Energy Expenditure in Infants with Pulmonary Insufficiency: Is There Evidence for Increased Energy Needs?1,2

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ABSTRACT The observed growth failure in infants with pulmonary insufficiency is postulated to be a consequence of elevated rates of energy expenditure. Assessment of energy expenditure by the classical technique of indirect calorimetry has yielded conflicting results. The adoption of the newer, doubly labeled water technique has provided evidence to support increased rates of energy expenditure in infants with chronic lung disease, congenital heart disease and in minimally ill, extremely low birth weight infants. The doubly labeled water technique holds great promise for the detailed study of energy expenditure in a variety of clinical conditions, including very ill as well as free-living subjects. J. Nutr. 131: 935S–937S, 2001.

KEY WORDS: • energy expenditure • rate of growth • pulmonary insufficiency

It would seem logical to assume that increased energy requirements have been clearly established in infants with pulmonary insufficiency. Poor rates of growth have been repeatedly documented in premature infants with bronchopulmonary dysplasia (now called chronic lung disease) and in infants with congenital heart disease (Mehrzti and Drash 1962, Strangway et al. 1976, Markstad and Fitzhardinge 1981, Ariagno et al. 1991); increased rates of energy expenditure would appear to be a rational explanation to account for diminished growth rates. However, limitations in study designs and measurement techniques have complicated the interpretation of energy expenditure determinations in infants with pulmonary insufficiency.

A variety of studies over the last 20 y have attempted to answer the question of whether premature infants with chronic lung disease have higher rates of energy expenditure. The results of most of the studies measuring energy expenditure with respiratory calorimetry in infants with chronic lung disease are shown in Figure 1 (Weinstein and Oh 1981, Kao et al. 1988, Yeh et al. 1989, Yunis and Oh 1989, Billeaud et al. 1992, de Gamarra 1992, Wahlig et al. 1994, Chessex et al. 1995, Merth et al. 1997); from the data presented, it would be difficult to come to a definitive conclusion about energy expenditure in these infants. In addition, a number of important points must be made about these studies. The results of nine studies are shown, but only five of these studies included control groups. Many of the control groups were not well matched for postnatal and sometimes gestational age, both important determinants of energy expenditure (Chessex et al. 1981, Sauer 1984). Furthermore, most of these studies were small (10 or fewer subjects in each group), four of the studies were conducted prior to the availability of surfactant, only three studied ventilated infants and very few extremely premature infants (< 1000 g birth weight) were included in any study. All these investigations used respiratory calorimetry as the tool to measure energy expenditure. Although respiratory calorimetry has the advantage of being noninvasive, because of practical considerations measurements can usually be obtained for only several hours, and therefore can examine resting energy expenditure, which then must be extrapolated to total energy expenditure. Furthermore, the accuracy of respiratory calorimetry in neonates is questionable in a supplemental oxygen environment and during mechanical ventilation (Kalhan and Denne 1990). These limitations in measurement techniques and study designs have resulted in continuing uncertainty about the rates of energy expenditure in infants with chronic lung disease.

Fortunately, there is another method to assess energy expenditure, the doubly labeled water method, which allows total energy expenditure to be determined noninvasively over a longer time period (5–7 d) without altering clinical care or normal activity of the study subjects (Schoeller 1988). This method requires the oral administration of trace amounts of deuterium- and oxygen 18–labeled water. Both labels mix with total body water, and over time both are lost from the body; however, they are not lost at the same rate. The deuterium label is lost as water (urine or evaporation). The 18O is also lost as water; however, because of the action of carbonic
from this study, it seems unlikely that a strategy directed simply at increasing caloric intakes in infants receiving dexamethasone will be successful in achieving normal growth.

The doubly labeled water technique has also been used to evaluate energy expenditure in nonventilated premature infants with chronic lung disease at 2 mo of age. De Meer and colleagues (1997) measured higher rates of energy expenditure in 2-mo-old 29-wk gestation infants with chronic lung disease (73 kcal \(\cdot\) kg\(^{-1}\) \(\cdot\) d\(^{-1}\)) compared to 1-mo-old control infants (63 kcal \(\cdot\) kg\(^{-1}\) \(\cdot\) d\(^{-1}\)). The fact that the control and chronic lung disease groups were not well matched for postnatal age is a limitation; nevertheless total energy expenditure determinations in both early and established chronic lung disease suggest energy needs in this population are increased 15–25% over controls, although further work is clearly necessary.

It is an attractive hypothesis to attribute the increase in energy expenditure in infants with chronic lung disease to increased work of breathing. Indeed, a number of studies have observed a correlation between energy expenditure and some measure of respiratory status (Billeaud et al. 1992, Wahlig et al. 1994, de Gamarra 1992, Merth et al. 1997). However, Kao and colleagues (1988) examined the relationship between work of breathing and energy expenditure more rigorously. Energy expenditure and the mechanical power of breathing was measured in 4-mo-old infants with oxygen-dependent chronic lung disease at baseline and then in response to diuretic therapy or theophylline plus diuretic therapy. Although the mechanical power of breathing decreased 40–50% in response to either therapy, no change in energy expenditure was measured. The energy cost of breathing was calculated at approximately 1–2 kcal \(\cdot\) kg\(^{-1}\) \(\cdot\) d\(^{-1}\), unlikely to contribute significantly to increased energy expenditure in infants with chronic lung disease. Alternative explanations for increased energy expenditure, such as inflammation, appear more likely.

Recent studies using the doubly labeled water technique to measure total energy expenditure in infants with congenital heart disease have begun to better establish the energy needs of this population; previous studies investigating energy metabolism in this population have been difficult to interpret because of limitations in study design and measurement techniques (Lees et al. 1965, Krieger 1970, Monen and Posselt 1985). A recent study has reported total energy expenditure (using doubly labeled water), resting energy expenditure (using respiratory calorimetry) and energy intake in infants with cyanotic congenital heart disease and healthy control infants (Leitch et al. 1998). Subjects were studied at both 2 wk and 3 mo of age. Although growth rates were significantly lower in infants with cyanotic heart disease, no significant difference was observed in energy intake or resting energy expenditure between groups at either age. In contrast, total energy expen-
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Energy intake (EI), resting energy expenditure (REE), total energy expenditure (TEE), and the difference between total and resting energy expenditure (TEE-REE) in 4-mo-old subjects with moderate to large ventricular septal defects and normal healthy controls. Means ± SD. *P < 0.05. [Data from Ackerman et al. (1998).]

The use of the doubly labeled water technique in infants with a variety of disease processes has begun to more clearly establish energy requirements and has also allowed detailed assessments of the components of energy expenditure. Well-controlled studies are now beginning to convincingly demonstrate that premature infants with chronic lung disease and congenital heart disease have increased rates of total energy expenditure, with good estimations of the magnitude of this increase. Somewhat unexpected results are also being produced in hard-to-study populations, such as the very high energy expenditures in critically ill term infants. Additional application of the doubly labeled water technique in populations of infants with pulmonary insufficiency is likely to yield a more specific understanding of the determinants of energy expenditure and a more precise knowledge of energy requirements.

LITERATURE CITED


