

THE REQUIREMENTS OF SODIUM CHLORIDE

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A widely recognized complication following the administration of large amounts of saline solution rectally or parenterally is the occurrence of oedema of the lungs or the extremities. Collier, Dick, and Maddock (1936) showed that this oedema is the result of the administration not so much of large quantities of water as of excessive amounts of sodium chloride, for the oedema will disappear if glucose solutions are substituted for salt solutions. Jones and Eaton (1933) pointed out that a reduction of the protein intake such as occurs in certain gastrointestinal disorders, profuse surgical drainage, the general effects of sepsis, and the loss of serum protein by massive haemorrhage, all lead to a reduction in the serum proteins of the blood. There is thus a diminution in the osmotic pressure exerted by the blood colloids, and this diminution probably accounts for the tendency to oedema which arises when the tissue reserves of chloride are raised. We have observed that following repeated injections of sodium chloride solution oedema may occur before chloride appears in the urine in more than negligible proportions.

Recently Maddock and Collier (1937) have established criteria as to the correct amounts of fluid required by patients at rest, after operation, and in conditions of dehydration. We think it advisable to add criteria which we have obtained as to the amounts of sodium chloride required by the body in health and in hypochloreaemia.

The Basal Requirements of Sodium Chloride

The usual daily intake of 6 to 12 grammes of sodium chloride in an ordinary diet represents an amount in excess of the actual needs of the body, the excess salt being excreted in the urine. In order to ascertain the basal requirements of salt we selected three healthy male subjects who were confined to bed because of fractures of the leg. For the first three days they were given the usual ward diet. Twenty-four specimens of urine were collected and the daily sodium chloride excretion estimated.* Blood specimens were collected daily for plasma chloride and haematocrit estimations.* Following this control period each subject was given a diet as low in chloride as possible, compatible with ensuring a balanced diet and with using foodstuffs which were readily procurable. After six days on this diet alone (salt intake approximately 2.1 grammes daily) the salt intake was increased by the addition of 2 grammes a day for three or four days, and then by the addition of 4 grammes a day for three days.

* The plasma chloride (as NaCl) was estimated by van Slyke and Sendroy's method on oxalated specimens of blood, which, however, were not collected under paraffin. The same method was used for the urinary chloride. The haematocrit estimations were made by means of capillary haematocrit tubes.

The following basic salt-poor diet was given to two of the three subjects:

	NaCl Content
Brown bread 150 grammes	.. 0.911 gramme
Butter 45 "	.. 0.545 "
Milk 300 c.cm. 0.318 "
White fish 100 grammes	.. 0.106 "
Egg 1 0.063 "
Chicken 60 grammes	.. 0.060 "
Tomato 100 "	.. 0.034 "
Potato 75 "	.. 0.028 "
Cream 30 c.cm. 0.024 "
Apple 200 grammes	.. 0.010 "
Orange juice 100 c.cm. 0.003 "
Sago 10 grammes	.. 0.002 "
Gooseberry jam 120 "	.. —
Sugar 45 "	.. —
	2.104 grammes

This diet contains 189 grammes of carbohydrate, 62 grammes of protein, and 75 grammes of fat, and has an energy value of 1,680 calories and a total sodium chloride content of 2.1 grammes.

The findings observed in each of our three subjects are presented in graphical form (Charts I, II, and III). These charts show that, after a diet containing 2.1 grammes of sodium chloride has been taken for six days, the salt excretion falls and is about 2 grammes a day. If then salt is added to the diet, the excess salt is excreted in the urine after a latent period of one or two days has elapsed. In Chart III it will be seen that cessation of the salt output occurred as the result of an attack of acute tonsillitis on the eleventh day. When this attack subsided the excess salt was excreted.

We deduced from these observations that for short periods the basal requirement of sodium chloride in health is less than 1 to 2 grammes a day.

Requirements of Sodium Chloride in Hypochloreaemia

To observe the effects of salt administration in hypochloreaemia we chose a number of patients in whom there had been excessive chloride loss following vomiting due to obstruction in the alimentary tract and to whom known quantities of saline were given (with one exception) only by parenteral routes. In each case the plasma chloride values were estimated before and after administration, while the urinary chloride output was estimated and found to remain negligible. The results are summarized graphically in Chart IV.

From this chart it will be seen that in hypochloreaemia about 20 grammes (from 15 to 30 grammes) of salt are required on the average to raise the plasma chloride by 100 mg. per 100 c.cm. (from, say, 400 to 500 mg.). Marked variations, however, are seen in the responses to saline administration. In assessing the significance of these findings it should be remembered that the total amount of sodium chloride normally present in the circulating blood is about 30 grammes, with a tissue reserve of probably double that amount. We believe from personal observations (Falconer and Lyall, 1937) that the undoubted benefits of saline administration are dependent more on the correction of the dehydration than on the alteration of the plasma chloride values, and that salt given in normal solution exerts a greater effect on the plasma chloride levels than when given in concentrated solution. We have evidence to show that, after the administration of saline, chloride may be stored in the tissues and later be used to raise the plasma chloride. These observations probably account for the apparent discrepancies seen in Chart IV.

CHART I.—Showing the daily chloride excretion in a man aged 54 while on a diet containing varying amounts of sodium chloride.

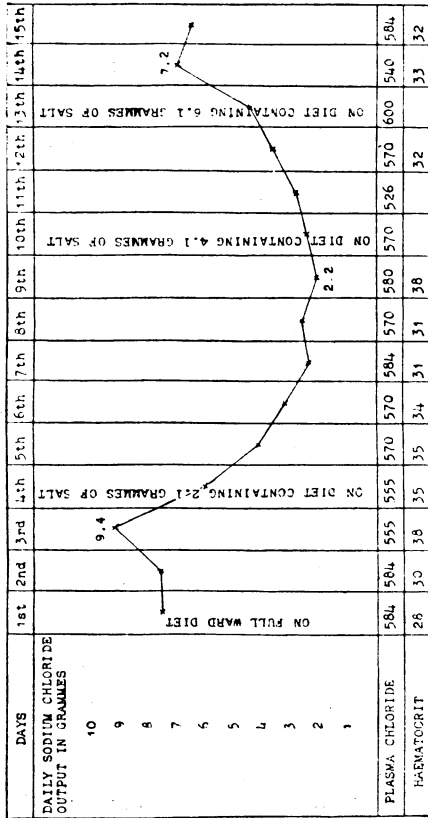


CHART III.—Showing the daily chloride excretion in a man aged 41. The patient developed an attack of acute tonsillitis on the eleventh day.

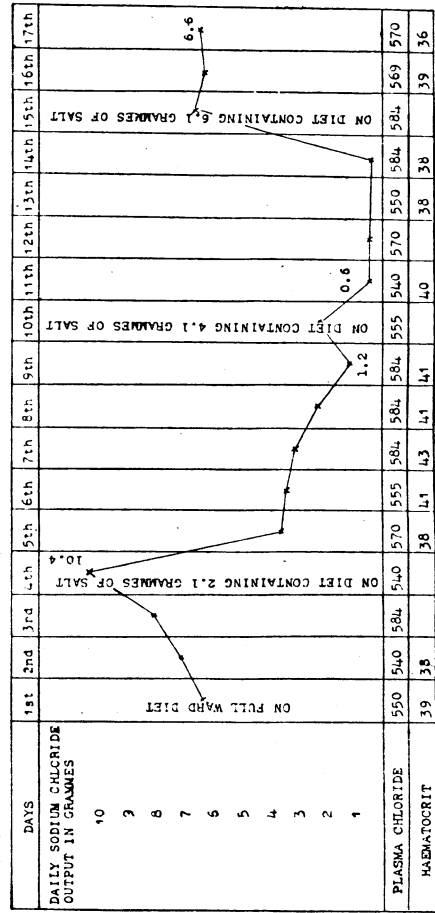


CHART II.—Showing the daily chloride excretion in a man aged 51.

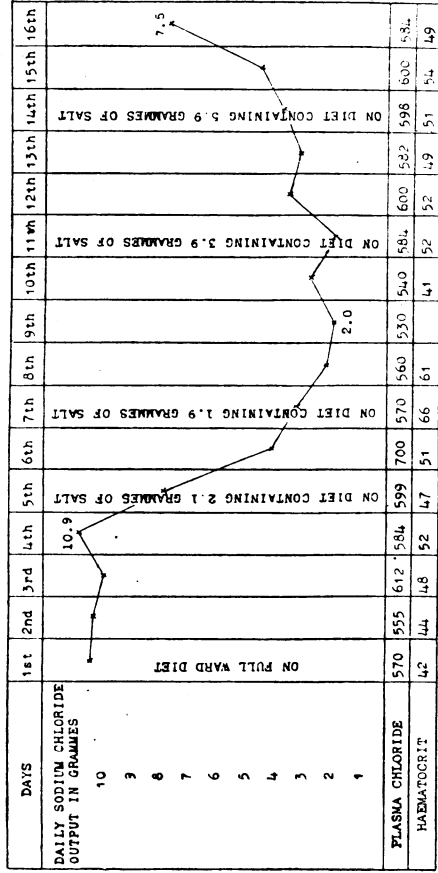
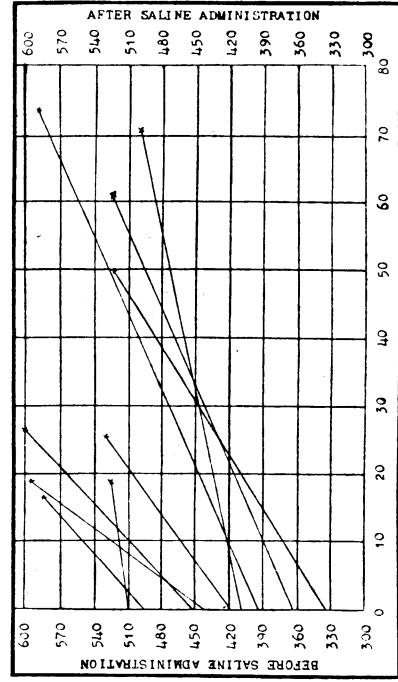


CHART IV.—Showing the effect of the administration of sodium chloride on the plasma chloride values in cases of hypochloreaemia.



The abscissa represents the amount of sodium chloride given in grammes, the ordinate the plasma chloride in milligrammes per 100 c.c.m.

Discussion

In the production of oedema following the administration of large quantities of saline the efficiency of the kidneys plays an important part, for when the renal function is good the kidneys can excrete chloride in the urine in high concentration and so mitigate the possibility of oedema. Very rarely, however, does the urinary chloride concentration approach to that of normal saline, and it is therefore inadvisable in the absence of hypochloraemia to tax the kidneys by the administration of such large quantities of salt as are included in 3,000 to 4,000 c.cm. of normal (0.9 per cent.) saline. Such amounts of solution contain from 27 to 36 grammes of sodium chloride, in contrast to the basal requirement of less than 2 grammes, the ordinary daily intake of 6 to 12 grammes, and the total chloride content of the body in health, which is about 90 grammes.

In administering salines, rectally, parenterally, or by jejunostomy, two factors must be considered—the need for fluid and the need for salt. The first of these is well discussed in a recent paper by Maddock and Collier (1937). An average patient requires at least 2,500 c.cm. of fluid daily in order to ensure an adequate urine output of from 1,000 to 1,500 c.cm. If dehydration is present this intake should be increased to 5,000 c.cm., or even more. As a general rule as much fluid as possible should be taken by mouth and the balance given rectally or parenterally. In all cases the urine output should be recorded, and when it reaches an adequate level the administration of fluid should be curtailed.

The need for salt arises when hypochloraemia is present, as after profuse vomiting, in diarrhoea, or after loss of large quantities of fluid by gastric aspiration or via intestinal fistulae. In such cases sodium chloride is necessary in amounts varying from 15 to 20 grammes daily, and may be given as 1,500 to 2,000 c.cm. of 1 per cent. solution or in larger amounts of more dilute saline. Any additional fluid required may be administered as water by mouth or by rectum, or as 5 per cent. glucose solutions rectally or parenterally. Such amounts of salt as we recommend are adequate to correct chloride deficiency, and contrast with the basal requirements of less than 2 grammes and the usual intake of 6 to 12 grammes. In order to obviate the risk of oedema the plasma chloride should be estimated at least every second day, and when it approaches to 550 mg. per 100 c.cm. the salt intake should be restricted and should not exceed 10 grammes (1,000 c.cm. of 1 per cent. solution) a day.

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SERUM TREATMENT OF TYPHOID
FEVER*

BY

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In May, 1935,¹ I published the results obtained when eight bacteriologically confirmed cases of typhoid fever were given an "anti-Vi" and "anti-O" serum prepared by Dr. Felix at the Lister Institute. These results, while insignificant statistically, did suggest that in this new serum we had a remedy of definite value in relieving the toxæmic symptoms of typhoid fever and worthy of further trial. In the present contribution I propose very briefly to review our experiences to date with the Felix serum.

In all, sixty-one cases of typhoid fever admitted to Cork Street Hospital since September, 1934, have received serum treatment. Every case included was bacteriologically confirmed—if not by blood culture, by unequivocal serological findings. Since my original paper was published we have ceased to give serum to mild cases of typhoid, and therefore cases of this type are excluded from this survey, as are, of course, all paratyphoid infections.

Results in Sixty-one Cases Receiving Serum (September, 1934, to July, 1937)

Serum effect excellent	23
Serum effect good	21
Serum effect doubtful	7
Serum effect absent	10
	61

The usual route of administration followed was intramuscular, but the intravenous route has been adopted in some very toxic cases, and the intrathecal in cases presenting meningeal symptoms. The dose given has varied from 15 or 20 c.cm. to 33 c.cm., the latter amount being usual for adults. Serum is given on three successive days. In this series of sixty-one cases there were ten deaths, but it is hardly necessary to point out that a fair comparison of the mortality rate for serum-treated cases with the usual mortality rate for typhoid is not possible because of the fact that the serum-treated cases represent a selected group—that is, were given serum because they were toxic or otherwise seriously ill.

To begin with the debit side of the balance sheet—the ten deaths: three of these were due to perforation. One of the patients was actually the first case in the series, and he had had what we now know to have been a very inadequate dose of serum—a single injection of 10 c.cm. The second perforation was in a woman whose typhoid was complicated by a septic abortion. The remaining case perforated two days after the third 25 c.cm. of serum was given, and the course of the illness seemed to have been uninfluenced by specific therapy. A fourth death occurred in a case of haemorrhagic enteric beginning with nephritic symptoms. This patient's blood culture was positive for *B. typhosus* very early in the disease, and she bled extensively from mucous membranes and into the skin. Because of a temporary shortage of supplies she received only half the usual adult dose of serum. While admitting a doubt as to whether any treatment would have saved her life, I ought to say that the only other haemorrhagic case of enteric included in this survey recovered dramatically after adequate serum treatment. Two other fatal cases were interesting, in that

* Read in the Section of Hygiene and Public Health at the Annual Meeting of the British Medical Association, Belfast, 1937.

¹ McSweeney, C. J. (1935). Clinical Trials with a New Anti-typhoid Serum. *Lancet*, **1**, 1095.

A further gift of £50,000 has been made by Mr. John A. Dewar to the Gordon Hospital for Rectal Diseases, Vauxhall Bridge Road, London. Mr. Dewar had already given £80,000 for the erection of two new blocks of wards, and his latest gift will enable the old part of the hospital to be reconstructed, and thus increase the original accommodation threefold.