Quantitation of Oxidation of Medium-Chain Triglycerides in Preterm Infants¹

ERIC J. SULKERS, HARRY N. LAFEVER, AND PIETER J. J. SAUER

*Department of Paediatrics, Division of Neonatology, Erasmus University and University Hospital Rotterdam/
Sophia Children's Hospital, Rotterdam, The Netherlands*

ABSTRACT. Medium-chain triglycerides, with a chain length of eight and 10 carbon atoms, form up to 50% of the total fat content in some preterm infant formulas. In 20 small preterm infants (birthwt: 1153 ± 227 g; mean $\pm$ SD) fed a special formula containing 40% MCT, a primed constant oral infusion study of 1-¹³C-potassium octanoate was conducted to quantify the oxidation of MCT. A plateau in ¹³C enrichment in breath CO₂ was reached in all patients within 1–3 h. Simultaneously, substrate utilization was measured using a closed system indirect calorimeter. No significant difference was found between appropriate for gestational age ($n = 8$) and small for gestational age ($n = 12$) infants in the percentage of the administered tracer that was oxidized ($44.9 \pm 9.1\%$ versus $48.5 \pm 11.0\%$). In all patients, the recovery was calculated to be $47.1 \pm 10.2\%$, which is less than previously estimated and corresponds to a mean MCT oxidation of 1.26 ± 0.27 g/kg/d. With indirect calorimetry, a total fat oxidation of 1.42 ± 0.84 g/kg/d in appropriate for gestational age and 2.00 ± 0.85 g/kg/d in small for gestational age infants was found, indicating that MCT accounted for around 85% of the total fat oxidation in appropriate for gestational age versus 65% in small for gestational age infants. (*Pediatr Res* 26:294–297, 1989)

Abbreviations

AGA, appropriate for gestational age
APE, atom percent excess
LCT, long-chain triglycerides
MCFA, medium-chain fatty acids
MCT, medium-chain triglycerides
SGA, small for gestational age
VCO₂, carbon dioxide production
VO₂, oxygen consumption

The optimal composition of the oral feeding solution for a preterm infant remains a matter of debate. Milk from mothers who delivered preterm, although containing more protein and minerals than milk from mothers who delivered at term, may not be sufficient to prevent deficiencies or to produce wt gain equivalent to the intrauterine growth curve (1, 2). The various formulas specially designed for preterm infants differ consider-

ably, reflecting unanswered questions regarding the optimal composition of such formulas.

Some preterm infant formulas contain up to 50% of the fat as MCT, intended to enhance fat absorption and to provide a readily available energy source. Improved wt gain and retention of fat, protein, and calcium have been described with MCT-containing formulas (3, 4). No reliable data exist regarding the percentage of orally administered MCT that is oxidized by the preterm infant. The objectives of this study were to quantify octanoic acid oxidation as an indication of MCT oxidation and to measure utilization of other substrates in preterm infants receiving a formula containing 40% of fat as MCT.

MATERIALS AND METHODS

Subjects. Infants with a birthwt of <1600 g were included in the study after they were on full oral feedings, gaining wt, and clinically stable breathing room air. Twenty patients entered the study, eight patients AGA, group I, and 12 patients SGA, group II.

AGA was defined as a birthwt within 2 SD of the mean for gestation, according to the growth curves of Usher and McLean (5). SGA was defined as a birthwt more than 2 SD below the mean. Gestational age was determined by medical history and Ballard score (6). All infants were initially admitted to the Neonatal Intensive Care unit of the Academic Hospital Rotterdam/Sophia Children's Hospital, five in group I and six in group II had been ventilated for the respiratory distress syndrome in the neonatal period. Mean body wt, gestational age, and age at the time of study are shown in Table 1.

Feeding regimen. All infants received a formula (Nenatal, Nutricia, Zoetermeer, the Netherlands) in which 40% of the fat is provided as MCT, from the day oral feedings started, usually at day 7. The composition of the formula is given in Table 2. In our ward very low birth wt infants routinely are fed by continuous nasogastric gavage. Infants were studied at least 3 d after they had reached the maximum intake of 150 mL/kg/d of the formula. During the studies, the gavage feeding was administered using a syringe pump (Perfusor Secura FT, Braun, Melsungen, FRG).

Study procedure. The study protocol was approved by the Human Subject Review Committee of the Academic Hospital Rotterdam and Erasmus University. Written informed consent was obtained from the parents. The study design was as follows. In the 4th postnatal wk urine was collected for 72 h. In the middle of this collection period, indirect calorimetry was performed for a 6- to 8-h period. During indirect calorimetry, a primed constant infusion of 1-¹³C potassium octanoate was given.

Indirect calorimetry. Metabolic rate and substrate utilization were measured by a closed circuit indirect calorimeter. Continuous measurements were performed for 6–8 h, as previously described (7). Briefly, an air mixture devoid of carbon dioxide

Received December 16, 1988; accepted May 17, 1989. Correspondence and reprint requests to Prof. Dr. P. J. J. Sauer, Department of Pediatrics, Division of Neonatology, Sophia Children's Hospital, Gordelweg 160, 3038 GE Rotterdam, The Netherlands.

Supported in part by grants from the Sophia Foundation for Medical Research and Nutricia, The Netherlands.

¹ Presented in part at the meeting of the Society for Pediatric Research, May 1988, Washington, D.C. (*Pediatr Res* 1988;23:492A).

Table 1. *Clinical parameters of infant groups studied**

	Birth wt (g)	Gestational age (wk)	Age when studied (d)	Wt when studied (g)
Total (<i>n</i> = 20)	1153 ± 227	31.0 ± 1.7	28 ± 6	1508 ± 313
AGA (<i>n</i> = 8)	1362 ± 170	30.3 ± 1.7	28 ± 7	1761 ± 243
SGA (<i>n</i> = 12)	1014 ± 134	31.4 ± 1.6	28 ± 6	1340 ± 233
	<i>p</i> < 0.001	NS	NS	<i>p</i> < 0.005

* Values expressed as mean ± 1 SD.

Table 2. *Composition NENATAL 07 (Nutricia, The Netherlands) per 100 mL**

Energy	80 kcal
Protein	2.2 g
Carbohydrates	8.0 g
Lactose	4.0 g
Dextrine maltose	4.0 g
Fat	4.5 g
MCT C8	1.1 g
C10	0.7 g
LCT C16:0	0.3 g
C18:0	0.1 g
C18:1	0.9 g
C18:2	1.4 g
Sodium	23 mg
Potassium	60 mg
Calcium	100 mg
Phosphorus	50 mg

* Composition before September 1988.

enters the incubator. In a sample of the air leaving the incubator the CO₂ concentration is measured, whereafter all carbon dioxide is filtered out by a soda-lime filter. The CO₂ is injected again into the airflow by a mass flow injector system until the same concentration of CO₂ is measured by the infrared meter (Unor 6N, Maihak, Hamburg, FRG). The amount of carbon dioxide injected into the system equals the carbon dioxide production of the infant. Thereafter all CO₂ is filtered by a second filter. The amount of oxygen consumed by the infant is equal to the amount of oxygen that has to be injected into the system to keep the oxygen tension constant, as measured by polarographic oxygen cells (type 6223771 Beckman Instruments, Fullerton, CA) in the system and in a reference vessel. To compensate for changes in air-pressure, the reference vessel is connected to the flow circuit by means of a capillary. Oxygen consumption and carbon dioxide production are measured with an accuracy of 0.2 mL/min, the RQ during calibration with butane was within 2% of the theoretical value. Urine was collected in plastic bags over a period of 3 d. Urinary nitrogen concentration of a pooled sample was determined by combustion in an automatic nitrogen analyzer (ANA 1400; Carlo Erba, Milano, Italy) by the Dumas procedure (8).

Measurement of octanoate oxidation. Octanoic acid oxidation was measured using 1-¹³C-potassium octanoate. The labeled octanoic acid (99% purity, Sigma Chemical Co., St. Louis, MO) was converted into its potassium salt by means of titration with KOH in our laboratory and diluted in sterile water. To determine the natural background of ¹³C, three baseline breath samples were collected during 15 min each before starting the isotope infusion. The bicarbonate pool was then primed with 6.9 μmol·kg⁻¹ of a 6.9 mM solution of NaH¹³CO₃ (80% purity, Merck Isotopes, Montreal, Canada) as previously described (9). At the same time, a 1-¹³C-octanoate priming dose of 2 mg/kg was given, followed by a constant infusion of 2 mg/kg/h for 6–8 h. All isotopes were administered through a separate nasogastric tube. The delivery rate of the pump during the study was measured by dividing the difference in weight of the syringe before and after

the experiment by the duration of the experiment to determine the actual quantity of 1-¹³C-octanoate administered. Once the isotope infusion was started, 15 min CO₂ breath collections were made every hour for 4 h, and every 30 min for 2–4 more h. Breath CO₂ was collected by passing a sample of the air leaving the incubator through an all glass spiral condenser, containing 10 mL of a fresh 1 M NaOH solution. Samples were transferred to Vacutainers and stored at -20°C until analysis. Trapping of CO₂ was shown to be complete during 15 min at a flow of approximately 10 mL/min and hence isotopic fractionation was prevented. In a study conducted without the administration of isotopes, a shift in natural background over time was ruled out, as could be expected during a continuous feeding regime.

Isotopic ratio mass spectrometric analysis. Respiratory carbon dioxide was liberated at <10⁻³ torr by adding 85% phosphoric acid to the NaHCO₃ solution. Pure CO₂ was collected in a small glass container in liquid nitrogen whereas the water was trapped in a methanol dry ice bath. The glass container with pure CO₂ was connected to a VG Sira 10 isotope ratio mass spectrometer (Vacuum Generators, Winsford, Cheshire, UK). Results of ¹³C abundance of both baseline and plateau were calculated as APE/reference CO₂ tank standard sample. Isotopic plateau was defined by eyeballing as the absence of a change in abundance with time.

Calculations. The percentage of ¹³CO₂ recovery was calculated as follows. 1) ¹³CO₂ production (μmol·kg⁻¹·h⁻¹) =

$$\frac{\text{VCO}_2 \times 60}{22.4} \times \frac{\text{H}}{100} \times \frac{100}{\text{C}} \times 1000$$

VCO₂ = carbon dioxide production (STPD) in mL·kg⁻¹·min⁻¹; H = plateau height ¹³CO₂ above baseline in APE; C = correction factor for ¹³CO₂ retention in the bicarbonate pool, calculated from the energy intake of the infant (9).

2) ¹³C administered (μmol·kg⁻¹·h⁻¹) = 1-¹³C octanoate (μmol·kg⁻¹·h⁻¹) × 0.99

$$0.99 = \text{purity of } ^{13}\text{C octanoate}$$

3) ¹³C recovery =

$$\frac{{}^{13}\text{CO}_2 \text{ production}}{{}^{13}\text{C administered}} \times 100\%$$

4) The percentage ¹³C recovery was considered to be equal to the percentage of the tracer that was oxidized.

5) Nonprotein VO₂ and nonprotein VCO₂ were derived from VO₂ and VCO₂ by correcting the values for the protein oxidation, calculated as 6.25 × the timed urinary nitrogen-excretion.

6) Metabolic rate and partition of the non-protein macronutrients were calculated from nonprotein RQ and nonprotein VO₂ using the tables of Lusk (10).

7) Statistical analysis of the differences between the results of the two groups was conducted using the Mann-Whitney U test.

RESULTS

The energy and substrate intake of the infants is shown in Table 3. There were no differences in intake between SGA and AGA infants. The results of indirect calorimetry are shown in Table 4. The metabolic rate was significantly higher in the SGA

Table 3. *Substrate and total caloric intake of infant groups**

	Intake (kcal/kg/d)	Total fat intake (g/kg/d)	MCT intake (g/kg/d)	Glucose intake (g/kg/d)
Total (<i>n</i> = 20)	120 ± 4	6.71 ± 0.20	2.69 ± 0.08	11.23 ± 0.41
AGA (<i>n</i> = 8)	119 ± 2	6.71 ± 0.10	2.68 ± 0.04	11.19 ± 0.16
SGA (<i>n</i> = 12)	120 ± 5	6.73 ± 0.26	2.73 ± 0.10	11.26 ± 0.52
	NS	NS	NS	NS

* Values expressed as mean ± 1 SD.

Table 4. Results of indirect calorimetric measurements*

	Vo ₂ (mL/kg/min)	Vco ₂ (mL/kg/min)	RQ	Metabolic rate (kcal/kg/d)	Fat utilization (g/kg/d)	Glucose utilization (g/kg/d)
Total (n = 20)	8.34 ± 0.64	7.58 ± 0.58	0.91 ± 0.03	61.7 ± 4.5	1.77 ± 0.87	10.77 ± 1.91
AGA (n = 8)	7.90 ± 0.35	7.23 ± 0.38	0.92 ± 0.03	58.4 ± 2.4	1.42 ± 0.84	10.77 ± 1.95
SGA (n = 12)	8.63 ± 0.63	7.81 ± 0.58	0.91 ± 0.03	63.6 ± 4.5	2.00 ± 0.85	10.77 ± 1.97
	p < 0.01	NS	NS	p < 0.005	NS	NS

* Values expressed as mean ± 1 SD.

infants ($p < 0.005$) per kg body wt, as described earlier (11), probably due to a higher fat oxidation (2.00 ± 0.85 versus 1.42 ± 0.84 g/kg/d), although the difference in fat oxidation did not reach statistical significance. The production of $^{13}\text{CO}_2$ in breath rose in the 1st h in all patients and a plateau was reached in all patients within 1–3 h. An example of a characteristic study is shown in Figure 1. The results of the isotopic studies are shown in Table 5. These results show a $^{13}\text{CO}_2$ recovery for AGA and SGA infants of 44.9 and 48.5%, respectively. The difference between the two groups is not significant, and the mean $^{13}\text{CO}_2$ recovery of the labeled octanoate in all patients is 47% with a SD of 10% and a range of 32 to 64%.

DISCUSSION

Premature infants have a relative deficiency of pancreatic lipase and bile salts, causing loss of part of the administered lipids in the faeces (12, 13). Orally administered MCT are absorbed mainly as free fatty acids, because their intraluminal hydrolysis is rapid and almost complete. Recently it was shown that marked hydrolysis occurs in the stomach of the preterm neonate and that a significant part of octanoate acid is absorbed directly in the stomach (14). MCT can also be absorbed in part as triglycerides (15). In most cases a total of more than 99% are absorbed (3, 16, 17). If absorption as a triglyceride takes place, hydrolysis by an intestinal lipase will follow within the enterocyte (15). Unlike LCT, the MCFA derived from MCT are not reesterified, so all MCT will leave the intestinal cells as MCFA and reach the liver via the portal vein as free fatty acids in solution in plasma or bound to albumin (18).

To study the metabolism of MCT, sodium- ^{13}C -octanoate has been used as a tracer in adults (19). Octanoate can be regarded as a tracer representative of trioctanoin metabolism, considering the fact that both the free fatty acid and triglyceride with a chain length of eight carbons will enter at one stage the free fatty acid pool in the intestinal cells.

MCT have been included in preterm infant formulas because of their high rate of absorption. They are also referred to as a readily available source of energy, implying a rapid and almost complete oxidation of MCT (15, 20, 21). Even the existence of an obligatory oxidation of MCFA with increased heat production has been suggested (22, 23). In this study, we found that in both AGA and SGA infants an average of no more than 47% of the administered octanoate was oxidized, with a range of 32 to 64%.

In a study using the bolus technique and ^{13}C labeled trioctanoin as a tracer in a small number of preterm infants, a cumulative oxidation of 27% of the tracer was found (24). Recent studies showed that MCT might have a tendency to adhere to the feeding tube, due to its hydrophobic properties (25). If part of the trioctanoin used as a tracer adheres to tubing during the experiment, this can give falsely low results on recovery of the tracer. By using the water-soluble potassium salt of octanoic acid we minimized the risk that tracer would adhere to the tubing. This might explain the fact that we found a higher oxidation rate, although the bolus technique is not fully comparable to the constant infusion technique. When discussing the physiologic significance of our findings we will have to consider the further steps in the metabolic pathways followed by MCT.

In the liver, MCFA readily cross the membrane into the

Fig. 1. Time course of $^{13}\text{CO}_2$ enrichment in breath after a primed constant oral infusion of 1- ^{13}C -octanoate in one patient. Three baseline breath samples were taken before the isotope administration.

Table 5. Results of stable isotopic measurements*

	Recovery (%)	MCT oxidation (g/kg/d)
Total (n = 20)	47.1 ± 10.2	1.26 ± 0.27
AGA (n = 8)	44.9 ± 9.1	1.20 ± 0.24
SGA (n = 12)	48.5 ± 11.0	1.30 ± 0.29
	NS	NS

* Values in mean ± 1 SD.

mitochondria, where they are activated and broken down into acetyl-CoA. This acetyl-CoA can enter the tricarboxylic acid cycle and, under the conditions of our study, will be detected as labeled CO_2 after oxidation. When there is excess acetyl-CoA, a major pathway is formation of ketone bodies; in fact, MCFA are known to be ketogenic (26). Feeding of an MCT-containing formula for 4 d promotes a mild ketosis in preterm infants (27). These ketone bodies will be quickly utilized peripherally, especially after a period of adaptation (28). Because the conversion to ketones is a rapid process (29), most of the excreted $^{13}\text{CO}_2$ due to the oxidation of ketone bodies derived from MCT will also contribute to the ^{13}C enrichment in expired air, thus being included in our calculation.

One of the conditions that have to be fulfilled to make this assumption is that the pool of ketones remains constant, which means that the concentration of ketone bodies in the plasma should not change during the experiment. We think this was the case during these studies, because these infants were on the same intake of the MCT formula for at least 3 d before starting the study, and were in a clinical stable condition. Hence, there is no reason to assume that in the groups studied an increase in the ketone body pool during the experiment could have been responsible for retention of the label.

We conclude that both ways of immediate oxidative disposal of MCFA, entering the Krebs cycle directly or via the formation of ketone bodies, are included in the values for oxidation of MCT we found in this study. Following this line of reasoning, about half of the MCT in this feeding regimen follows other

pathways than oxidation. Urinary loss of dicarboxylic acids that can exist during MCT feeding probably accounts for less than 1% of the dietary intake of MCT in preterm infants (30).

Furthermore, MCFA are not to a significant amount activated by coenzyme A in the extramitochondrial space to participate directly in triglyceride and phospholipid synthesis (31). Accordingly, storage of octanoate as a triglyceride in adipose tissue does not seem to be of great importance (32–34). Apparently, MCFA have to be converted into long-chain fatty acids before they can be stored as LCT in the body fat tissue. Probably the most important route quantitatively for this is the breakdown of MCT into acetyl-CoA, whereafter LCT is formed through *de novo* lipogenesis (35).

The relatively low oxidation rate we found is consistent with the findings that breakdown of MCFA and lipogenesis occur sequentially during MCT feeding (36). The oxidation rates we found might indicate that in these patients lipogenesis is an important pathway for MCT, whereas fitting less well with the assumption of an obligatory oxidation as a cause of the enhanced thermogenesis that is sometimes encountered on a MCT diet (22, 23). If we assume a mean absorption of 85% of the LCT in these patients (16, 17), MCT would account for around 45% of the absorbed fatty acids. Combining the mean value for total fat oxidation we obtained by indirect calorimetry with results from the isotopic studies, we find that oxidation of MCT accounts for 65% of the fat oxidation in SGA and 85% in AGA infants. Apparently there is a preferential oxidation of MCT, but whether this aspect of MCT metabolism is advantageous remains to be proven.

Remarkably, although SGA infants have a significantly higher metabolic rate, we found no increase in the MCT oxidation, suggesting there might be a limit to the amount of MCT that can be completely oxidized by the small preterm infant.

Acknowledgments. The authors thank S. C. Pellekaan, R.N. for expert technical assistance and Dr. H. Przyrembel and Prof. H. J. Degenhart for critically reviewing the manuscript.

REFERENCES

1. Fomon SJ, Ziegler EE, Vasquez HD 1977 Human milk and the small premature infant. *Am J Dis Child* 131:463–467
2. Gross SJ 1983 Growth and biochemical response of preterm infants fed human milk or modified infant formula. *N Engl J Med* 308:237–241
3. Tantibedhyangkul P, Hashim SA 1975 Medium-chain triglyceride feeding in premature infants: effects on fat and nitrogen absorption. *Pediatrics* 55:359–370
4. Tantibedhyangkul P, Hashim SA 1978 Medium-chain triglyceride feeding in premature infants: effects on calcium and magnesium absorption. *Pediatrics* 61:537–545
5. Usher RH, McLean F 1969 Intrauterine growth of live-born Caucasian infants at sea level: standards obtained from measurements in 7 dimensions of infants born between 25 and 44 weeks of gestation. *J Pediatr* 74:901–910
6. Baillaud JL, Kazmaier Novak K, Driver M 1979 A simplified score for assessment of fetal maturation of newly born infants. *J Pediatr* 95:769–774
7. Sauer PJJ, Dane HJ, Visser HKA 1984 Longitudinal studies on metabolic rate, heat loss and energy cost of growth in low birth weight infants. *Pediatr Res* 18:254–259
8. Kirsten WJ, Hesselius GU 1983 Rapid, automatic, high capacity Dumas determination of nitrogen. *Microchem J* 28:529–547
9. Van Aerde JEE, Sauer PJJ, Pencharz PB, Canagarayar U, Beesley J, Smith JM, Swyer PR 1985 The effect of energy intake and expenditure on the recovery of $^{13}\text{CO}_2$ in the neonate during a 4-hour primed constant infusion of $\text{NaH}^{13}\text{CO}_3$. *Pediatr Res* 19:806–810
10. Lusk G 1924 Analysis of the oxidation of carbohydrate and fat. *J Biol Chem* 54:41–42
11. Chessex P, Reichman B, Verellen G, Putet G, Smith JM, Heim T, Swyer PR 1984 Metabolic consequences of intrauterine growth retardation in very low birthweight infants. *Pediatr Res* 18:709–713
12. Williams ML, Rose CS, Morrow G, Sloan SE, Barness LA 1970 Calcium and fat absorption in the neonatal period. *Am J Clin Nutr* 23:1322–1330
13. Fomon SJ, Ziegler EE, Thomas LN, Jensen RL, Filer LJ 1970 Excretion of fat by normal full term infants fed various milk and formulas. *Am J Clin Nutr* 23:1299
14. Hamosh M, Bitman J, Liao TH, Mehta NR, Buczek RJ, Wood DL, Grylack LJ, Hamosh P 1989 Gastric lipolysis and fat absorption in preterm infants: Effect of medium-chain triglyceride or long-chain triglyceride-containing formulas. *Pediatrics* 83:86–92
15. Bach AC, Babayan VK 1982 Medium-chain triglycerides: an update. *Am J Clin Nutr* 36:950–962
16. Jensen C, Buist NRM, Wilson T 1986 Absorption of individual fatty acids from long chain or medium chain triglycerides in very small infants. *Am J Clin Nutr* 43:745–751
17. Okamoto E, Muttart CR, Zucker CL, Heird WC 1982 Use of medium-chain triglycerides in feeding the low-birth-weight infant. *Am J Dis Child* 136:428–431
18. Isselbacher KJ 1968 Mechanisms of absorption of long and medium chain triglycerides. In: Senior JR (ed) *Medium Chain Triglycerides*. University of Pennsylvania Press, Philadelphia, pp 21–34
19. Décombaz J, Arnaud MJ, Milon H, Moesch H, Philippoussian G, Thelin AL, Howald H 1983 Energy metabolism of medium-chain triglycerides versus carbohydrates during exercise. *Eur J Appl Physiol* 52:9–14
20. Scheig R 1968 Hepatic metabolism of medium chain fatty acids. In: Senior JR (ed) *Medium Chain Triglycerides*. University of Pennsylvania Press, Philadelphia, pp 39–49
21. Bach A, Debry G, Metais P 1977 Hepatic metabolism of medium chain triglycerides. *Bibl Nutr Dieta* 25:24–35
22. Baba N, Bracco EF, Hashim SA 1982 Enhanced thermogenesis and diminished deposition of fat in response to overfeeding with diet containing medium chain triglycerides. *Am J Clin Nutr* 35:678–682
23. Geliebter A, Torbay N, Bracco EF, Hashim SA, Van Itallie TB 1983 Overfeeding with medium-chain triglyceride diet results in a diminished deposition of fat. *Am J Clin Nutr* 37:1–4
24. Putet G, Thelin A, Arnaud MJ 1984 Oxidative metabolism of ^{13}C medium chain triglyceride fed to preterm infants. *Pediatr Res* 34A:1491(abstr)
25. Mehta NR, Hamosh M, Bitman J, Wood DL 1988 Adherence of medium chain fatty acids to feeding tubes during gavage feeding of human milk fortified with medium-chain triglycerides. *J Pediatr* 112:474–476
26. Bach A, Schirardin H, Weryha A, Bauer M 1977 Ketogenic response to MCT load in the rat. *J Nutr* 107:1863–1870
27. Wu PYK, Edmond J, Auestad N, Rambithla S, Benson J, Picone T 1986 Medium chain triglycerides in infant formulas and their relationship to plasma ketone body concentrations. *Pediatr Res* 20:338–341
28. Crozier G, Bois-Joyeux B, Chanez M, Girard J, Peret J 1987 Metabolic effects induced by long term feeding of medium-chain triglycerides in the rat. *Metabolism* 36:807–814
29. Yeh YY, Zee P 1976 Regulation of ketosis to metabolic changes induced by acute medium-chain triglyceride feeding in rats. *J Nutr* 106:58–67
30. Whyte RK, Whelan D, Hill R, McClorry S 1986 Excretion of dicarboxylic acids and ω -1 hydroxy fatty acids by low birth weight infants fed with medium-chain triglycerides. *Pediatr Res* 20:122–125
31. McGarry JD, Foster DW 1980 Regulation of hepatic fatty acid oxidation and ketone body production. *Annu Rev Biochem* 49:395–420
32. Sarda P, Lepage G, Roy CC, Chessex P 1987 Storage of medium-chain triglycerides in adipose tissue of orally fed infants. *Am J Clin Nutr* 45:399–405
33. Jonxis JHP 1979 The fatty acid composition of brown and white fat in newborn infants and the influence of the ingested fat on the fatty acid composition of their body fat. In: Visser HKA (ed) *Nutrition and Metabolism of the Fetus and Infant*. Martinus Nijhoff Publishers, The Hague, pp 123–129
34. Zurier RB, Campbell RG, Hashim SA, Van Itallie TB 1967 Enrichment of the depot fat with odd and even numbered medium chain fatty acids. *Am J Physiol* 199:415–419
35. Leveille GA, Pardini RS, Tillotson JA 1967 Influence of medium-chain triglycerides on lipid metabolism in rat. *Lipids* 2:287–294
36. Crozier GL 1988 Medium-chain triglyceride feeding over the long term: The metabolic fate of ^{14}C octanoate and ^{14}C oleate in isolated rat hepatocytes. *J Nutr* 118:297–304