Total Body Water Content of Neonates with Obstruction of Alimentary Tract

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Tsingoglou, S., Phillips, H., and Wilkinson, A. W. (1972). *Archives of Disease in Childhood*, **47**, 941. **Total body water content of neonates with obstruction of alimentary tract.** The total body water content was measured by the deuterium oxide dilution method in 55 neonates admitted to hospital for surgical treatment within 90 hours of birth. The mean total body water of the whole group was 77.03 ± 0.62 (SEM) % of the body weight (range 67.4 to 88.6%), or 1.974 ± 0.005 (SEM) litres (range 1.010 to 2.830 litres). Over a range of body weights from 1.160 to 3.851 kg, total body water content expressed as a percentage of body weight decreased by 5% per kg rise in body weight, but when expressed as litres per kg body weight it increased by 737 ml for each rise of 1 kg in body weight. There was a small difference in water content between babies with obstruction of the alimentary tract and those with other nonobstructive lesions, which was not statistically significant.

It has been widely assumed that in neonates with congenital obstruction of the alimentary tract, vomiting and starvation result in gross disturbances of the volume and composition of body fluid which must be corrected before the obstruction is relieved by operation. Practical experience during the past 13 years in the treatment of more than 500 such neonates has shown that, unless the circulating blood volume is so reduced as to cause impaired peripheral capillary blood flow, the arbitrary preoperative replacement of such fluid losses with 0.9% or 0.18% saline is unnecessary. The only circumstances in which preoperative restoration of circulating blood volume is required are (1) when there has been sequestration or loss of whole blood, in a volvulus of the midgut or of a small intestinal atresia, or (2) when a baby with duodenal atresia has been allowed to continue to vomit and starve for 10 to 14 days. Disturbance of acid base equilibrium is uncommon in neonates with intestinal obstruction unless surgical relief of the obstruction is delayed beyond a week. A negative base excess of up to 15 mEq/litre is a usual sequel of starvation for 3 or 4 days at any age and does not need to be corrected, since equilibrium is rapidly re-established when the oral consumption of food begins. Even when there is a change in acid-base equilibrium of more than 15 mEq, treatment

immediately affects only the extracellular fluid component of the disturbance, which may be of acute benefit in babies with incipient cardiac failure; complete correction depends mainly on the homeostatic influence of the oral consumption of an adequate intake of milk.

The association of hydramnios with atresia of the oesophagus or duodenum may be the result of abnormal circulation of amniotic fluid between mother and child, and this has aroused the suspicion that the body composition and particularly the water content of the baby may also be altered. Up to 40% of babies with atresia of the oesophagus or duodenum are unusually small at birth, and some of them have severe associated anomalies in other systems. Postoperative complications are common and often severe and may interfere with feeding and cause large losses of intestinal secretion. The consequent need for repeated replacement of lost fluids by intravenous infusion, combined with starvation, leads to complicated disturbances of whole body composition, of which little is known except by analogy with the effects of tropical protein malnutrition (Garrow, Smith, and Ward, 1968).

It seemed, therefore, that the total body water content should be measured before operation in neonates with atresia of the oesophagus and duodenum, and in some other kinds of alimentary obstruction.

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tion, to find out whether their initial body water content was normal or not.

Methods

Heavy water (D_2O) 99.8% pure, pyrogen-free, and made isotonic with 0.85% NaCl was injected into the muscles of the lateral aspect of the thigh in doses approximately 1.5 g/kg body weight. The syringe was weighed to the nearest ± 0.0005 g before and after injection. 1 to 2 ml venous blood was collected after equilibration for at least 2 hours, mean 2 hours 15 minutes (Faller *et al.*, 1955). When estimations were repeated, a preliminary blank sample of blood was collected. Water was extracted from the whole blood by freeze-drying in a manifold closed vacuum system, 6 samples being treated simultaneously (Schloerb *et al.*, 1950).

The D_2O content of the extracted water was then measured on a Hilger and Watts H900 double-beamed absorption infrared spectrophotometer with an NaCl prism. The machine was modified to have a fixed

slit width of 2.0 mm at 3.8 μ . Scanning was from 2880 cm^{-1} to 2400 cm^{-1} (with D_2O wavelength at 2520 cm^{-1}), using CaF₂ windows and 0.2 mm cell spacers (Fydelor and Rawson, 1964). Samples of the distillate were equilibrated from 10 minutes at 25 °C in a water bath. The samples were read at a $\times 5$ scale expansion. Each sample was read twice between two standards. Between each estimation the cell was washed and dried three times with acetone and nitrogen. Standard samples were prepared by adding known amounts of deuterium oxide to distilled water (Turner, Neely, and Hardy, 1960). Recoveries of D_2O added to whole blood were 99.9% $\pm 0.29\%$ at 0.1% w/w D_2O level, 99.9% $\pm 0.80\%$ at 0.3% w/w D_2O level.

Total body water (TBW) was measured from 6 to 86 hours after birth in 55 neonates who had been referred for surgical treatment. In 39 neonates, congenital abnormalities of the gastrointestinal tract produced intestinal obstruction which required relief by operation (Table I); 16 other babies suffered from various disorders (Table II). None of these babies had been given any

TABLE I
Obstructive Group

Diagnosis	Case No.	Weight (kg)	Age (hr)	Weight Loss (%)	TBW (% of Body Weight)	TBW (l.)	Duration of Pregnancy (wk) and Method of Delivery
Oesophageal atresia	27	2.470	6.5	-2.1	80.6	1.99	Caesarean
Oesophageal atresia	28	2.290	30	-8.2	78.2	1.79	
Oesophageal atresia	31	1.945	68	-10.8	77.6	1.51	
Oesophageal atresia	33	1.998	19	-6.0	79.6	1.59	Twin
Oesophageal atresia	35	2.500	15	-0.9	78.8	1.97	
Oesophageal atresia	44	2.285	53	-1.5	76.6	1.75	
Oesophageal atresia	47	2.885	44	-6.1	73.2	1.87	
Oesophageal atresia	57	2.390	45	-1.2	76.2	1.82	36
Oesophageal atresia	77	2.740	26	-4.3	73.0	2.00	36
Oesophageal atresia	90	2.605	12	-	75.6	1.97	
Oesophageal atresia	180	1.160	18	4.8	87.1	1.01	35 Twin 2
Oesophageal atresia	118	2.985	32	-5.2	73.4	2.19	41
Oesophageal atresia	119	2.730	19	-3.9	76.2	2.08	Term
Tracheo-oesophageal fistula	104	2.400	85	-7.0	77.1	1.85	
Oesophageal and rectal atresias	24	3.170	15	-7.6	69.7	2.21	Term
Anorectal atresia	8	3.390	13	-2.8	73.7	2.50	
Anorectal atresia	12	2.030	7	-1.6	73.9	1.50	34
Anorectal atresia	13	3.605	36	-10.5	72.4	2.61	42
Anorectal atresia	19	2.390	16	-0.8	76.6	1.83	37 Caesarean
Anorectal atresia	51	3.100	17	-0.7	73.5	2.28	Caesarean
Anorectal atresia	98	2.500	44	-15.2	76.4	1.91	3
Anorectal atresia	120	2.900	24	-4.5	77.9	2.26	40
Anorectal atresia fistula	70	2.585	14	-2.5	77.0	1.99	41
Rectovaginal fistula	81	2.190	9	-	78.5	1.72	34
Hirschsprung's disease	2	2.585	50	-	72.3	1.87	
Hirschsprung's disease	9	3.455	53	-7.7	69.8	2.41	Term
Hirschsprung's disease	52	2.707	60	-7.9	77.6	2.10	40
Hirschsprung's disease	64	2.770	64	-4.2	82.3	2.28	Term
Volvulus	43	2.686	36	-8.9	74.5	2.00	
Volvulus	61	2.675	65	-15.8	71.0	1.90	36
Volvulus	112	2.385	53	-12.4	69.6	1.66	Term
Volvulus	106	3.220	72	-13.3	75.2	2.42	39
Duodenal atresia	60	2.050	26	-	78.0	1.60	33
Deodenal atresia	114	1.500	51	-13.2	82.0	1.23	
Jejunal atresia	26	2.230	11	-8.6	80.3	1.79	36 Twin 2
Jejunal atresia	54	1.531	28	-8.4	82.3	1.26	33.5
Meconium ileus	25	1.703	42	-1.6	83.4	1.42	38 Twin 2
Meconium ileus	116	2.830	24	-	77.7	2.20	
Exomphalos with intestinal obstruction	49	2.540	12	-3.6	79.9	2.03	37

TABLE II
Nonobstructive Group

Diagnosis	Case No.	Weight (kg)	Age (hr)	Weight Loss (%)	TBW (% of Body Weight)	TBW (l.)	Duration of Pregnancy (wk) and Method of Delivery
Retention of urine	11	3.560	53	—	67.4	2.40	
Urinary obstruction	20	3.851	72	+1.9	70.1	2.70	Term
Hydronephrosis	62	3.216	16	—7.4	76.5	2.46	Term
Vesicointestinal fissure	111	2.225	7	—1.9	78.7	1.75	33
Vesicointestinal fissure	113	2.583	34	+11.4	79.8	2.06	
Meconium plug	95	2.097	42	—9.0	83.0	1.74	Caesarean
Pseudo-obstruction	36	3.475	40	—6.1	77.1	2.68	42
Pseudo-obstruction	59	1.332	84	—4.1	88.6	1.18	35 Caesarean
Pseudo-obstruction	78	2.235	48	—6.1	85.9	1.92	34–36
Pseudo-obstruction, sclerema	3	1.600	63	—4.4	86.3	1.38	37
Pseudo-obstruction, sclerema	107	2.400	58	—5.4	75.8	1.82	Term
Cleft lip and palate	40	2.941	15	+0.7	78.9	2.32	Term
Cleft lip and palate	117	3.160	50	—5.4	70.3	2.22	37
Sacroccoccygeal teratoma	110	3.690	22	—6.3	76.7	2.83	Term
Exomphalos	75	3.692	12	—	75.3	2.78	40, Caesarean
Tracheo-oesophageal fistula	34	2.509	30	—4.8	78.5	1.97	33

FIG. 1.—Total body water as percentage of body weight related to body weight. $r = 0.7089$, $P < 0.001$.

fluid by intravenous infusion before admission or body water estimation, 25 of them had no oral fluids either, and those who had drunk fluids had vomited most of what they had taken. TBW was measured soon after admission and before operation or treatment was started.

Results

The body weight of the 55 neonates on admission ranged from 1.160 to 3.551 kg (mean 2.588 ± 0.003 kg). Compared with their stated birthweight, some babies appeared to have lost up to 15.2%

of birthweight while others appeared to have gained up to 11.4%.

The mean TBW of the whole group when expressed as a percentage of body weight was $77.03\% \pm 0.62\%$ (SEM), range 67.4 to 88.6, and when expressed in litres was 1.974 ± 0.055 (SEM), range 1.010 to 2.830 litres.

When TBW was expressed as a percentage of body weight (or in ml per kg body weight) and was plotted against weight (Fig. 1), there was a

FIG. 2.—Total body water in litres related to body weight. $r = 0.9782$, $P < 0.001$.

negative correlation coefficient of 0.7089 ($P < 0.001$) and TBW as a percentage of body weight decreased by 5.2% per kg over the range 1.160 to 3.851 kg. When TBW in litres was plotted against weight (Fig. 2) there was a positive correlation of 0.9782 ($P < 0.001$) and total body water in litres increased by 736.6 ml/kg over the range 1.160 to 3.851 kg.

The detailed results of the two groups of babies with obstruction and the results of 16 other neonates are shown in Tables I and II. The results of further analysis of those babies in whom data were sufficiently complete is shown in Table III. Of the babies who were obstructed, 23 had not been given any fluid since birth and the remainder had vomited what had been given. Only 2 babies in the group without obstruction had not been given oral feeds since birth.

When TBW is expressed as a percentage of body weight or as litres of water against body weight, the difference in the correlation coefficients between

the two groups of obstructed and nonobstructed babies is not significant. When body water is expressed as a percentage of body weight, this is a percentage of total water and total body solids, whereas when it is expressed as litres of water against weight, variation in body solids is not such a complicating factor.

Discussion

The deuterium oxide dilution method is probably the most accurate available method of measurement of total body water, since there is only a small amount of exchange of deuterium with labile hydrogen ions in proteins and carbohydrate, and only a small percentage of the water in bone and in the gastrointestinal secretion fails to reach equilibrium within 2 hours.

The mean value for TBW of 77.03% of body weight over a range of 1.332 to 3.692 kg in this whole series of 55 babies admitted for the treatment of various surgical emergencies compares well

TABLE III
Total Body Water (TBW) in Neonates with and without Intestinal Obstruction

	No. of Cases	Mean Weight at Time of Estimation	Length	Age (hr) at Time of Estimation	TBW (ml/kg)	TBW (l.)	Correlation Coefficient (<TBW as % of Body Weight Against Weight)	Correlation Coefficient (TBW in litres against Weight)
Obstructive	37	2.469 ± 0.092	46.92 ± 0.7	34.91 ± 3.5	770.1 ± 7	1.884 ± 0.060	-0.7528	0.9813
Nonobstructive	13	2.747 ± 0.199	47.20 ± 1.35	39.94 ± 6.3	784.5 ± 1.46	2.126 ± 0.130	-0.7788	0.9711

with the 77.0% over a range of 2.5 to 4.0 kg reported by Friis-Hansen (1965) and 80.0% over a range of 2.001 to 2.435 kg (Clapp, Butterfield, and O'Brien, 1962), both also made with the D_2O dilution method in normal babies. McLaurin (1966), who used antipyrine, found TBW was 71.5% of a mean body weight of 2.46 kg. Friis-Hansen (1969) found that the reported values obtained by the chemical analysis of whole cadavers ranged from 83.0% for a 1.5 kg body to 73.0% at 3.5 kg. It is difficult to compare these more recent observations and our own with the results of earlier studies because of the lack of some of the essential data about weight and maturity at birth.

The good correlation between total body weight whether expressed as a percentage of body weight or in litres against body weight is similar to that found for total body water and extracellular fluid by Clapp *et al.* (1962), McLaurin (1966), and Cassady (1970), and suggests that there is not much disturbance of water content in the neonates with obstruction of the alimentary tract or other abnormalities which we have studied. On the whole the obstructed babies had lost more weight than the others, and this was probably due to the combination of starvation and fluid loss. Widdowson (1960) calculated that the starving neonate loses water and solids in about the same proportion as those in which they are present in the body at birth, and that in both premature and term babies the percentage composition of the body after two days of starvation is much the same as it was at birth. In the surgical management of neonates with oesophageal or duodenal atresia, it is of considerable importance to know that the total body water content is within the normal range for weight at birth and for up to 3 days thereafter, in spite of starvation and the lack of water intake. The maintenance of metabolism depends on the endogenous provision of energy derived from the oxidation of existing fat deposits, muscle protein, and the small quantity of available glycogen. The small indispensable requirements of water for insensible water loss and minimum urine formation can be provided from fat and protein catabolism and some loss of water from otherwise intact cells, consequent on the mobilization of potassium from them and its excretion in the urine. Little sodium

is lost from the body except in vomited secretions; though maximal sodium conservation by the kidneys seems to depend on the provision of sufficient exogenous calories, very little is lost in the urine even by the starving neonate (Wilkinson, Stevens, and Hughes, 1962). Though the total water content of the starving neonate falls, it seems to do so in proportion to reduction in other measurable constituents unless there are large extrarenal losses of water and minerals. More information is clearly needed about the coincident changes in the body contents of sodium and potassium.

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