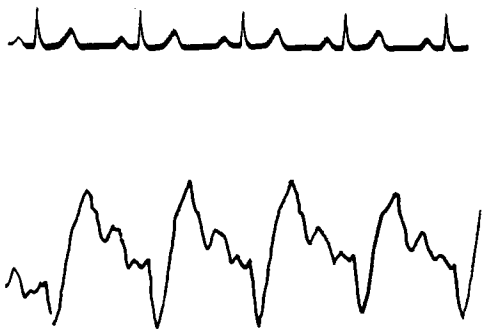

FIG. 2.
Illustrates the simultaneous record of the jugular pulse and the electrocardiogram.

compares favorably with the best devices in the literature. In Fig. 2 is shown a record of the venous pulse with a simultaneous recording of the electrocardiogram.

In presenting this application of the transducer tube it is desired to point out that this is only one of its many possible uses and that it should have rather wide usefulness in biology and medicine. The tube itself is about the size of the end of a pencil and can thus be used in small places if necessary. Furthermore, since the plate current in the transducer tube depends upon the displacement of the plate it is possible with a slight change in the circuit of Fig. 1 to measure displacements rather than changes in displacement. The sensitivity is high, and it has been our experience that it is easier to obtain a given sensitivity with a transducer than with a resistance wire strain gage.

Summary. This paper presents the application of the transducer tube to the detection and recording of movements of the type associated with the peripheral venous pulses. An adequate amplifier circuit is given and the usefulness of the device in other applications is suggested.

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The Fate of C^{14}-Labeled Palmitic Acid Administered Intravenously as a Tripalmitin Emulsion.*†

S. R. LERNER, I. L. CHAIKOFF, C. ENTENMAN, AND W. G. DAUBEN.
From the Division of Physiology of the Medical School and the Department of Chemistry, University of California, Berkeley.

The need for providing sufficient calories in small volumes for parenteral feeding has focussed attention upon methods for the intravenous administration of fat in a highly emulsified form. Now that several investigators have shown that the intravenous administration of fat can be achieved with some degree of safety,[1-3] it has become of importance to determine whether fat so administered pursues a normal metabolic path. Several attempts have been made to study the utilization of parenterally administered fats but the results obtained until recently were not conclusive. Thus Dunham and Brunschwig[4] failed to observe protein-sparing effects in 9 of 11 dogs when a highly emulsified fat was injected intravenously for periods as long as one month. Their emulsions, however, were quite toxic. McKibbin *et al.*,[1] on the other hand, have concluded that intravenously administered emulsions of fat are

* Aided by grants from the American Cancer Society (recommended by the Committee on Growth), and the Cutter Laboratories, Berkeley.

† A preliminary report of the results of the present investigation has appeared in *Science.*

1 McKibbin, J. M., Pope, A., Thayer, S., Ferry, R. M., Jr., and Stare, F. J., *J. Lab. Clin. Med.*, 1945, **30**, 488.

2 Meng, H. C., and Freeman, S., *J. Lab. Clin. Med.*, 1948, **33**, 689.

3 Shafiroff, B. G. P., Baron, H., and Roth, E., PROC. SOC. EXP. BIOL. AND MED., 1948, **69**, 387.

4 Dunham, L. J., and Brunschwig, A., *Arch. Surg.*, 1944, **48**, 395.

TABLE I.
Recovery of C^{14} Activity in the Fatty Acids Isolated from Organs and Tissues 24 Hours After the Injection of C^{14}-Palmitic Acid as Tripalmitin.

Tissues	Rat 1 (188 g)	Rat 2 (152 g)	Rat 3 (161 g)	Rat 4 (159 g)
	% of the injected C^{14} recovered			
Liver	2.64	5.68	3.84	3.31
Lungs	0.58	2.58	0.24	0.14
Spleen	0.51	1.01	0.10	0.26
Kidney	0.42	0.33	—	—
Small Intestine*	1.33	1.54	0.95	0.79
Large Intestine*	—	—	0.13†	0.13†
Brain	—	—	0.05	0.05
Depot:				
Perirenal	0.30	0.26	—	—
Genital	0.31	0.34	—	—
Omental	0.21	0.09	—	—
Mesenteric	0.74	0.39	—	—
Skin‡	6.6	3.2	—	—
Carcass§	5.6	6.6	15.9	13.8
Feces	0.76‖	1.13‖	0.36	0.32
Total	19.8	22.1	21.6	18.8

* Washed free of intestinal contents as described in text.
† The large intestines of rats 3 and 4 were pooled; 0.13 is half of the total C^{14} recovered.
‡ Includes hair and subcutaneous fat
§ Includes all organs and tissues not specified above.
‖ The value includes the activity of the feces plus that of the large intestine and its contents.

utilized, for not only did they find weight improvement and nitrogen retention in 2 dogs, but they were also unable to find any considerable portion of the infused fat stored in an unmodified form. A gain in body weight in dogs that received fat emulsions intravenously was also noted by Meng and Freeman,[2] but they point out that such results furnish no direct proof of fat utilization.

In order to study the path of utilization of fat introduced by the intravenous route, palmitic acid labeled at its 6th carbon with C^{14} was used in the present investigation. It is shown here that palmitic acid, when injected directly into the blood stream in the form of highly emulsified tripalmitin, is oxidized at a rapid rate, converted to phospholipid, and deposited in the fat depots.

Experimental. Preparation of emulsion. Palmitic acid containing C^{14} in the sixth carbon atom was synthesized, as described in an earlier communication,[5] and then esterified with glycerol by a modification of the method of Feuge *et al.*[6] The labeled tripalmitin was melted, together with half its weight of glycerol monostearate, and enough 5% glucose solution was added to yield an emulsion containing 4% fat. A propeller attached to a high speed motor was then inserted and the mixture was agitated violently for 5 minutes at a temperature maintained near the boiling point. The resulting emulsion was irradiated with supersonic energy (Ultra-sonorator, Model SL520) for 10 minutes at 700,000 cycles per second. The usual volume so treated was 3-5 ml. The particles obtained were almost all less than 1 μ in diameter.

Treatment of animals and collection of expired $C^{14}O_2$. Rats of the Long-Evans strain, weighing from 152 to 188 g, were used. After being fasted for 24 hours, they were anesthetized lightly with ether. One or 1.5 ml of the emulsion containing 20-25 mg of labeled tripalmitin (from 4 to 7 $\times$ 10^4 counts per minute per mg tripalmitin) were then slowly injected into the foot vein of each rat. The injection lasted about one minute. The rats were then placed in large pyrex desiccators arranged so that urine and feces could be collected and CO_2-free air could be drawn

[5] Daubert, W. G., *J. Am. Chem. Soc.*, 1948, **70**, 1376.

[6] Feuge, R. O., Kraemer, E. A., and Bailey, A. E., *Oil and Soap*, 1945, **22**, 202.

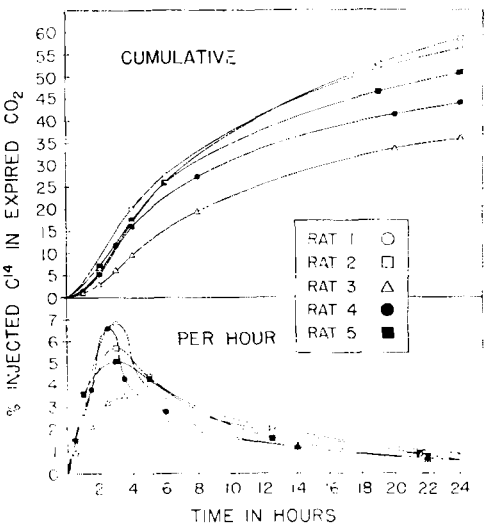

FIG. 1.
Rate of conversion of intravenously injected C14-labeled tripalmitin to CO_2.

through. Water, but not food, was provided. The air leaving the desiccator was dispersed, by a sintered glass disc, into a tower containing a sodium hydroxide solution. The sodium hydroxide was changed at intervals so that collection times were 0-2, 2-4, 4-6, 6-19, and 19-24 hours for three rats, and 0-1, 1-2, 2-3, 3-4, 4-8, 8-20, and 20-24 hours for 2 rats.

The expired CO_2 collected as the carbonate was precipitated as $BaCO_3$ and prepared for counting as described previously.[7]

Treatment of tissues. At the end of 24 hours, the rats were deeply anesthetized with ether. The organs and tissues indicated in Table I were removed and covered with alcohol. The small and large intestine were washed free of their contents with cold ethyl alcohol and these contents added to the collected feces. All remaining tissues were labeled carcass. Saturated potassium hydroxide solution (1 cc per g tissue) was added to each tissue sample and the fats were saponified. After saponification, the solutions were made acid to methyl red with sulfuric acid and the fatty acids extracted with ether. Aliquots of the ether extracts were mounted on lens-paper-covered aluminum discs for determination of their radioactivity, as described elsewhere.[7]

The time required to yield 1024 counts was determined several times for each sample. A Geiger-Müller tube with a mica window of 1.7 mg per sq. cm was used. All counting rates were at least several times that of background.

Results. The rapidity with which the intravenously injected tripalmitin is oxidized by fasted rats is shown in Fig. 1. Significant amounts of C^{14} appeared in the expired CO_2 as early as one hour, and by the time 24 hours had elapsed, from 36 to 59% of the sixth carbon atoms of the palmitic acid molecules were recovered as $C^{14}O_2$. The rate of elimination of $C^{14}O_2$ was not uniform throughout the period studied. It was most rapid between the second and fourth hours—from 19 to 25% of the total 24-hour elimination was expired during these 2 hours.

The recovery, at the end of 24 hours, of the injected C^{14} among the fatty acids isolated from various tissues is shown in Table I. Significant amounts, namely, 6-8%, were found in the areas designated as fatty depots and of these, the largest amount was present in the subcutaneous fat. If these values are considered in conjunction with the amount of C^{14} undoubtedly present in intermuscular fat of the carcass, there can be no doubt that fatty depots constitute a most important metabolic pathway for *intravenously* administered fat.

The only other tissue that contained appreciable amounts of the injected C^{14} was the liver. One day after the administration of the labeled palmitic acid, approximately 3-6% of the C^{14} was recovered in the fatty acid fraction of this tissue. Negligible amounts of C^{14} were found in the brain, spleen, lungs, and kidneys.

That the intravenously administered emulsified tripalmitin is available for phospholipid formation is shown in Table II. In rats 3 and 4, the major portion (70-80%) of the C^{14}-labeled fatty acids in the liver and small and large intestine had been incorporated into phospholipids. This was also true for the small intestine of rats 1 and 2, but in the case of

[7] Entenman, C., Lerner, S. R., Chaikoff, I. L., and Dauben, W. G., PROC. SOC. EXP. BIOL. AND MED., in press.

TABLE II.
Incorporation of Labeled Fatty Acids into Phospholipid and Nonphospholipid Fractions of Tissues 24 Hours After the Injection of C^{14}-Palmitic Acid as Tripalmitin.

Tissue	Lipid fractions	Rat 1	Rat 2	Rat 3	Rat 4
		% of each tissue's lipid C^{14} found in respective fraction			
Liver	Phospholipid fatty acids	34	50	72	72
	Nonphospholipid "	66	50	28	28
Small Intestine	Phospholipid "	64	71	74	78
	Nonphospholipid "	36	29	26	22
Large Intestine	Phospholipid "	—	—	69*	69*
	Nonphospholipid "	—	—	31*	31*

* The large intestines of rats 3 and 4 were pooled and the value shown is half of the total.

their livers, 34 and 50%, respectively, of their fatty acids were in the phospholipid fraction.

Comment. The manner in which long-chain fatty acids are utilized when administered by routes other than the gastrointestinal tract has aroused considerable interest in recent years. The use of radioactive carbon provided, for the first time, a direct method for determining the rate at which an animal can convert parenterally administered, long-chain fatty acids to CO_2. In the present investigation, a 16-carbon fatty acid containing C^{14} in the sixth carbon atom was used and injected in the form of its triglyceride. It is shown here that as much as 59% of the sixth carbon atoms are converted to CO_2 in 24 hours. This observation, in addition to the demonstration of storage of significant amounts of the labeled fatty acids in adipose tissues and their recovery in the phospholipids isolated from liver and intestine, can leave no further doubt that palmitic acid is utilized when used for intravenous feeding.

Since the completion of the present study, Geyer *et al.* have reported on the oxidation of intravenously administered trilaurin.[8] They injected a fat emulsion containing trilaurin in which the carboxyl group of the 12-carbon fatty acid was labeled with C^{14}, and found that in 4.5 hours, 71% of the C^{14} injected into rats was exhaled as CO_2. In this interval we found that only 11-23% of the sixth carbon atoms of palmitic acid, which had been administered intravenously as a tripalmitin emulsion, are exhaled as CO_2. The more rapid oxidation rate of trilaurin is most likely due to the fact that the 12-carbon fatty acid is not deposited in adipose tissue to a measurable extent.

Summary. 1. In order to test the extent of utilization of fat emulsions in parenteral feeding, palmitic acid labeled with C^{14} at its sixth carbon was injected intravenously, in the form of the triglyceride, into fasted rats.

2. From 36 to 59% of the administered C^{14} was expired as CO_2 in 24 hours.

3. Considerable amounts of the administered fatty acids were stored in adipose tissues throughout the body.

4. The availability of intravenously administered tripalmitin for metabolic purposes is further shown by the finding that as much as 78% of the radioactive fatty acids recovered from the liver and small intestine had been incorporated into phospholipids.

[8] Geyer, R. P., Chipman, J., and Stare, F. J., *J. Biol. Chem.*, 1948, **176**, 1469.