AMERICAN ACADEMY OF PEDIATRICS

REPORT

COMMITTEE ON NUTRITION

Water Requirement in Relation to Osmolar Load as It Applies to Infant Feeding

THE DEMONSTRATION of the importance of the content of solutes in the food of infants[1-3] has introduced a new and important consideration in infant feeding. It is now apparent that a formula or diet satisfactory in all other respects may, under certain circumstances, be detrimental to the infant because of the excessive load of solutes presented to the kidney. Such circumstances include principally the feeding of unusually large amounts of electrolytes and protein to normal infants exposed to relatively high environmental temperatures for prolonged periods of time or to infants with renal insufficiency.

The purpose of the present communication is to consider whether any practical advantage is achieved by feeding a normal infant, in a normal environment, a formula containing fewer solutes or relatively more water than are contained in one composed of cow's milk and carbohydrate in the usual proportions, fed at a concentration of 150 ml/100 cal (20 cal/oz). From this point of view the question can be raised as to whether there is any advantage in feeding unusually dilute formulas to newborn infants.

Origin of the Renal Solute Load

The load of solutes requiring excretion by the kidneys is derived almost entirely from the protein and electrolyte in the diet. In Table I the content of nitrogen and electrolytes is listed for human and cow's milk. Also given in the table are calculated values for the approximate quantity of solutes requiring excretion by the kidney. It will be noted that an infant receiving 133 cal/kg from human milk would be required to excrete 14.0 m0sm/kg/day while an infant receiving 133 cal/kg from whole cow's milk without added carbohydrate would be required to excrete 60.9 m0sm/kg/day. Furthermore, it is apparent that an infant receiving two-thirds of the calories from cow's milk and one-third from added carbohydrate would need to excrete only two-thirds the quantity of solutes excreted by the infant fed cow's milk without added carbohydrate ($2/3 \times 60.9 = 42.7$ m0sm/kg/day). Assuming that a small infant is unable to concentrate the urine to more than 700 m0sm/l, the excretion of 14.0, 60.9, and 42.7 m0sm/kg for human milk, whole cow's milk and cow's milk plus carbohydrate, respectively, would necessitate the expenditure of 20, 87, and 61 ml of water per kilogram of body weight, respectively, by the kidneys.

Renal Requirements for Water

In Table II are given calculations concerning the supply and expenditure of water for infants fed human milk, cow's milk and cow's milk with added carbohydrate. It will be noted that at an environmental temperature of 21°C (70°F) all of the feedings, even cow's milk without added carbohydrate, supply more water than is required for combined extrarenal and renal losses. At an environmental temperature of 34°C (93°F), human milk can still provide an excess of water, and so does the formula of cow's milk with added carbohydrate, but cow's milk without additional carbohydrate does not.

Actually, the renal requirements for water may be less than those listed in Table II. The assumption that the kidneys of in-

TABLE I

LOAD OF SOLUTES PRESENTED TO THE KIDNEYS BY FEEDING HUMAN MILK AND COW'S MILK

(When fed at 200 ml/kg, 150 ml/100 cal; i.e., 133 cal/kg.)

	Concentration of Protein and Electrolytes		*Intake of Protein and Electrolytes*		*Load of Solutes Requiring Renal Excretion*	
	Human Milk	*Cow's Milk*	*Human Milk*	*Cow's Milk*	*Human Milk*	*Cow's Milk*
Protein (gm/100 ml)	1.2	3.3				
Nitrogen (mg/l)	1920	5300				
Nitrogen (mg/kg)			384	1060	184*	860*
	mOsm/l		*mOsm/kg*		*mOsm/kg*	
Urea					6.6†	30.7†
Electrolytes						
Calcium	8	31	1.6	6.2	0.6**	5.2**
Phosphorus	5	31	1.0	6.2	0‡	5.2‡
Chloride	12	29				
Sodium	7	25				
Potassium	14 } 39	35 } 104	7.8	20.8	6.8§	19.8§
Magnesium	2	5				
Sulfur	4	10				
Total electrolytes					7.4	30.2
Total solutes					14.0	60.9

* Assuming retention of nitrogen of 200 mg/kg/day.

† Assuming that all nitrogen not retained by body is excreted as urea $\left(\text{e.g., } \frac{184}{28} = 6.6\right)$.

** Assuming retention of calcium of 1 mOsm/kg/day.

‡ Assuming retention of phosphorus of 1 mOsm/kg/day.

§ Assuming retention of electrolyte in growth of 1 mOsm/day (a gain in weight of 5 gm/kg/day incorporates 60% water, or 3 gm of water/kg/day. The water contains 300 mOsm/l = 1 mOsm/3 ml).

fants are unable to concentrate urine to more than 700 mOsm/l is based on studies of edematous premature infants in the first 48 hours of life.[4] But young infants free of edema are able, at least in some instances, to achieve considerably greater concentrations of solutes in the urine.[2,5,6]

Practical Considerations

It appears that the physician may safeguard the water balance of infants in either of two ways. He may routinely administer a formula with so small a content of solutes and so large a content of water that a mild state of water diuresis would exist, even

TABLE II

SUPPLY OF WATER IN DIET AND EXPENDITURE OF WATER FROM ALL ROUTES AT ENVIRONMENTAL TEMPERATURES OF 21° AND 34°C

	Supply of Water			*Expenditures of Water*					*Water in Excess of Expenditures*	
	*Performed Water**	*Water of Oxidation*	*Total Water*	*Renal*	*Extrarenal at 21°C*	*Extrarenal at 34°C*	*Total at 21°C*	*Total at 34°C*	*At 21°C*	*At 34°C*
Human milk	200	13	213	20	80	147	100	167	113	46
Cow's milk	200	13	213	87	80	147	167	234	46	−21
Cow's milk plus carbohydrate†	200	13	213	61	80	147	141	208	72	5

* For concentration of 150 ml/100 cal (20 cal/oz).

† Two-thirds of the calories from cow's milk and one-third from added carbohydrate.

under conditions necessitating relatively large extrarenal expenditures of water. Alternatively, a physician may use any of the common formulas at a concentration of 150 ml/100 cal (20 cal/oz), and instruct the parents to offer additional water when the environmental temperature is excessively high for prolonged periods of time or when the infant is febrile. Because no physiologic advantage is known to attend a state of continuous water diuresis (concentration of solutes in the urine less than 310 m0sm/l, the routine administration to newborn infants of formulas more dilute than 150 ml/100 cal (20 cal/oz) would seem to have no better rationale than the routine administration of antibiotics to newborn infants because of apprehension concerning exposure to pathogenic organisms.

From the practical point of view, it appears that the relation between the content of solutes and content of water in the diet need be a primary consideration in choosing a formula only under conditions requiring excessive extrarenal expenditures of water, such as febrile states, serious impairment of renal function and hot weather.

Special consideration of this feature of an infant's diet is also advisable when formulas are fed which are more concentrated than 150 ml/100 cal. Except in the circumstances mentioned, it seems reasonable to choose a formula or diet on the basis of other nutritional features than the absolute or relative content of solutes and water.

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COMMITTEE ON NUTRITION

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