Alcohol-induced lipid change in the lung[1]

Deng F. Liau, Sami A. Hashim, Richard N. Pierson III, and Stephen F. Ryan

Pulmonary Research Group, Department of Pathology and Pulmonary Division, Department of Medicine, St. Luke's-Roosevelt Hospital Center and Columbia University College of Physicians and Surgeons, New York, NY 10025

Abstract Quantities and qualities of lipids in lung lavage and lavaged lung tissue were studied in ethanol-fed male Sprague-Dawley rats. Experimental rats received 36% of daily energy as ethanol for 7 weeks and each control rat, receiving an isocaloric amount of sucrose, was pair-fed with an experimental rat. Body weight gain and lung protein content in these two groups were similar. The mean lung dry weight of ethanol-fed rats as compared to controls was significantly elevated. The quantity of phosphatidylcholine (PC), a key surfactant lipid, recovered from lung lavage of ethanol-fed rats was double that of controls, but the proportion of palmitate in its fatty acids was reduced. The content of cholesterol and cholesteryl ester in lung lavage of ethanol-fed rats was nearly twice that of controls but the content of triglyceride was not different. The quantity and quality of PC in lung tissue were not significantly different between these two groups. Triglyceride content of lung tissue in ethanol-fed rats was nearly three times that of controls. Ethanol increased the proportion of oleic and decreased the relative amount of palmitic, palmitoleic, and linoleic acids in triglycerides of lung tissue.—**Liau, D. F., S. A. Hashim, R. N. Pierson III, and S. F. Ryan.** Alcohol-induced lipid change in the lung. *J. Lipid Res.* 1981. **22:** 680–686.

Supplementary key words pulmonary surfactant · triglyceride

The presence of well-documented abnormalities in liver, heart, and central nervous system of alcoholic patients (1–3) and the fact that ethanol metabolites accumulate in the lung (4) lead one to suspect that the lung may be directly altered by ethanol and to postulate the existence of alcoholic lung disease (5). Chronic non-tuberculous pulmonary disease such as bronchitis, emphysema, pulmonary fibrosis, bronchiectasis, chronic airway obstruction, and impairment of gas diffusion have been described in association with alcoholism (6–8) and a number of causative factors have been suggested (5, 8). These include malnutrition, aspiration, pneumonitis, and tobacco-related injury as well as direct damage by ethanol. However, the association between alcoholism and pulmonary disease appears to be based on clinical impressions and few studies of this association have been made.

The complex and multifaceted effects of ethanol upon lipid metabolism and cell function of liver have been extensively investigated and reviewed by Lieber (9, 10). Ethanol has been found to stimulate the synthesis of cholesterol and triglycerides in intestine (11–14) and in isolated heart (15, 16). However, investigations upon the effects of ethanol on lipid metabolism in the lung are limited. We have described massive accumulation of neutral lipid in the Type II cells of alcoholic patients with acute lung injury and advanced alcoholic liver disease (17). Wagner and Heinemann (18) found that prefeeding rats for 3 days with small quantities of ethanol equivalent to the daily dose of social drinkers limits in vivo and in vitro incorporation by lung tissue of precursors such as palmitic acid or cytidine diphosphocholine into phosphatidylcholine (PC), a key component of the surfactant system. The retarded precursor incorporation into PC was not a consequence of delayed intestinal absorption or a direct caloric effect of ethanol but resulted from changes in the rate of phospholipid formation. Whether the inhibition of precursor incorporation by ethanol might alter surfactant function has not been established.

Burnell et al. (19) recently found in rats fed a diet deficient in essential fatty acid for 14 weeks that the amount of PC in lung lavage remained unchanged. However, the PC fraction contained significantly less palmitic acid than that from controls. This reduction in palmitate concentration was associated with a significant decrease of disaturated PC. The decrease in percentage of palmitate in the PC fraction resulted in a significant increase in minimal surface tension of lipid extract from lung lavage and intracellular lipoprotein fraction. Air pressure-volume curves on degassed excised lungs also showed that greater pressure is required to maintain a given lung volume

Abbreviations: TLC, thin-layer chromatography; GLC, gas-liquid chromatography; PL, phospholipid; PC, phosphatidylcholine; PG, phosphatidylglycerol, DSPC, disaturated phosphatidylcholine.

[1] Parts of this study were presented at the 63rd Annual Meeting of the Federation of American Societies for Experimental Biology (Dallas, TX 1–10 April, 1979). *Federation Proc.* **38:** 1751 (Abstract).

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in the deficient rats. They concluded that the fatty acid composition of surfactant PC is a major determinant of its surface activity. The correlation between the quality of surfactant and surface tension was also supported by Colacicco, Ray, and Buckelew (20).

The purpose of the present study was to investigate the effects of ethanol on certain parameters of lipid metabolism in the lung. The lipid content of lavaged lung tissue and of lung lavage were studied in ethanol-fed rats and in their pair-fed controls. This report is the first to present evidence that chronic intake of ethanol influences the quantities and qualities of lipids in rat lung tissue and lung lavage.

METHODS

Animals

Male Sprague-Dawley rats, 6 weeks old and weighing 200 ± 5 g were used. The animals were purchased at 5 weeks of age from Charles River Breeding Laboratories (Wilmington, MA) and closely observed for signs of pulmonary infection for 1 week during which time they were fed Purina chow (Ralston Purina Co., St. Louis, MO). Then they were individually housed in cages and fed a liquid diet (#711 A-C; Bioserve Inc., Frenchtown, NJ) developed by De Carli and Lieber (21) for feeding ethanol to rats as part of a nutritionally adequate diet. Experimental rats received 36% of their daily energy as ethanol and control rats received isocaloric amounts of sucrose. Both ethanol and control diets yielded 1 Kcal per ml. The diets were delivered through calibrated glass feeding tubes (116 ml capacity) and no supplemental food or water was provided.

Forty-six rats of uniform weight were used for this study. Twenty-three rats were fed the experimental diet for 7 weeks, and 23 control rats were pair-fed to the experimental rats. Pairs were assigned so that each animal's body weight was within 5 g of his control in the beginning of the experiment. The experimental animals were offered more diet than they would consume in a 24-hour period. The amount of diet consumed by the experimental animal was fed to his paired control animal.

The animals were killed with intraperitoneally-injected sodium nembutal. The chest was opened wide, and the lung and the heart were removed en-bloc. To remove blood, each lung was perfused via the pulmonary artery with 80 ml of 0.01 M Tris-saline buffer, pH 7.4, at a pressure of 20 cm of water while inflating and deflating the lung. After perfusion, the lungs were lavaged with the same Tris buffer as used for perfusion at room temperature. Six lavages with six separate aliquots of 15 ml of buffer were performed for each lung. The lavages were then combined and filtered through a 5.0 μm millipore membrane (SM type, Millipore Co., Bedford, MA) to remove cells. The recovery was 83 ± 2 ml (92 ± 2%) in the ethanol-fed rats and the controls. The filtrate was lyophilized for subsequent lipid extraction.

The lavaged lung tissues from sets of two rats were combined, minced, and homogenized in 0.01 M Tris-saline buffer (pH 7.4) containing 0.25 M sucrose (20% w/v solution) with a Polytron homogenizer. Aliquots of the homogenates were used for the determinations of dry weight, protein content, and lipids. For dry weight determination, the aliquot was dialyzed against water in Spectra Por 3 membrane tubing (3000 mol. wt. cutoff, Spectrum Medical Industries, Inc., Los Angeles, CA) to remove salt and sucrose, and lyophilized. Initial experiments indicated that the lung dry weight determined by this method was comparable with that obtained by drying the whole lung. The amount of physiological salt in the lung was not therefore included in the dry weight.

Lipid analysis

Total lipids of lung lavage and lavaged lung tissues were extracted from aliquots of the lyophilized powders by the method of Folch, Lees and Sloane Stanley (22) with several modifications. To assure complete removal of all lipids, the volume of chloroform–methanol 2:1 (v/v) was increased ten-fold. The lavages were extracted twice and the lung tissue three times. The washed lipid extracts were concentrated to a small volume by flash evaporation and made to a volume of 5 ml with chloroform–methanol 2:1 and stored at −20°C. All subsequent lipid analyses were done from these stock solutions.

Phospholipid phosphorus was determined from stock solutions according to the modified method of Beveridge and Johnson (23). Lipids were separated by TLC on silica gel G (250 μm thick, Kieselgel, E. Merck) using the following solvents: (A) chloroform–methanol–conc. ammonium hydroxide 85:30:6 (by volume); (B) chloroform–methanol–water 65:25:4 (24); and (C) n-hexane–ether–glacial acetic acid 70:30:2.

Quantities of PC were determined using the method of Nicolosi, Smith, and Santerre (25) in solvent (A) with modifications developed in our laboratory (26). PG was separated by one-dimensional TLC in solvent (B) and quantitated by fluorometry (27). The quantities of DSPC were determined by reacting an aliquot of stock solution with osmium tetroxide in carbon tetrachloride according to the method of Mason, Nellenbogen, and Clements (28). Fatty acid composi-

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TABLE 1. Effects of ethanol on lung growth[a]

Lung Growth	Control	Ethanol	P^b
Initial body wt (g)	206 ± 5.6	206 ± 4.9	NS[c]
Final body wt (g)	379 ± 32	373 ± 30	NS
Dry wt (mg/lung)	179 ± 8	194 ± 14	<0.01
Protein (mg/lung)	92 ± 18	91 ± 13	NS

[a] Values are means ± SD; ten rats were used in each group. Controls and ethanol-fed rats were pair-fed for 7 weeks.
[b] Paired comparisons.
[c] NS, not significant.

tion of PC and triglycerides was determined by GLC as previously described (26). Free cholesterol, cholesteryl esters, and triglycerides were separated in solvent (C) and also quantitated by fluorometry on TLC (25, 29). Total cholesterol was determined colorimetrically by the Liebermann-Burchard reaction (30). Aliquots of stock solutions and cholesterol standard were evaporated to dryness, redissolved in chloroform, and treated with acetic anhydride-sulphuric acid mixture. The color was developed in the dark at 25°C for 15 min and read immediately at 680 nm. Total cholesterol determined by this method has been found to correlate well with the results obtained by TLC.

Determination of protein

Protein content of cell-free lavage and of tissue digested with 1 N sodium hydroxide was determined by the method of Lowry et al. (31) with the addition of 1% sodium dodecyl sulfate (SDS) to the reagent. The addition of SDS was found necessary to prevent the turbidity caused by lipid.

Morphologic studies

The lungs of seven experimental and of seven control animals were excised immediately after killing and inflated via a tracheal cannula with cold formal-glutaraldehyde (3.7%:1%) at a pressure of 20 cm H_2O while floating in a container of the same fixative. After fixation at 4°C for 24 hr, the lungs were sampled for light and electron microscopic examinations.

Statistics

The values obtained in the ethanol-fed animals were compared to those obtained in their pair-fed controls and the means of the individual difference were tested by the Students' *t*-test (32).

RESULTS

Effects of ethanol on body weight and lung growth

The effects of ethanol on body weight, dry weight of the lung, and lung protein are shown in **Table 1.** Initial body weights in both groups were identical. Daily body weight measurements were recorded for each rat. Changes in body weight for ethanol-fed rats and controls were very similar over the 7-week experimental course. The mean lung dry weight of ethanol-fed animals as compared to controls was significantly elevated ($P < 0.01$).

The protein content of the lungs of ethanol-fed animals did not differ from that of controls. The identity in the protein content between these two groups suggests that the protein content of a perfused rat lung can serve as a more reliable baseline than the lung weight to express changes in lipid quantities.

Effects of ethanol on neutral lipid content of lung lavage and tissue

Total lipid and neutral lipid analyses of lung lavage and tissue are summarized in **Table 2.** The content of free cholesterol, cholesteryl ester, and total cholesterol of the lung lavage in ethanol-fed rats was nearly twice that of controls. However, the content of triglycerides, in contrast to that found in the lung tissue, was not significantly different in both groups. Total

TABLE 2. Effects of ethanol on neutral lipid content of lung lavage and tissue[a]

Neutral Lipid	Lavage, mg/lung			Tissue, mg/lung		
	Control	Ethanol	P^b	Control	Ethanol	P^b
Free cholesterol	0.098 ± 0.02	0.171 ± 0.01	<0.005	4.77 ± 0.4	5.66 ± 1.1	NS[c]
Cholesteryl ester	0.171 ± 0.04	0.304 ± 0.04	<0.01	1.72 ± 0.7	1.86 ± 0.6	NS
Triglyceride	0.322 ± 0.07	0.293 ± 0.02	NS	3.78 ± 1.1	10.16 ± 2.4	<0.001
Total lipid[d]	1.802 ± 0.25	3.278 ± 0.11	<0.001	39.50 ± 2.6	48.90 ± 1.7	<0.001

[a] Values are means ± SD; four rats were used in each group for lung lavage and ten rats were used in each group for tissue. The mean value of triplicate determinations was used.
[b] Paired comparisons.
[c] NS, not significant.
[d] Total lipid, total neutral lipid + total phospholipid from Table 3.

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TABLE 3. Effects of ethanol on phospholipid and protein content of lung lavage and tissue[a]

Phospholipid[d]	Lavage, mg/lung			Tissue, mg/lung		
	Control	Ethanol	P^b	Control	Ethanol	P^b
Total PL	1.21 ± 0.3	2.51 ± 0.2	<0.001	29.3 ± 2.0	31.7 ± 2.8	NS[c]
PC	1.04 ± 0.3	2.01 ± 0.2	<0.001	15.9 ± 1.6	17.8 ± 2.7	NS
PG	0.065 ± 0.03	0.105 ± 0.01	<0.02	0.82 ± 0.08	0.88 ± 0.09	NS
DSPC	0.53 ± 0.1	0.96 ± 0.1	<0.001	5.38 ± 1.0	5.24 ± 1.1	NS
Total protein	17.9 ± 2.1	18.3 ± 5.9	NS	92.1 ± 18	91.2 ± 13	NS
PL/protein	0.067	0.137	<0.001	0.32	0.34	NS

[a] Values are means ± SD; ten rats were used in each group and the mean value of triplicate determinations was used.
[b] Paired comparisons.
[c] NS, not significant.
[d] PL, phospholipid; PC, phosphatidylcholine; PG, phosphatidylglycerol; DSPC, disaturated phosphatidylcholine.

neutral lipid, obtained from the sum of total cholesterol and triglyceride, was significantly different ($P < 0.005$).

In the lung tissue, the content of free cholesterol, cholesteryl ester, and total cholesterol in ethanol-fed rats was not significantly changed. The most striking difference between the two groups of animals was that the lungs of ethanol-fed rats contained triglycerides in amounts almost triple those of the controls ($P < 0.001$). Total neutral lipid was also significantly higher in ethanol-fed rats than that in controls ($P < 0.001$).

Total lipid was determined from the sum of neutral lipid and phospholipid. The difference of total lipid in the lung lavage and tissue between the ethanol-fed rats and the controls was significant ($P < 0.001$). This difference could account, in part, for the difference in the lung dry weights (Table 1).

Effects of ethanol on phospholipid and protein content of lung lavage and tissue

A remarkable difference between ethanol-fed animals and controls was found in the content of phospholipid in lavage (**Table 3**). Total PL, PC, and PG in ethanol-fed animals was twice that of the controls. However, the protein content of the lavage in both groups was similar. The ratios of PC/PL, PG/PC, and DSPC/PC in ethanol-fed animals were not significantly different from those of controls. In contrast, ethanol had no effect on the content of PL, PC, PG, and DSPC in lung tissue (Table 3). The ratios of PC/PL, PG/PC, and DSPC/PC were also not significantly changed for both groups.

Effects of ethanol on fatty acid composition of triglyceride of lung tissue

Lung tissue triglyceride contained primarily palmitic, oleic, and linoleic acids (**Table 4**). Ethanol increased the proportion of oleic ($P < 0.001$) and decreased significantly the relative amount of palmitic, palmitoleic, and linoleic acids.

Effects of ethanol on fatty acid composition of PC of lung lavage and tissue

Fatty acid composition of the PC fraction isolated from lung lavage and tissue is shown in **Table 5.** In the lavage, palmitate not only dominated the fatty acid spectrum of the molecule but was significantly different between both groups. The percentage of palmitate of ethanol-fed rats was lower as compared to controls (75.3% versus 83.8%, $P < 0.01$). The percentage of total saturated fatty acids of ethanol-fed rats also was significantly lower than controls ($P < 0.02$). Higher percentage of total unsaturated fatty acids was found in ethanol-fed rats ($P < 0.02$).

Ethanol had no effect on the fatty acid composition of the tissue PC. The PC contained over 70% of saturated fatty acids and 87% of them were palmitate.

TABLE 4. Effects of ethanol on the fatty acid composition of triglyceride of lung tissue[a]

Fatty Acid[d]	Control	Ethanol	P^b
	% of total fatty acids		
14:0	2.48 ± 0.4	2.72 ± 0.6	NS[c]
15:0	0.34 ± 0.1	0.52 ± 0.4	NS
16:0	42.3 ± 2.8	37.1 ± 2.7	<0.02
16:1	3.77 ± 0.3	1.43 ± 0.4	<0.001
18:0	9.61 ± 2.0	10.9 ± 3.3	NS
18:1	24.3 ± 2.1	35.6 ± 1.5	<0.001
18:2	16.9 ± 0.2	11.7 ± 3.4	<0.02
20:4	—	—	
Saturation	54.6 ± 1.6	50.9 ± 4.0	NS
Unsaturation	45.3 ± 1.5	48.8 ± 4.1	NS

[a] Values are means ± SD; duplicate samples were done with six rats in each group.
[b] Paired comparisons.
[c] NS, not significant.
[d] Carbon chain length: no. of double bonds.

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TABLE 5. Effects of ethanol on the fatty acid composition of PC of lung lavage and tissue[a]

Fatty Acid[d]	Lavage			Tissue		
	Control	Ethanol	P^b	Control	Ethanol	P^b
			% of total fatty acids			
14:0	5.54 ± 0.7	5.94 ± 2.4	NS[c]	2.72 ± 0.4	2.75 ± 0.6	NS[c]
15:0	0.52 ± 0.1	0.76 ± 0.2	<0.02	0.39 ± 0.1	0.69 ± 0.8	NS
16:0	83.8 ± 3.4	75.3 ± 2.1	<0.01	62.6 ± 3.0	62.4 ± 2.1	NS
16:1	5.29 ± 1.9	9.7 ± 1.8	<0.01	8.06 ± 0.9	8.54 ± 0.7	NS
18:0	2.58 ± 1.5	2.8 ± 0.1	NS	5.36 ± 1.0	5.84 ± 0.8	NS
18:1	1.69 ± 0.1	3.01 ± 0.4	<0.02	9.92 ± 0.4	9.83 ± 1.3	NS
18:2	1.01 ± 0.1	2.2 ± 0.4	<0.005	5.18 ± 0.7	5.11 ± 0.8	NS
20:4	trace	trace		5.76 ± 2.4	4.76 ± 0.7	NS
Saturation	92.5 ± 4.4	85.0 ± 3.8	<0.02	71.1 ± 3.6	71.8 ± 1.9	NS
Unsaturation	7.5 ± 4.4	15.0 ± 3.8	<0.02	28.9 ± 3.6	28.2 ± 1.9	NS

[a] Values are means ± SD; duplicate samples were done with six rats in each group.
[b] Paired comparisons.
[c] NS, not significant.
[d] Carbon chain length: no. of double bonds.

Effects of ethanol on lung morphology

Histologic sections of lungs from experimental animals were not different from those of controls. No abnormalities of the Type II cells were detected in the experimental group by electron microscopy. The only observable neutral lipid was within vesicles in interstitial cells, and their size and numbers were similar in experimental and control animals.

DISCUSSION

The lung is no longer believed to be a metabolically passive organ engaged only in ventilation and gas exchange. Many of its cell populations are now known to be engaged in complex metabolic processes. Gas exchange function is dependent on at least one set of these processes, namely that involved in surfactant production. One or more indices of gas exchange function are often impaired in chronic abusers of ethanol (5, 7, 8) but a direct effect of ethanol as a cause of this impairment has not been established. Experimental studies have shown that ethanol metabolites are fixed in lung tissue and that ethanol unmetabolized by the liver reaches the lung (4). Lung tissue of rats has been shown to oxidize ethanol completely and to utilize ethanol in the synthesis of fatty acids (33). Thus ethanol may cause cellular injury to the lung, either by direct toxicity or by interfering with metabolic processes (5).

Our observations establish that the lipid metabolism in the lung, as determined by the quantities and qualities of neutral lipids and surfactant phospholipids, is affected by chronic ethanol ingestion in rats. The growth of rats, in both ethanol-fed and pair-fed control groups, was almost identical (Table 1) as reflected by growth curves (figure not shown) and final body weight. No difference was observed in the growth of lungs as determined by the content of total lung protein. These similarities suggest that the diets containing ethanol used in these experiments did not significantly impair the growth of the rat and its lung. It does appear that this is a reliable experimental model for studying the effects of ethanol on pulmonary lipid metabolism and physiology, and the changes induced by ethanol cannot be attributed to impaired growth.

The increase in total lung dry weight but not in protein content in ethanol-fed rats suggests that such increase was likely attributable, in part, to the increase in lipids, especially total neutral lipids (Table 2). The most striking effect of ethanol upon lungs was the tripling of the quantity of triglycerides. The mechanism of this accumulation of triglycerides in lung tissue in response to ethanol feeding is not certain. Ethanol has been found to increase intestinal synthesis of cholesterol and triglycerides (12, 14) in rats, and given acutely or chronically, to stimulate incorporation of palmitate into triglyceride by intestinal slices or microsome fractions derived from them (11). Similar effects on palmitate incorporation into triglyceride also were found in in vitro studies using ethanol in amounts equivalent to those found in intestinal lumen of social drinkers (2.6% alcohol) (11). These data indicate that ethanol, both in vivo and in vitro, stimulates intestinal triglyceride synthesis from fatty acids, and that this effect is associated with a marked increase in the activity of microsomal enzyme systems involved in fatty acid esterification similar to those found in liver (34). This suggests that the increased synthesis of triglycerides is not simply attributed to increased ethanol metabolites. Ethanol may cause

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metabolic imbalance and affect the normal metabolism of triglyceride either directly through unknown mechanisms or indirectly through its metabolites.

Although we have previously described massive accumulation of neutral lipid in the alveolar Type II cells of alcoholic patients with acute lung injury (17), no increase in neutral lipid could be detected in the lung of ethanol-fed rats by electron microscopy. The only detectable neutral lipid was in cytoplasmic droplets of interstitial cells and the number and size of these were not notably greater in the ethanol-fed animals. Because neutral lipids were increased both in tissue and in alveolar lavage, it seems likely that the cellular origin of the increase is the Type II cells. The increased lipid may exist in dispersed form within the cytosol rather than in detectable droplets. Perhaps more prolonged ethanol ingestion is necessary to cause increase in Type II cell neutral lipid of such magnitude as to be detectable by electron microscopy. Our previous observation in human alcoholic patients also suggested that a combination of insults such as hypoxia and alcohol may be necessary to cause electron microscopically detectable accumulation of neutral lipid in the Type II cells.

The phospholipid content (PL, PC, PG, and DSPC) in lavaged lung tissue was similar in both groups (Table 3). However, the phospholipid content in lung lavage of ethanol-fed rats was twice that of pair-fed controls. The DSPC content in the lavage of ethanol-fed rats accounted for 15.5% of total lung DSPC, while the DSPC content in controls was only 8.9%. This interesting finding may indicate that an excess synthesis and subsequent secretion of the lung surfactant from Type II cells occurs as a consequence of ethanol. However, the increase in the PC content of the lavage of ethanol-fed rats (0.97 mg/lung) was twice that observed for DSPC (0.43 mg/lung). This might account for the apparent reduction in total saturation of the PC in the lavage. Another possible explanation for the relative desaturation of the lavage PC would be that there was enhanced fatty acid desaturation in the ethanol-fed animals. However, this possibility would appear unlikely in light of the lack of differences between controls and experimentals in terms of the fatty acid composition of tissue PC. The excess phospholipid content of lavage found in ethanol-fed rats was not paralleled by the protein content (Table 3). The protein content of lavage of both groups was similar. The ratio of phospholipid to protein was therefore much higher in ethanol-fed rats than in controls. This phenomenon is similar to that reported by Petty et al. (35) in their studies of lung surfactant purified from a patient with adult respiratory distress syndrome (ARDS), and to our recent findings in the surfactant isolated from the dog model of acute alveolar injury induced by N-nitroso-N-methylurethane (NNNMU) (36). In both instances, human ARDS and our dog model, the surfactant contained higher lipid to protein ratios than normal. These lipid-protein aggregates were found in the lower sucrose density region upon ultracentrifugation. Whether ethanol causes a change in the lung surfactant similar to that found in ARDS and experimental NNNMU-induced acute lung injury remains to be determined.

A decrease in the percentage of palmitate in the PC fraction has been shown to result in a significant increase in minimum surface tension in the lung lavage of rats fed with an essential fatty acid deficient diet (19). Although the quantity of PC is increased in the lavage of ethanol-fed rats, the reduction in palmitate may have a similar effect on surface tension-lowering properties when compared on a mole to mole basis with normal surfactant. Similar effect of ethanol on the fatty acid patterns was also found in the triglyceride fraction of lung tissue (Table 4). The similarity of the fatty acid pattern of triglycerides affected by ethanol found here with that found in the liver (37) indicates that ethanol probably has a common effect on the metabolism of triglycerides both in liver and lung tissue. We are currently investigating correlation between the changes in quantity and quality of PC from lavage and surface tension-lowering ability, behavior of surface films, and lung mechanics in response to chronic ethanol intake.

The authors are grateful to Giselle Cernansky, Charles Dumais, Borbala Tornai, and Constance LePeter for expert assistance. This work was supported by grants from the U.S. Public Health Service (HL-23981; AM-1719) and the Stony Wold-Herbert Fund, Inc., New York.

Manuscript received 9 June 1980 and in revised form 12 January 1981.

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