WATER DIURESIS IN CHILDREN AGED 1-3 YEARS

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It is now well established that newborn animals and infants are unable to excrete as great a percentage of a test dose of water as adults of the same species (Table 1). The age at which this function of the kidney matures in human beings has been varyingly assessed as 3 months (Ames, 1953) to between 6 and 10 years (Ohlmann, 1920). It therefore seemed of interest to see what percentage of a water load given by mouth is excreted by children aged 1-3 years, especially as this may be of clinical interest in controlling intravenous fluid therapy in this age group.

Moreover the choice of parameter for comparing renal functions in adults and infants is still in doubt. McCance and Widdowson (1952) advocate in theory the use of total body water as a parameter but in practice use body weight. Smith (1951) states that 'there is no *a priori* basis upon which to select any one standard of reference, body weight, surface area, or kidney weight'. However, Smith has some slight preference for kidney weight, and he points out that in man the correlation between kidney weight and surface area is greater than between kidney weight and height or body weight. Other workers (Barnett, Vesterdal, McNamara and Lauson (1952), Calcagno, Rubin and Weintraub (1954) prefer to use body surface as a measure of comparison between renal functions of adults and infants. Barnett *et al.* (1952) state that the failure of others to observe water diuresis in young infants may have been due to 'comparison being made between adults and infants who were given doses of water equivalent on a weight rather than a surface basis'.

In view of these difficulties two parameters (body weight and surface area) were used in the present investigation.

TABLE 1

WATER DIURESIS IN NEWBORN ANIMALS AND IN MAN

Species	Age	Authors	Water Load (ml./100 g. Body Weight)	% Water Load Excreted	Period of Observation (min.)
Rat	1–2 days 7–8 days 14–16 days Adults	Heller (1947, 1951)	4–5	20 (approx.) 30 (approx.) 55 (approx.) 85 (approx.)	145
	Newborns 4 days 12 days Adults	McCance and Wilkinson (1947)	5	13·4* 40·8* 55·0* 39·2*	180
Guinea-pig	Newborn Adult	Dicker and Heller (1951)	5	50 115	180
Dog	2 days 8 days 25 days	Adolph (1943)	5	40 (approx.) 80 (approx.) 100 (approx.)	240
Man	Newborn 3 days 7 days	Ames (1953)	3	10 (approx.) 35 (approx.) 50 (approx.)	180
	6–18 days Adults	McCance *et al.* (1954)	5	55 (approx.) 95 (approx.)	240
	Newborns to 3 months old	Aschenheim (1919)	200 ml. per child	23–77 (approx.)	240
	Newborns—3 months old	Ohlmann (1920)	200 ml. per child	70 (approx.)	240
	3–6 months old		200 ml. per child	80	

* Recalculated from data.

Methods

The renal response to water was tested by the method of Fishberg (1939). Sixteen children were the main subject of the investigation, none of them had any evidence of renal, hepatic or cardiac disease and they were all at the end of a period of convalescence. They were fasted overnight (12 hours) and on the following morning a catheter was inserted. Eight children were then given 860 ml. water/m.^{2} body surface by stomach tube. A further eight children received 22·0 ml. water/kg. body weight. The total water load of five children included in the latter group contained 25 ml. of deuterium oxide. Virtual deuterium space was calculated from the deuterium concentration of specimens of urine obtained between the second and third hours after the water load had been given. Urine specimens were collected hourly. Deuterium was estimated by a photoneutron method (Haigh, 1954; Haigh and Schnieden, 1956). Nine healthy adults were also tested after a similar overnight fast. These lay down on reaching the laboratory and only got up to pass urine. Following the procedure of McCance, Naylor and Widdowson (1954) they were not catheterized. Urinary osmotic pressure was measured by estimating freezing point depression. The specific gravity of the urine was estimated using an urinometer but when the volume of urine for estimation was small the method of Heller (1940) was used. Four children and one adult were rejected from the series because they vomited following the administration of water.

Results

Tables 2-4 show that the maximum concentrations of urines obtained from the children after

TABLE 2

RENAL RESPONSE TO A WATER LOAD OF 860 ML./M^2 BODY SURFACE IN ADULTS

Patient No.	Sex	Age (Yr.)	Diagnosis	Total Water Load (ml.)	Water Load (ml./kg.)	% Water Load Excreted in 3 Hours	Maximum Concentration of Urine (Sp.G.)	Minimum Concentration of Urine (Sp.G.)
1	M	22	Healthy adult	1,720	20·2	109	1·023	1·002
2	M	35	,, ,,	1,560	22·5	106	1·024	1·001
3	M	24	,, ,,	1,500	26·0	103	1·024	1·001
4	M	23	,, ,,	1,500	22·0	111	1·024	1·002
5	M	19	,, ,,	1,600	25·6	118	1·012	1·001
6	M	27	,, ,,	1,500	22·0	107	1·020	1·001
7	M	23	,, ,,	1,650	22·1	110	1·023	1·002
8	M	21	,, ,,	1,560	22·8	85	1·025	1·001
9	M	29	,, ,,	1,590	24·2	104	1·017	1·001

TABLE 3

RENAL RESPONSE TO A WATER LOAD OF 860 ML./M^2 BODY SURFACE IN CHILDREN

Patient No.	Sex	Age (yr.)	Diagnosis: Convalescent from	Total Water Load (ml.)	Load (ml./kg.)	% Water Load Excreted in		Maximum Concentration of Urine		Minimum Concentration of Urine	
						3 Hours	4 Hours	Sp.G	mosM/1	Sp.G.	mosM/1
10	M	2 2/12	Bronchopneumonia	430	32·6	82	84	1·021	813	1·001	65
11	F	2 1/12	Primary T.B.	450	35·5	93	95	1·022	796	1·001	59
12	M	2 2/12	Tonsillitis	430	38·5	81	82	1·002	748	1·002	45
13	M	2 2/12	Cervical gland	437	42·0	77	82	1·025	824	1·002	97
14	F	2 11/12	Bronchopneumonia	500	36·9	89	91	1·023	749	1·002	48
15	M	2	Gastroenteritis	450	38·2	104	105	1·016	792	1·001	86
16	M	2 6/12	Bronchopneumonia	470	36·1	101	104	1·017	623	1·001	54
17	M	1 10/12	Bronchopneumonia	370	31·2	64	69	N.D.	N.D.	1·003	161

TABLE 4

RENAL RESPONSE TO A WATER LOAD OF 22 ML./KG. BODY WEIGHT IN CHILDREN

Patient No.	Sex	Age	Diagnosis : Convalescent from	Total Water Load (ml.)	Water Load (ml./m.)	Water Load Excreted in		Maximum Concentration of Urine		Minimum Concentration of Urine	
						3 Hours	4 Hours	Sp.G.	mosM/1	Sp.G.	mosM/1
18*	F	2 6/12	Otitis media	235	47·0	60	67	1·020	714	1·003	134
19*	M	1 5/12	Upper respiratory infection	210	44·5	113	118	1·019	732	1·001	54
20*	M	2 9/12	Admitted ? petit mal, no evidence found	275	45·5	103	108	1·015	670	1·001	62
21*	F	1 2/12	Pneumonia	220	50·0	73	78	1·024	870	1·001	62
22*	F	2 7/12	Otitis media	255	52·1	85	N.D.	1·017	660	1·001	154
23	M	2 9/12	Anaemia	272	46·5	101	109	1·023	790	1·001	51
24*	M	1 7/12	Pneumonia	215	53·1	88	100	1·021	754	1·003	129
25	M	2 5/12	Bronchitis	268	48·5	54	59	1·024	615	1·003	97

* These children were given deuterium oxide.

withdrawal of food and water for 12 hours does not differ significantly from those in adults (mean ±S.E.: adults, 1·022±0·002; children, 1·021±0·002), t=0·5, P>0·5).

The minimum concentration of urine obtained in the adults varied between a specific gravity of 1·001 and 1·002 whilst the minimum concentration in children varied between 1·001 and 1·003.

Fig. 1 shows that infants aged 1½-3 years who

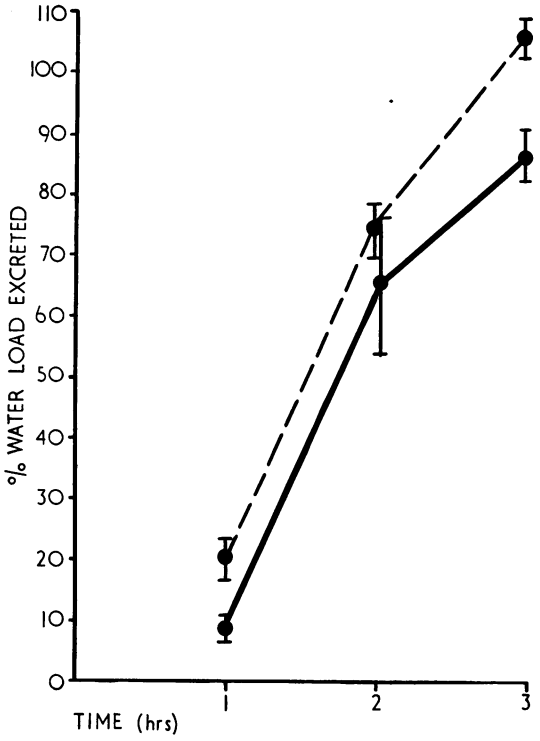

FIG. 1.—The renal response (mean±S.E.) to water of a group of eight children between the ages of 1½ and 3 years.
● - - - ● adults. ● ——— ● children.

were given a water load of 860 ml./m² did not in three hours excrete as much of their water load as adults (mean±S.E.: adults, 105·9±3·0; children, 86·4±4·6, t=3·63, P>0·001). The difference remains significant (children, 89·5±4·0; adults, 105·9±3·0, t=3·3, P>0·001), even if infant 17, who was under 2 years old, is excluded. In fact Tables 2-4 show that the percentage of the water load excreted by the children in four hours did not quite attain that excreted by the adults in three hours.

Children of the same age group who were given a water load of 22 ml./kg. excreted in three hours 84·6±5·8% of their water load only and in four hours 91·3±8·7% as compared with the excretion of 105·9±3·0 by adults in three hours. The difference is again significant at three hours (t=3·2, P>0·001).

The mean virtual deuterium space in five infants was 62·6±1·7% of the total body weight (Table 5). These results are in good agreement with those of Friis-Hansen, Holiday, Stapleton and Wallace (1951) who found that in five children aged 1 year 3 months to 3 years 10 months, deuterium space varied between 58·2 and 62·8% of their body weight.

Discussion

The results obtained indicated that in children up to the age of 3 years the capacity for water diuresis lay between that of newborn infants and adults although it clearly approached that of adults rather than of infants. This conclusion applied whether the water load was given in relation to surface area or to the body weight of the child.

McCance *et al.* (1954) advocated the use of total body water as a parameter. Assuming, as they did, that a 70 kg. man has 42 litres of body water (equals 60% of the body weight), a water load of 1,500 ml. (which equals a load of 22·0 ml./kg. body weight or 860 ml./m² if the surface area of such a person is taken as 1·73 m²) represents a water load per litre of body water of 35·5 ml. In the present series the water load per litre of body water given to infants 18-24 varied from 32·5 to 38·5 ml. (mean±S.E., 35·2±1·1). This suggests that the water load per litre body water was much the same in the experiments on adults (Table 2) as in the children of group 18-25, although there was a significant difference in water diuresis.

The results of this investigation are more in keeping with those of Ohlmann (1920) than those of Ames (1953). The former found that five children aged between 1 and 4 years excreted an average of

TABLE 5
VIRTUAL DEUTERIUM SPACE (TOTAL BODY WATER) IN FIVE CHILDREN

Patient No.	Virtual Deuterium Space (% body weight)	Total Water Load (ml.)	Water Load/Litre Body Water
18	56·9	235	38·5
19	64·8	210	34·0
20	61·2	275	36·0
21	62·1	220	35·1
24	67·9	215	32·5

68% of their water load. However, the procedure employed by Ohlmann (1920) differed appreciably from that of Ames (1953): Ohlmann gave 400 ml./child whilst Ames gave 30 ml./kg. body weight.

Other tests of kidney function suggest that renal maturation is not complete for several years after birth. Smith (1951) states that the inulin clearance, the renal plasma flow and the maximal rate of tubular p-aminohippuric acid excretion do not attain adult levels until the child is at least 2 years old.

It may be argued that the children investigated were not healthy. Whilst it is not denied that they all had been recently ill, they had all recovered and were fit for discharge on the day after the test. It is unlikely therefore that the difference of approximately 20% found between the urinary excretion of water by the children and adults is due to their previous illness. But since, as Heeley and Talbot (1955) have shown, the insensible water loss per day is considerably higher in infants than in adults, it may have been due to that difference.

Summary

The renal response to water of 16 children between the ages of $1\frac{1}{2}$ and 3 years was tested. Eight children received a water load of 860 ml./m^2 body surface, the others a water load of 22·0 ml./kg. body weight. The children concentrated their urine as well as adults but, in contrast to adults, did not excrete a volume of urine equal to that of the test dose within three hours. The virtual deuterium oxide space in five children was determined. The question of parameters for the study of kidney functions is discussed.

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