axial scan)

CT

Triolein Oleic Acid 30 , 4 , 24 , 48 , 72 CT (prone position)  
. Hispeed i/Pro (GE, milwaukee, U.S.A.) 140 KVP, 170 mA, 3 mm, (pitch) 1.2/1, (field of view) 10 cm x 10 cm 0.8

Hematoxylin - Eosin  
(coagulation necrosis), (intra-vascular thrombosis), (hyaline membra - ine), (PMN infiltration), (fibro - blast) (mild, moderate, severe)

(window width) 1100 HU, (window level) -350 HU

40 가 100 가

CT

CT

CT

, 30% , 30 - 70% , 70% CT

(pattern), , 가 (extent)

가 3-4 mm (Fig. 1).  
 10-30% . 72 CT (n=5/5)  
 CT (Table 1) 30 (n=8/8) 4 2 CT (Table 2) 30 CT 25%  
 (n=7/7) CT 24 CT 86% (n=2/8)  
 (n=6/7) 14% (n=1/7) 가 (Fig. 2), 75% (n=6/8)  
 2-3 mm 가 . 25% (n=2/8)  
 10% . 48 CT 83.3% (n=5/6) 가 10-30%/10%  
 24 CT 75% (n=6/8) , 가 (n=8/8)

**Table 1.** CT Findings in Rabbit Lungs Embolized by Intravenous Injection of 0.2 mL Triolein (group I)

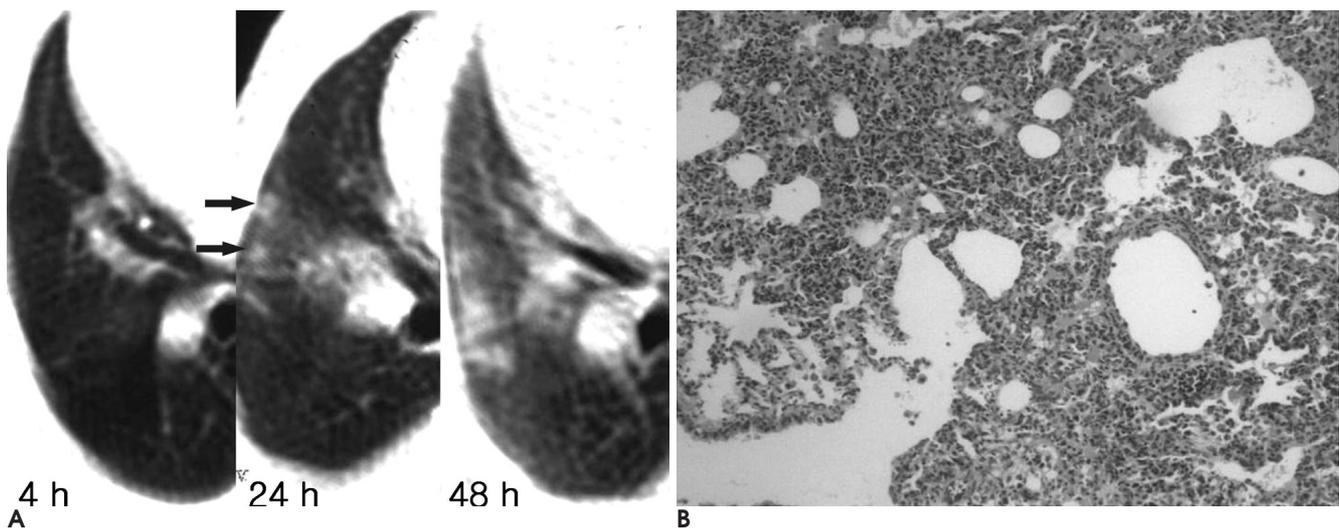
Hours	0.5	4	24	48	72	
CT findings	N	8	8	7	6	5
Ground glass opacities		0 (0)	0 (0)	1 (14)	1 (17)	0 (0)
Consolidation		0 (0)	0 (0)	0 (0)	1 (17)	0 (0)
Nodule		0 (0)	0 (0)	1 (14)	1 (17)	0 (0)

Note. Hours: Time duration between triolein injection and CT scan.  
 N: number of rabbit  
 ( ): percentage

**Table 2.** CT Findings in Rabbit Lungs Embolized by Intravenous Injection of 0.2 mL Oleic Acid (group II)

Hours	0.5	4	24	48	72	
CT findings	N	8	8	7	6	5
Ground glass opacities		8 (100)	8 (100)	7 (100)	0 (0)	0 (0)
Consolidation		6 (75)	8 (100)	7 (100)	6 (100)	5 (100)

Note. Hours: Time duration between oleic acid injection and CT scan.  
 N: number of rabbit  
 ( ): percentage



**Fig. 1.** The CT scans and pathology of the rabbit embolized by an intravenous injection of 0.2 mL Triolein (Group I).  
**A.** Peripheral predominant ground glass opacities and small nodules (arrows) are observed on the 24 hour CT scan and these findings are aggravated at 48 hours.  
**B.** The pathologic findings noted at 48 hours are mainly intraalveolar edema (H & E, × 100).

Triolein Oleic Acid CT

. 75% (n=8/8) , 가

25% (n=2/8) , , 24 가

2 (12.5%) 10% , 6 가

10 (62.5%) 10-30%, 2 4 (25%) .

30-50% . 4 CT 30 CT

2 (n=7/7) 1 2 (Table 3)

4 8 1 4 3

(56%) 가 , 3 6 (44%)

10-30% 가 30-50% . 24 CT

(n=7/7) 가

. 4 8 (56%) 가 4

30-50% 10-30% (Fig. 3) 3

6 (44%) 가 . 48 CT

(n=6/6)

24 가 . 72 CT 6 12 (n=5/5)

가

CT

30 , 24 , 72 1 3 CT

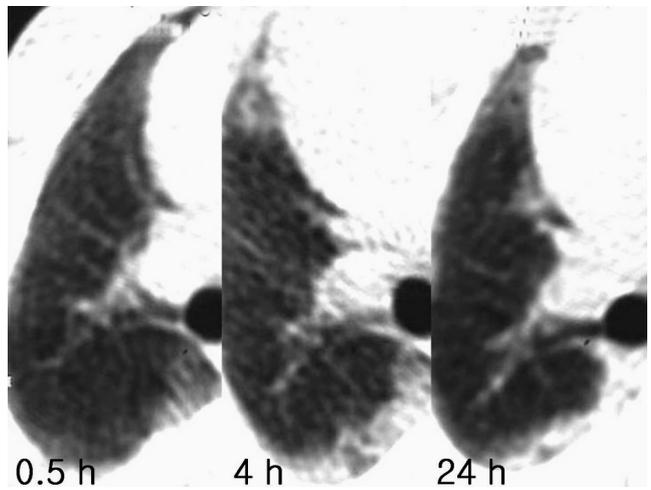
. 48 CT

2 30 CT

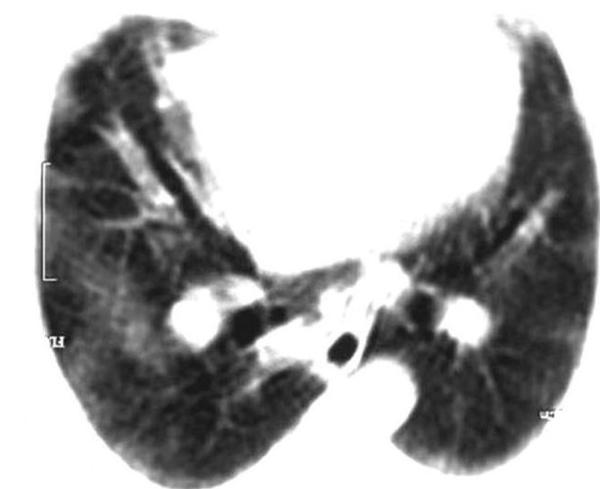
. 24

가 . 48

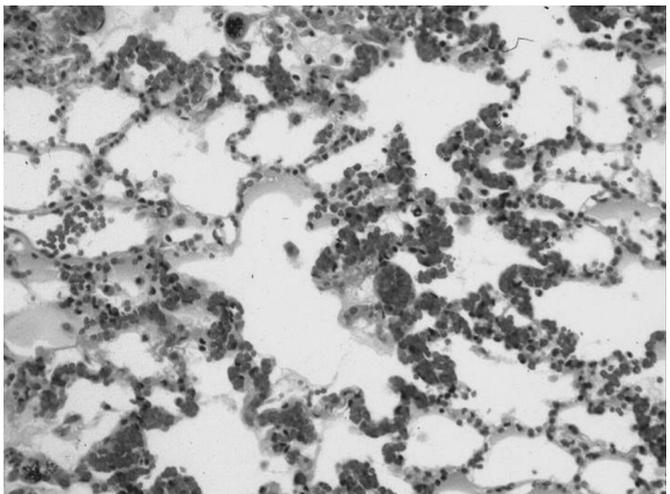
72 CT



**Fig. 3.** The CT findings of a group II rabbit: At 0.5 hours after 0.2 mL oleic acid injection, the CT scan shows peripheral ill-defined opacities in the right lung. At 4 hours, the CT scans show ground glass opacities and consolidations with an increased extent. At 24 hours, the extent of the consolidation is decreased and the margin of the consolidation is sharper.



**A**  
**Fig. 2.** CT scan and pathology of the rabbit taken at 0.5 hours after 0.2 mL oleic acid injection (group II).  
**A.** The CT scan shows ill-defined multiple peripheral wedge shaped ground glass opacities with a mild right lung predominance.  
**B.** The pathology shows interstitial edema and congestion with minimal intraalveolar edema (H and E, × 200).



**Table 3.** Pathologic Findings in Rabbit Lungs Embolized by Intravenous Injection of 0.2 mL Triolein (group I) and 0.2 mL Oleic Acid (group II)

Pathologic findings	Groups		Group I				Group II			
	Hours		0.5	24	48	72	0.5	24	48	72
Interstitial congestion			1	1	1	1	3	-	-	-
Interstitial edema			-	-	1	-	2	-	-	-
Alveolar edema			-	-	2	-	1	2	3	2
Alveolar hemorrhage			-	-	-	-	-	2	2	2
Coagulation necrosis			-	-	-	-	-	2	3	3
Intraalveolar macrophage			-	-	-	-	-	1	2	3
PMN infiltration			-	-	-	-	-	2	2	2
Hyaline membrane			-	-	-	-	-	-	-	1
Fibroblast proliferation			-	-	-	-	-	-	1	3

Note. hours: Time duration between triolein or oleic acid injection and sacrifice  
 1: mild, 2: moderate, 3: severe

가 (12). 가 가  
 (biochemical theory)  
 (catecholamine) 가 1  
 (chylomicron) 10 - 40 가  
 (isolated long bone (13, 14).  
 fracture) 0.5 - 3.5% (pelvic bone 4 , 24 48  
 fracture) (multiple fracture) 5 - 10%  
 (lipase) 가  
 (soft tissue trauma), (9).  
 (intramedullary nailing)  
 (liposuction), 가 CT  
 , , , , ,  
 (1 - 3). 가 60% 가  
 . Triolein 가 Oleic Acid  
 CT 가  
 . Triolein Oleic Acid  
 가 Nakata Y Triolein 0.125, 0.25,  
 가 0.5 mL/kg (15), Baker Triolein (1  
 mL/kg) Oleic Acid (0.07 mL/kg)  
 (lung compliance),  
 (arterial oxygen saturation),  
 (8). Baker Oleic Acid  
 가 Triolein  
 (10). Alastair  
 (intramedullary nailing) Triolein 1 30 CT 4 CT  
 (transesophageal echocardiogram) 가 24 CT  
 (nailing) Oleic Acid  
 가 (mechanical theory) CT  
 (11). 가 ( $p < 0.01$ , Chi - Square  
 , 10 - 30% ),  
 (fat embolism)  
 1% 가 (biochemical theory) 가 .

: Triolein Oleic Acid CT  
 Triolein CT 24 CT 가  
 Acid Triolein 100% Oleic CT ' '  
 Triolein 0.3 mL Christian  
 8 Oleic Acid (19).  
 Triolein 가 가 Oleic Acid 8  
 (fat embolism) Acid 가 Oleic  
 (pulmonary fat embolism syndrome) 8  
 , Maruyama (20)  
 Oleic Acid 가 Arakawa 가 (21).  
 Triolein  
 가가 Oleic Acid 25%  
 Oleic Acid (decubitus)  
 가  
 (anterior neck), (anterior chest), Arakawa 6  
 5 CT 10 mm  
 (21). Katerina 9 CT 7  
 가 50% 가 (centrilobular nodule) 2 CT (22).  
 Hyeneman 가 CT  
 Swan ganz 가 (16, 17). (23).  
 (bronchoalveolar lavage, BAL) Oleic Acid  
 (BAL fluid) 가 30%  
 2% (18).  
 (24)  
 Swan ganz catheter 12 CT 12  
 가 89%  
 CT 가 CT 100% 가 (25).  
 Triolein 1 (1/8, 12.5%)  
 Oleic Acid (100%)  
 가 Oleic Acid CT 가  
 Oleic Acid 0.2 mL 30 CT , CT

Oleic Acid CT  
 CT  
 CT Triolein Oleic Acid 가  
 CT 가  
 , , , Triolein Oleic Acid  
 . CT

- Nichols GR 2nd, Corey TS, Davis GJ. Nonfracture-associated fatal fat embolism in a case of child abuse. *J Forensic Sci* 1990;35:493-499
- Todd N. Fatal fat embolism during ritual initiation. *Can Med Assoc J* 1975;113:133-137
- Broder G, Ruzumma L. Systemic fat embolism following acute primary osteomyelitis. *JAMA* 1967;199:150-152
- Peltier LF. Fat embolism: a perspective. *Clin Orthop* 1988; 232:263-270
- Gossling HR, Pellegrini VD. Fat embolism syndrome: a review of the pathophysiology and physiological basis of treatment. *Clin Orthop Relat Res* 1982;165:68-82
- Lepisto P, Alho A. Diagnostic features of fat embolism syndrome. *Acta Chir Scand* 1975; 141:245-250
- Evarts CM. The fat embolism syndrome: a review. *Surg Clin North Am* 1970;50:493-507
- Dines DE, Burgher LW, Okazaki H. The clinical and pathologic correlation of fat embolism syndrome. *Mayo Clin Proc* 1975;50: 407-411
- Morton KS, Kendall MJ. Fat embolism: its production and source of fat. *Can J Surg* 1965;31:214-220
- Baker PL, Kuenzig MC, Peltier LF. Experimental fat embolism in dogs. *J Trauma* 1969;9:577-586
- Pell AC, Hughes D, Keating J, Christie J, Busuttill A, Sutherland

GR. Brief report: fulminating fat embolism syndrome caused by paradoxical embolism through a patent foramen ovale. *N Engl J Med* 1993;329:926-929

- Lwquire VS, Snapiro JL, Lwquire CB, Cobb CA Jr, Fleet WF Jr. A study of the pathogenesis of fat embolism based on human necropsy material and animal experiments. *Am J Pathol* 1959;35:999-1015
- Baker PL, Pazell JA, Peltier LF. Free fatty acids, catecholamines, and arterial hypoxia in patients with fat embolism. *J Trauma* 1971; 11:1026-1030
- Peltier LF. Fat embolism: a current concept. *Clin Orthop* 1969;66: 241-253
- Nakata Y, Tanaka H, Kuwagata Y, Yoshioka T, Sugimoto H. Triolein-induced pulmonary embolization and increased microvascular permeability in isolated perfused rat lungs. *J Trauma* 1999 Jul;47:111-9
- Dorr LD, Merkel C, Mellman MF, Klein I. Fat emboli in bilateral total knee arthroplasty. Predictive factors for neurologic manifestations. *Clin Orthop Relat Res* 1989;248:112-118
- Byrick RJ, Kay JC, Mullen JB. Capnography is not as sensitive as pulmonary artery pressure monitoring in detecting marrow microembolism. Studies in a canine model. *Anesth Analg* 1989;68:94-100
- Chastre J, Fagon JY, Soler P, Fichelle A, Dombret MC, Hutten D et al. Bronchoalveolar lavage for rapid diagnosis of the fat embolism syndrome in trauma patients. *Ann Intern Med* 1990;113:583-588
- Derks CM, Jacobovitz-Derks D. Embolic pneumopathy induced by oleic acid. A systematic morphologic study. *Am J Pathol* 1977; 87:143-158
- Maruyama Y, Little JB. Roentgen manifestations of traumatic pulmonary fat embolism. *Radiology* 1962;79:945-952
- Arakawa H, Kurihara Y, Nakajima Y. Pulmonary fat embolism syndrome: CT findings in six patients. *J Comput Assist Tomogr* 2000;24:24-29
- Malagari K, Economopoulos N, Stoupis C, Daniil Z, Papiris S, Muller NL, et al. High-resolution CT findings in mild pulmonary fat embolism. *Chest* 2003;123:1196-1201
- Heyneman LE, Muller NL. Pulmonary nodules in early fat embolism syndrome: a case report. *J Thorac Imaging* 2000;15:71-74
- . 가 가  
 :  
 1999;41:303-311
- . CT 2001;44:153-159

## Comparison of the CT and Pathologic Findings of Pulmonary Fat Embolism Induced by Triolein and Oleic Acid in Rabbits<sup>1</sup>

Hye Won Baik, M.D., Seung Min Yoo, M.D., Hwa Yeon Lee, M.D., In Sup Song, M.D., Hyeon Yu, M.D.,  
Jong Beom Lee, M.D., Yang Soo Kim, M.D., Byung Kook Kwak, M.D., Hyung Jin Shim, M.D.,  
Kun Sang Kim, M.D., Yong Chul Lee, M.D., Tae Jin Lee, M.D.<sup>2</sup>, Dong Wook Sung, M.D.<sup>3</sup>

<sup>1</sup>Department of Radiology, Chung-Ang University Hospital, Chung-Ang University College of Medicine

<sup>2</sup>Department of Pathology, Chung-Ang University Hospital, Chung-Ang University College of Medicine

<sup>3</sup>Departement of Radiology, Kyung-Hee University Hospital, Kyung-Hee University College of Medicine

**Purpose:** The aim of this study was to evaluate the CT findings of pulmonary fat embolism syndrome that was induced by triolein and oleic acid, along with its pathologic correlation.

**Materials and Methods:** 16 rabbits were included in this study. The rabbits in group I ( $n=8$ ) were embolized with 0.2 mL triolein and the rabbits of group II ( $n=8$ ) were embolized with 0.2 mL oleic acid through ear veins. HRCT scans were done prior to embolization and at 0.5, 4, 24, 48 and 72 hours post-embolization. The pathologic correlations were determined at 0.5, 24, 48 and 72 hours.

**Results:** At 24 hours, one group I rabbit showed abnormal CT findings that were composed of several 2 - 3 mm nodules and multiple ill-defined peripheral ground glass opacities. The pathologic finding of this rabbit at 48 hours was mainly intraarveolar edema. All the group II rabbits ( $n=8/8$ ) showed ill-defined bilateral and peripheral ground glass opacities with ( $n=6/8$ ) or without consolidations ( $n=2/8$ ) on the 0.5 hour CT. All the rabbits ( $n=7/7$ ) showed that the new ground glass opacities and ground glass opacities noted on the 0.5 hour CT were changed into consolidation. The margins of the ground glass opacities and consolidations were more sharpened on the 24 hours CT. All 6 rabbits ( $n=6/6$ ) showed consolidations without ground glass opacities and the margins of the consolidations were more sharpened on the 48 hours CT. There was no significant interval change on the 72 hours CT. The pathologic findings of ground glass opacities were interstitial edema or mild intraalveolar edema. The pathologic findings of consolidation were intraalveolar edema, hemorrhage and coagulation necrosis.

**Conclusion:** The CT findings after fat embolization using triolein and oleic acid were ill-defined peripheral ground glass opacities with/without consolidations. These findings occurred in only one triolein group with the time lag, but these findings were immediately and extensively seen in all group II rabbits. These CT findings may be important for making a diagnosis of pulmonary fat embolism syndrome.

**Index words :** Embolism, fat  
Embolism, pulmonary  
Lung, CT

Address reprint requests to : Seung Min Yoo, M.D., Department of Radiology, Chung-Ang University Hospital, Chung-Ang University College of Medicine, 65-207 Hangangro 3-ga, Youngsan-gu, Seoul 140-757, Korea.  
Tel. 82-2-748-9682 Fax. 82-2-6299-1077 E-mail: smyoo68@hanmail.net