SERUM MAGNESIUM LEVELS IN ACUTE GASTROENTERITIS IN CHILDHOOD

By Freda M. Paul, M.B.B.S. (Malaya), M.R.C.P. (Edin.), F.R.F.P.S. (Glas.), D.C.H. (Lond.)
(Department of Paediatrics, University of Singapore)

and

Donough O'Brien, M.D. (Cantab.), M.R.C.P. (Lond.), D.C.H. (Lond.)
(Department of Paediatrics, University of Colorado Medical Center, U.S.A.)

Magnesium is the fourth most abundant cation in the body and is second only to potassium in the intracellular water of soft tissues. In the past, however, the laboratory measurement of the small amounts of magnesium normally present in the plasma has been both cumbersome and not overly accurate. Now that these problems have been overcome by the use of flame photometric or fluorometric techniques, it is increasingly apparent that magnesium deficiency, at least as defined by low serum magnesium levels, is characteristic of a number of clinical states. The commonest in children are gastroenteritis, the malabsorption syndromes, protein caloric malnutrition, chronic renal disease, the renal tubular dystrophies and occasionally in the newborn, in diabetic acidosis, and in hyperparathyroidism. Hypermagnesemia is also recorded in renal failure.

Magnesium levels are still rather infrequently measured and for this reason information on the content and severity of hypomagnesemia in the above conditions is limited. The purpose of this study was to assemble information on serum magnesium levels in cases of severe gastroenteritis in children of a mixed Malay and Chinese population and to correlate these findings with other distortions of the extracellular electrolyte pattern as well as with the initial clinical state and the outcome.

CLINICAL MATERIAL, METHODS AND RESULTS

The subjects were 83 children aged 1 to 1½ months to 7 years, who were admitted to the wards of the Department of Paediatrics at the Singapore General Hospital suffering from severe gastroenteritis. Venous blood samples were taken for the most part within twenty-four hours of admission, and occasionally at a later stage. In no instance had magnesium been previously intravenously administered. The blood was immediately spun down and the plasma transferred to 400 ml capped plastic tubes. The samples were refrigerated and subsequently analysed for sodium and potassium by a conventional flame photometric technique, for the chloride electrometrically for magnesium and calcium fluorimetrically as described by O'Brien and Ibbott.

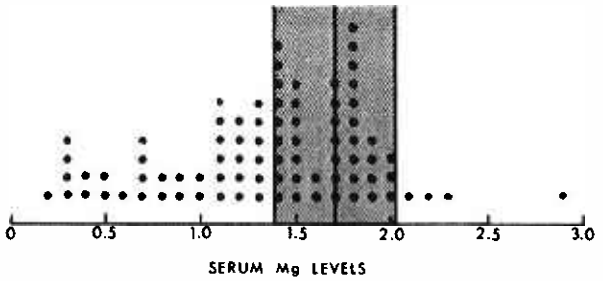

Figure 1

Blood samples from eighteen healthy normal children of the same age and ethnic distribution were similarly analysed to provide control data. The results are set out in Tables I and II and in Figure I. These show that the mean magnesium level in the cases of gastroenteritis was significantly below that of the normal ($p = 0{\cdot}01$). In individual terms 39 out of 83 cases had serum magnesium levels which were more than two standard deviations below the normal mean. Despite the high incidence of hypomagnesemia there was no apparent correlation between magnesium levels and sodium or potassium levels. There was however, a highly significant ($P = 0{\cdot}001$) positive correlation ($r = 0{\cdot}9$) between serum calcium and magnesium levels. It was also apparent that neither the severity of the illness nor its outcome could be predicted on the basis of the serum magnesium level.

DISCUSSION

The role of hypomagnesaemia in the various forms of the malabsorption syndrome is still obscure. Fitzgerald and Fourman have shown

TABLE I

P. No.	Reg. No.	Diagnosis	Sex	Age	State of Hydration ·/A.	Day Blood Taken After Admission	Na	K	Cl	HCO_3	Ca	Mg	Comments
55242	077663	G.E. with peritonitis	M	2 yrs	2· dehydration	2nd day	125	3·9	90			1·4	Died P.M. Peritonitis
55238	077652	G.E. with severe dehydration	F	2 yrs	Dehyd., acidotic	3rd day						2·0	Improved
54709	075388	G.E. with acidosis	F	11/2 yrs	Dehyd., acidotic	1st day	143	1·3	120		9·3	1·8	Improved
55233	077341	G.E. with dehyd.	F	2 yrs	dehyd., 2·	1st day	135	2·2	125		-	0·4	Improved
55095	077170	Post measles. bronch. pneumonia with card. failure & G.E.	M	7 yrs	Dehyd., acidotic	2nd day	135	5·8	121	6vol%	9·4	1·7	Improved
55140	077329	Encephalitis with diarrhea	F	21/2 yrs	Dehyd., acidotic	2nd day	135	4·4	111	28	7·5	1·4	Improved
55136	077321	G.E.	M	9 yrs	Mild dehyd.	1st day	143	6·1	115	24	8·8	1·0	Improved
54709	-	G.E.	M	2 yrs	2nd deg. dehyd.	-	131	4·2	109	-	-	0·5	Improved
54973	076638	G.E.	M	6 yrs	Dehyd., acidotic	1st day	131	4·2	109	41	7·3	0·3	Improved
55429	078225	G.E.	F	2 yrs	Dehyd., 2·	2nd day	-	-	-	-	-	1·7	Improved
55371	078030	G.E.	M	2 yrs	Dehyd., acidotic tetany	1st day	-	-	-	-	-	1·5	Died. No P.M.
55373	078034	G.E.	M	7 yrs	Dehyd., 1·	-	-	-	-	-	-	1·5	Improved
55133	077306	Emphyema L. chest staph with G.E.	M	7 yrs	Dehyd.	10th day	-	-	-	-	-	1·7	Improved
55387	078086	G.E. with dehyd.	M	1 yr	Dehyd., 2·		-	5·2	-	-	8·7	1·1	Improved
54910	076494	G.E.	F	4 yrs	Dehyd., 2·	3rd day	-	-	-	-	-	0·7	Improved
55364	077996	Pneumococcal meningitis with G.E.	M	9 yrs	Dehyd., 1·		-	-	-	38		1·4	Died of P. Meningitis
55896	079773	G.E. Severe dehyd. and acidosis	F	10 mths	Severe dehyd. acidosis	1st day	-	-	-	-	-	1·3	Improved
56115	080423	Encephalitis	M	4 yrs	Encephalitis	5th day	133	3·8	99		8·8	1·7	24.9.62 Discharged

TABLE I (Continued)

P. No.	Reg. No.	Diagnosis	Sex	Age	State of Hydration ·/A.	Day Blood Taken After Admission	Na	K	Cl	HCO_3	Ca	Mg	Comments
55387	078086	G.E.	M	1 yr	Dehyd. 3· acidotic	2nd day	141	2·8	109		9·2	1·2	Improved
55720	079143	G.E.	F	11 mths	Dehyd. 3· acidotic	3rd day	133	2·8	81	51	6·6	0·8	Improved
55782	079325	G.E. and worms	F	3 yrs	Dehyr. 1·	1st day	137	4·2	109			0·5	Improved
56562	081889	G.E.	F	18 mths	G.E.	1st day	-	-	-			1·3	Improved
56563	081896	G.E.	M	1 yr	Dehyd. 2·	1st day	-	-	-			1·2	Improved
56578	081953	G.E.	M	10 mths	Dehyd. 1·	1st day	139	3·7	115		7·3	0·4	Improved
56612	082061	G.E.	M	4½ mths	Dehyd. 1·	1st day	122	4·6	113		9·8	0·9	Improved
56615	082070	G.E.	M	17 mths	Dehyd. 2·	1st day	104	1·2	84			1·8	Improved
56618	082088	G.E.	M	6 mths	Dehyd. 1·	1st day	133	3·2	112		9·1	0·9	Improved
56633	082138	G.E.	F	4 mths	Dehyd. acidotic	2nd day	-	-	-	-	-	1·8	Improved
56578	081953	G.E.	M	10 mths	Dehyd. 1·	3rd day	135	2·9	107		Insuff.	1·8	Improved
55960		G.E.	M	1 yr	Dehyd. 1·	1st day	-	-	-			1·7	Improved
56751	083417	G.E.	M	9 mths	Dehyd. 2·	2nd day	131	2·6	105			1·7	Improved
56888	082683	G.E.	M	5 yrs	Dehyd. 2·	1st day	127	3·9	98	34	8·8	1·3	Improved
56884		G.E.	-	-	-							1·8	Improved
57012	083070	G.E.	F	14 mths	Not dehyd.	1st day	127	2·3	101		9·7	1·9	Improved
57024	083088	G.E.	M	2 mths	Dehyd. 1·	1st day	127	2·3	101		9·7	1·9	Improved
57018	083077	G.E.	M	5 yrs	Dehyd. 1·	1st day	120	5·3	96		8·3	1·3	Died
57148	083160	G.E. Bpnic	M	7 mths	Dehyd. 3·	1st day	135	4·4	107		10·6	1·2	Improved
57043	083141	G.E.	F	6 mths	Dehyd. 2·	1st day	146	4·5	110		7·0	0·3	Died of Broncho-pneumonia
57097	083520	G.E.	F	2½ yrs	Dehyd. acidotic	1st day	-	-	-			2·0	Improved
57481	084622	G.E.	M	9 mths	Dehyd. 1·	1st day	137	4·2	109			1·6	Died
58015	086268	G.E.	M	2 yrs	Not dehyd.		139	5·2	105		8·6	1·2	Improved
57991	086207	G.E.	M	7 yrs	Dehyd. 3· acidotic	1st day						1·5	Improved
58011	086246	G.E.	M	6 mths	Dehyd. 1·	2nd day	125	3.4	96	57		1.9	Improved
58014	086256	G.E.	F	6 mths	Dehyd. 2·	2nd day						1·8	Improved

TABLE I (Continued)

P. No.	Reg. No.	Diagnosis	Sex	Age	State of Hydration ·/A.	Day Blood Taken After Admission	Na	K	Cl	HCO_3	Ca	Mg	Comments
58455	087466	G.E.	F	11/2 mths	Dehyd. 2·	1st day	-	-	-	-	-	1·4	Improved
58454	087465	G.E.	M	4 mths	Dehyd. 3· acidotic	1st day	-	-	-	-	9.4	1·1	Improved
60086					Dehyd. 2·	1st day	-	-	-	-	-	1·5	Improved
60073	092601	G.E.	M	5 mths	Dehyd. 2·	1st day	-	-	-	-	-	1·8	Improved
60093	092672	G.E.	M	10 mths	Dehyd. 1·	2nd day	-	-	-	-	9·4	1·9	Improved
60091	092667	G.E.	M	10 mths	Dehyd. 4· acidotic	2nd day	-	-	-	-	-	1·8	Improved
60135	092814	G.E.	M	5 yrs	Dehyd. 3· acidotic	1st day	127	5·0	101	-	-	1·4	Improved
60224	093127	G.E.	M	2 yrs	Dehyd. 1·	1st day	-	-	-	-	-	0·7	Improved
60220	093113	G.E.	M	3 mths	Dehyd. 3· acidotic	1st day	141	4·2	107	39	8·5	1·2	Improved
	093154											1·0	Improved
46844	049942	Febrile fit	M	1 yr	Dehyd. 3· acidotic	1st day	141	4·2	107	39	8·5	1·8	Improved
61264	096587	Acute Broch. G.E., Meth.	F	1 yr	Dehyd. 1·	1st day	125	3·3	96	-	-	1·4	Improved
61680	098009	G.E.	M	1 yr	Dehyd. 1·	1st day	-	-	-	-	-	1·5	Improved
	097023						-	-	-	-	-	1·1	Improved
62537	101028	G.E.	M	6 mths	Acidotic							1·4	Improved
62652	101398	Bronchopneu. with worms	M	5 yrs	Dehyd. 3·	1st day	135	4·2	98	45		1·1	Improved
62730	101650	G.E.	M	2 mths	Dehyd. 1·	1st day	135	3·9	84	-	8·5	1·5	Died
62368	100354	G.E.	F	2 mths	Dehyd. 3· acidotic	1st day	-	-	-	-	-	1·8	Improved
62737	101666	G.E.	M	9 mths	Dehyd. 2·							1·5	Improved
62574						1st day	-	-	-	-	-	0·2	Recovered; in spite of low level
63681	104370	G.E.	M	11 mths	Dehyd. 2· acidotic							0·7	Improved
63682	104371	G.E.	F	2 yrs	Dehyd. 2· acidotic	1st day	-	-	-	16	-	1·1	Improved

TABLE I (Continued)

No. P.	Reg. No.	Diagnosis	Sex	Age	State of Hydration ·/A.	Day Blood Taken After Admission	Na	K	Cl	HCO_3	Ca	Mg	Comments
65381	109496	G.E.	M	2 mths	Dehyd. 1·	1st day	-	-	-	43	-	1·1	Died
65377	109506	G.E.	F	10 mths	Dehyd. 1·	1st day	133	5·9	109	-	-	2·9	Improved
65365	109461	G.E.	F	7 mths	Dehyd. 2·	2nd day	-	-	-	-	-	2·3	Improved
65544	109900	G.E.	M	7 mths	Dehyd. 2· acidotic	2nd day	-	-	-	-	-	1·4	Improved
65504	109831	G.E.	M	11 mths	Dehyd. 2·	1st day	-	-	-	-	9·7	0·6	Recovered
65628	110147	G.E.	M	11 mths	Dehyd. 2·	1st day	131	2·1	98		9·5	2·2	Improved
64646	110226	Bronchopneu. with G.E.	F	2 yrs	Acidotic	1st day	-	-	-	-	10·3	1·6	Improved
65712	110586					1st day	129	4·9	118	25	9·0	1·4	Improved
65781	110586	Bronchopneu. with G.E.	F	4 mths	Dehyd. 2· acidotic	1st day	-	-	-	-	-	1·3	Improved
65970	112147	G.E.	F	6 mths	Dehyd. 2· acidotic	1st day	-	-	-	21	8·9	0·7	Recovered
65965	112130	G.E. Bronpne.	F	11 mths	Dehyd. 2·	1st day	139	4·5	108	13	7·6	1·3	Died
66087	112400	G.E.	F	16 mths	Dehyd. 3· acidotic	-	-	-	-	-	-	2·1	Well
66076	112388	G.E.	F	9 mths	Dehyd. acidosis, tetany	1st day	-	-	-	-	-	0·3	Low level but well
66156	111113	G.E.	M	16 mths	Dehyd. acidotic	1st day	131	3·9	99	-	-	0·3	Low Level; but well
66337	111576	G.E.	M	2 yrs	Dehyd. 3· acidotic	-	139	3·5	101	36	8·3	2·0	Transferred to Middleton Hospital
66510	112671	Measles, Bropneu G.E.	M	6 mths	G.E. with dehyd.	1st day	-	-	-	19	11·2	0·8	Improved
56253		G.E. with fits	F	1 yr	Dehyd.	1st day	133	4·5	100	17	-	1·9	Well Calcium normal but had fits? Due to low magnesium

1° dehydration — mild
2° dehydration — moderate
3° dehydration — severe

TABLE II

SERUM MAGNESIUM LEVELS AND CORRELATIONS

(in mEq/l.)

Subject	n[1]	Mean ± I.S.D.[2]	Correlation coefficient[3]	p
Normals	18	1·70 ± 0·17	-	< 0·01
Gastroenteritis	83	1·35 ± 0·53	-	
Gastroenteritis	31	correlation viz serum calcium	0·91	< 0·001

1 n = number of subjects

2 S.D. = standard deviation = $\sqrt{\varepsilon x^2 / n - x^2}$

3 Correlation coefficient = $(\varepsilon xy/n) - x.y/sx.sy$

4 p = significance of difference between two means by the Aspen Welch test (Biometrika 42:203, 1950) or r/SE_r referred to the table of the normal curve for the correlation coefficient.

that it is extremely difficult to produce magnesium deficiency in normal man even with the use of severely restricted magnesium intake coupled with ion-exchange resins. Balint and Hirschowitz have not found significant hypomagnesaemia in patients with chronic non-specific diarrhoea, including post-gastrectomy steatorrhoea and the reason for the relatively frequent association of hypomagnesia with sprue remains obscure. Montgomery (1960) showed that in 27 cases of Kwashiokior there was no correlation between the clinical state and the degree of magnesium depletion and no symptoms could be directly attributed to it. His studies on Jamaican infants suffering from Kwashiokior showed that the deficiency was no greater in the ten fatal cases than in the survivors. MacIntyre (1963) showed that magnesium deficiency in man also occurs in renal tubular acidosis, and it has also been reported in diabetic acidosis by Dans, Harvey and Yu. (1965). Randall, Cohen, Spray and Rossmeisl (1964) have recorded hypermagnesia in renal failure. The precise mechanism in which magnesium excess produces the manifestations of toxicity is not well understood. However, tolerance of high serum magnesium is considerable and only about 10 mEq/litre does respiratory failure and heart block occur. About half of the total body magnesium is contained in bone and the remainder exists primarily in the intracellular water of soft tissue. In this locus magnesium acts as a co-factor in a wide spectrum of enzyme reactions. (Wacker and Vallee). Intracellular magnesium levels in animals appear to be much less labile than those for potassium although active equilibration with extracellular magnesium is known to occur. (Watchorn and McCance 1937). The factors which govern the balance between magnesium inside and outside the cell are very far from being understood and because of this the syndrome of magnesium deficiency has been hard to separate from the impact of other coincidental electrolyte disturbances. Nevertheless, such a syndrome has been defined (Hanna, Harrison, MacIntyre and Fraser 1960) and is seen to consist of weakness, irritability, a positive Chvostek's sign with a negative Trousseau's sign, ataxia, tremors and ultimately convulsions.

None of the children in this series had convulsions or other overt symptoms despite occasionally very low magnesium levels. It would, therefore, appear that the magnesium deficiency was of secondary import clinically. The actual aetiology of the low magnesium levels in gastroenteritis is probably multiple. Many of these children also showed signs of protein malnutrition and it would be reasonable to suppose that they also had an intracellular magnesium deficiency (Montgomery 1960). It has been shown by Colby and Frye (1951) that the high level of protein in diet increased the severity of the magnesium deficiency syndrome in rats. A low protein diet on the other hand would be expected to improve magnesium absorption supposing it to be adequate in the

diet. The actual inflammatory condition of the bowel though may also prevent effective magnesium absorption. The clear-cut relationship of serum magnesium to calcium is of considerable interest in view of the commonly held idea that these two cations compete for transport sites across the renal tubular and bowel epithelium. This can, however, occur in steatorrhoea and the suggestion has been made that it is due to coincidental vitamin D deficiency (Mereu et al 1962).

Despite the absence of overt clinical symptoms specific to magnesium deficiency the high incidence of hypomagnesia would justify treatment on its own account. It is not always practical to measure magnesium levels; for this reason magnesium should be included in polyelectrolyte solutions. Arbitrary decisions on the dose of replacement magnesium must, as with potassium, be judged on experience; because without elaborate technical methods neither the intracellular deficiency nor its rate of restoration can be judged. Montgomery (1960) has shown that the dose successful in suppressing convulsions is that which restores magnesium in extracellular volume. However, since hypermagnesia rarely seems to have significant clinical implications, the dangers of overdosage are small (Randall 1960). Assuming a twenty per cent loss of extra cellular water in the average case of gastroenteritis, an approximate prophylactic regimen would include 1·0 mEq/kg/24 hrs of Mg++ for as long as intravenous therapy is required.

CONCLUSIONS

Significant hypomagnesia was detected in 47% of a group of Malay and Chinese children with acute gastroenteritis. The depression of the magnesium value, however, did not correlate either with sodium, potassium or calcium levels or with the clinical severity of the illness. However, these findings justify the addition of magnesium to polyelectrolyte resuscitating solutions and is recommended for the management of gastroenteritis.

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