4. Title: Erythrocyte Composition in Malnourished Children.

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Background Body composition of malnourished children had been observed to be markedly altered, in particular to electrolyte metabolism. Hyponatremia, hypokalemia, hypomagnesemia and hypocalcemia were the most common findings. Muscle biopsy revealed an increase in cell water and sodium while potassium and magnesium were decreased. These changes could be reversed after proper therapy.

Since malnutrition is a major pediatric problem in Thailand and mortality rate in patients suffering from protein–caloric malnutrition (PCM) is still high, this study will provide data on erythrocyte composition of Thai malnourished children which represents the composition of general body cells. This may lead to the understanding of pathologic physiology of protein–caloric malnutrition and the appropriate therapeutic measures can be established.

Objective To describe the erythrocyte composition and its relation to plasma water and solute concentrations in patients suffering from protein–caloric malnutrition.

Description Patients who were diagnosed PCM and admitted to the Pediatric Ward, Chulalongkorn Hospital were included in the study. The criteria for diagnosis are as follows: low body weight, generalized edema with low serum albumin without evidence of other causes, history of low protein intake, and improvement after good dietary intake.

Routine hospital work-up, history taking, physical examination, routine blood, urine and stool examinations, and chest X–ray were performed in each patient. Blood specimens for this study were obtained on admission, during therapy (at the time when the edema subsided) and before being discharged from the hospital.

The patients received intravenous fluid infusion, blood transfusion, antibiotics and high protein diet as needed. The treatment was given by the attending pediatricians.

Progress Twenty–seven malnourished children of different degree of severity were studied. Their ages ranged from 6 months to 3 years. Due to uncontrolled circumstances, the study was completed on only 8 patients

Table 1 shows the data on plasma electrolytes, protein and alkaline phosphatase of 8 patients. The plasma Ca^{++} and Mg^{++} were lower than normal on admission in patients 3, 4, and 6. The plasma K^{+} was also low in cases 3 and 6. The phosphorus level was low in all except patients 1 and 6.

Table 2 shows the red blood cell water and solute contents and concentration. The results can be summarized as follows:

1. The sodium content and concentration were high in all patients except cases 2 and 8.
2. Changes in the Na^{+} and K^{+} concentrations were related to the red blood cell water which can be described as follows:
   a. An increase in cell water resulted in low Na^{+} and K^{+} concentrations in cases 2 and 8.
   b. A decrease in cell water resulted in high Na^{+} and K^{+} concentrations in cases 1, 3, and 7. The K^{+} content was decreased while the Na^{+} content and concentration was increased. The sodium entered the cell in exchange with potassium during the phase of cell dehydration which lead to high K^{+} concentration.
   c. An increase in cell water was associated with high cell Na^{+} and K^{+} content (cases 4, 5). The solute–gain was out of proportion to water which lead to high K^{+} and Na^{+} concentrations. Increases in cell water associated with high Na^{+} and low K^{+} concentration was observed in Case 6.

Table 1. Plasma Electrolytes in Protein—Calorie Malnourished Infants

Subjects		Plasma mEq/L				Mg%		Magnesium	Plasma Protein			Alkaline Phosphatase Sigma Unit
		Na^+	K^+	Cl^-	$CO_2^=$	Ca^{++}	$P^{\equiv}$		Total gm%	ALB gm%	GLO gm%	
Cs 1												
2 yr old	A	144	3.1	102	25.7	8.9	4.6	1.76	5.9	2.4	3.5	not done
MILD to MOD	B	140	4.7	111	15.0	11.0	5.2	1.92	6.2	2.8	3.4	—
PCM ♀	C	138	5.0	109	17.6	9.9	5.0	2.08	6.2	3.2	3.0	—
Cs 2												
1 yr old	A	132	4.6	103	17.4	8.8	3.5	2.08	6.6	2.6	4.0	—
MILD	B	135	4.5	109	17.3	9.1	5.4	2.04	8.2	3.6	4.6	—
PCM ♀	C	138	5.5	106	17.6	10.0	5.5	2.09	7.5	3.5	4.0	—
Cs 3												
3 yr old	A	142	2.4	109	26.1	5.0	3.3	0.98	3.4	1.0	2.4	—
Severe	B	141	4.0	104	21.4	7.6	3.1	1.44	5.3	1.3	4.0	—
PCM ♀	C	142	3.1	108	24.7	8.1	4.1	1.39	5.1	2.0	3.1	—
Cs 4												
1 yr old	A	137	3.8	102	24.9	5.8	3.1	0.90	3.5	.9	2.6	—
Severe	B	136	4.5	107	17.4	9.4	5.4	1.81	7.3	2.9	4.4	—
PCM ♀	C	138	5.2	104	22.0	10.1	6.3	2.01	7.9	3.5	4.4	—
Cs 5												
2 yr old	A	132	3.3	99	23.1	7.2	2.9	1.48	4.2	1.2	3.0	1.6
MOD to Severe	B	133	4.4	108	19.1	6.9	2.8	1.35	4.0	1.4	2.6	1.9
PCM ♀	C	137	4.7	106	20.3	8.3	4.3	1.64	5.5	2.6	2.9	3.4
Cs 6												
3 yr old	A	133	1.9	91	23.2	5.3	4.2	1.06	3.7	0.9	2.8	3.1
Severe	B	142	2.7	99	30.1	7.7	3.4	1.34	5.8	2.0	3.8	2.9
PCM ♂	C	136	3.9	110	11.4	9.1	4.9	1.6	7.7	3.3	4.4	3.0
Cs 7												
10 Mo old	A	141	3.9	108	24.1	7.9	2.7	1.92	4.1	1.5	2.6	3.2
MOD to Severe	B	139	3.2	106	23.0	7.6	—	1.8	4.5	2.0	2.5	1.6
PCM ♂	C	142	3.8	108	19.3	8.1	4.2	2.08	4.8	2.4	2.4	3.9
Cs 8												
2–5/12 yr old	A	135	4.3	112	17.2	7.7	3.5	1.64	4.4	2.1	2.3	3.0
MOD to Severe	B	142	3.6	116	17.6	8.2	—	1.68	5.6	2.6	3.0	2.8
PCM ♀	C	141	4.2	112	18.3	8.9	4.0	1.64	6.2	3.8	2.4	4.6

A = Acute stage
B = During treatment, edema subcide
C = Recovery, before dismissal
D = Recovery

Table 2. Red Blood Cell solute in Protein—Calorie Malnourished Infants

Subjects		Sodium mEq Per			Potassium mEq Per			Magnesium mEq Per			RBC H_2O Gm Per	Whole Blood Hb	Whole Blood Hct
		Kg RBC	100 Gm Solids	Kg RBC H_2O	Kg RBC	100 Gm Solids	Kg RBC H_2O	Kg RBC	100 Gm Solids	Kg RBC H_2O	100 Gm Solids	Gm%	%
Cs 1													
2 yr old	A	9.9	3.4	14.0	96.8	33.0	136	5.88	2.0	8.32	241	6.7	24
MILD to MOD	B	8.2	2.7	11.6	100	34.2	141	4.84	1.66	6.84	242	7.6	29
PCM ♀	C	8.3	3.0	11.4	97.7	35.0	134	4.97	1.80	6.85	281	8.9	32
Cs 2													
1 yr old	A	12.4	4.0	17.9	92.6	29.8	134	4.89	1.58	7.08	223	8.3	31
MILD	B	12.7	4.2	18.2	91.8	30.3	131	4.85	1.60	6.94	231	9.5	30
PCM ♀	C	13.5	3.9	20.5	99.1	28.8	151	5.25	1.53	7.99	194	10.2	35
Cs 3													
3 yr old	A	16.2	4.9	23.9	95.0	28.9	141	4.2	1.28	6.25	204	4.6	15
Severe	B	13.2	4.1	19.3	90.4	28.4	132	5.7	1.79	8.35	214	6.5	20
PCM ♀	C	13.7	4.2	20.1	92.3	28.9	135	4.6	1.44	6.75	213	10.2	33
	D	6.0	2.1	8.5	96.6	33.2	136	4.6	1.58	6.48	243	10.6	32
Cs 4													
1 yr old	A	9.8	3.2	14.2	105.6	34.2	153	4.5	1.45	6.51	223	6.3	19.5
Severe	B	6.5	2.1	9.4	93.9	30.5	135	5.4	1.76	7.79	225	9.5	32
PCM ♀	C	7.8	2.2	11.9	93.5	27.2	142	5.7	1.66	8.67	191	10.4	34
Cs 5													
2 yr old	A	10.5	3.5	15.0	89.5	29.9	128	4.7	1.57	6.7	234	6.0	19
MOD to Severe	B	9.2	2.7	13.9	92.1	27.3	139	4.5	1.33	6.78	196	7.4	24
PCM ♀	C	6.7	2.1	10.3	81.1	24.6	121	3.97	1.2	5.91	203	9.7	29
Cs 6													
3 yr old	A	20.9	7.0	29.7	84.5	28.3	120	5.8	1.94	8.2	235	8.6	29
Severe	B	17.6	5.7	25.0	90.6	29.8	130	4.2	1.38	6.0	228	8.9	27
PCM ♂	C	8.0	2.6	11.6	95.0	30.5	137	4.5	1.44	6.5	221	10.2	32
Cs 7													
10 Mo old	A	9.0	2.8	13.2	99.8	30.9	147	4.5	1.69	8.0	210	7.99	27
MOD to Severe	B	7.6	2.6	10.7	97.8	33.0	138	4.5	1.52	6.4	237	8.9	29
PCM ♂	C	7.4	2.5	10.5	97.2	32.2	139	4.5	1.48	6.3	232	9.7	39
Cs 8													
2—5/12 yr old	A	8.4	2.5	12.7	99.1	29.1	150	4.6	1.35	6.9	194	10.0	32
MOD to Severe	B	10.7	3.2	15.8	95.0	29.1	140	4.9	1.52	7.3	206	10.6	34
PCM ♀	C	9.5	2.7	14.5	115.1	33.2	175	4.4	1.27	6.7	189	10.4	33

Hypocalcemia was consistently found in our patients which is possibly due to impaired intestinal absorption (low protein binding sites) and/or low calcium intake. No symptoms of hypocalcemia were observed in these patients. The plasma calcium returned to normal after therapy.

Electrocardiographic changes were observed in patients with hypomagnesemia (cases 3, 4, and 6). The changes included inverted T-wave in cases 3 and 4; and flat T-wave in case 6 (Figure 1). The T-wave became upright during recovery after either plasma transfusion or improving of food intakes. The ECG was taken on admission in other 13 malnourished children and inverted T-wave in V5 was observed in one patient who showed normal serum magnesium. The changes in ECG in cases 3, 4, and 6 are similar to those described by Caddell*.

Conclusion Twenty-seven malnourished children of different degrees of severity were studied. The pertinent findings were as follows:

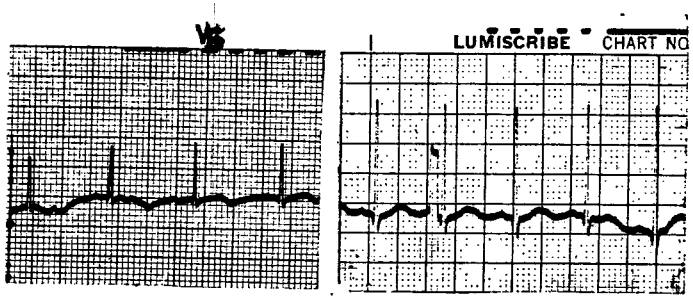
1. Hyponatremia was infrequent in Thai malnourished children.
2. Hypocalcemia and hypophosphatemia were the most common findings.
3. Hypomagnesemia was observed in 3 out of 27 patients.
4. The red blood cells gained sodium and water and lost potassium similar to those described in muscle during severe malnutrition. No significant changes in red blood cell magnesium were observed.

Further study is in progress to support these findings. It is expected that the changes in electrolyte content and concentration may be more obvious in more severe cases.

* Caddel, J.L.: J. Pediatrics 66, 392, 1965.

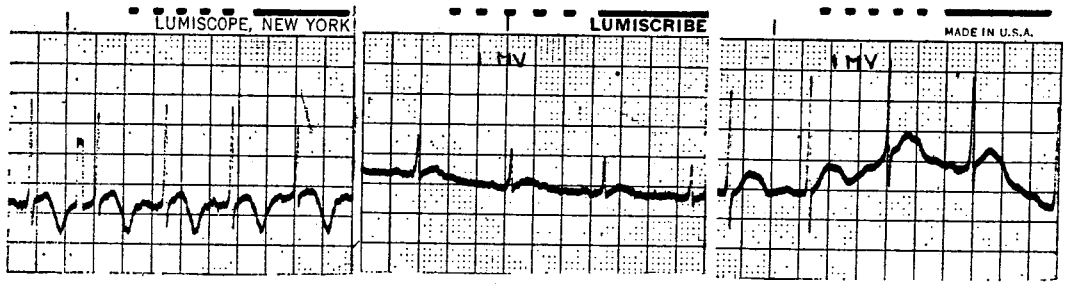
FIGURE I. FULL STANDARD SERIAL RECORDING OF LEAD V_5 IN 3 STUDY CASES

CASE 3

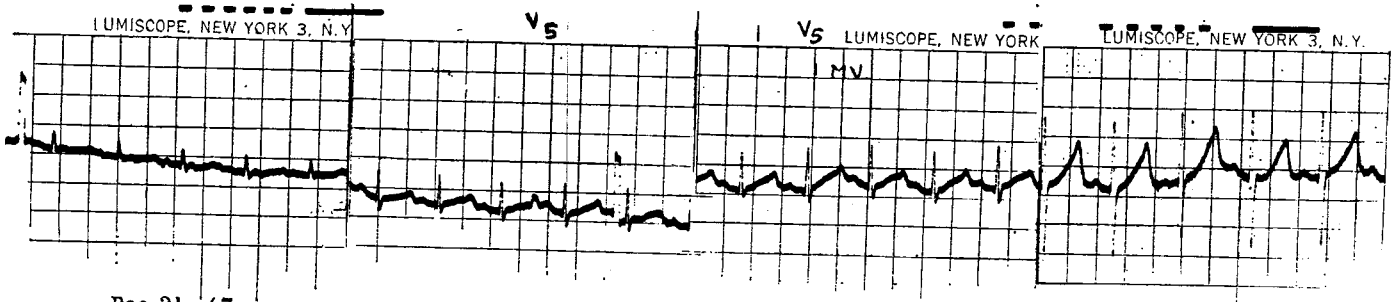


Oct 17, 67 Nov 14, 67

CASE 5



Nov 21, 67 Nov 27, 67 Dec 14, 67



Dec 21, 67 Jan 10, 68 Jan 17, 68 Feb 19, 68

CASE 6