WATER BALANCE IN SURGERY

A series of ninety operative cases,

using the McClure-Aldrich Test

as the clinical index of Water Balance.

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INTRODUCTION

Water balance is the ratio between the total intake and output of fluids by any route, normal or otherwise. It is one of the most important features of post-operative treatment. Before the advent of parenteral therapy, the surgeon depended on pre-operative hydration and trusted, that after operation, fluids could be taken by mouth before dangerous dehydration occurred. Now the benefit of parenteral administration of fluid is recognized. But this supply may be inadequate or excessive, when the same routine orders are carried out, regardless of individual need. It is only by studying each case and by careful correlation of all the factors concerned that the water and electrolytic balance in the surgical patient can be maintained at the physiological level. In critically ill patients, an adequate water balance may be the deciding factor in recovery. Water stands second only to oxygen as a vital physiological substance and every effort should be made to supply it in optimal quantities.

PHYSIOLOGY OF WATER AND CHLORIDE METABOLISM

Normally the water and electrolytic balance is regulated by various adjustments between fluid intake and output.

MAINTENANCE OF WATER BALANCE:

Thirst usually determines an appropriate fluid intake. The kidneys dispose of the larger part of excess fluid; they are concerned with the maintenance of a constant blood volume and stabilisation of blood chemistry. There is a wide range in the daily amount of water and salt consumed by different individuals, depending upon habit, activity and environmental temperature.

In addition to fluids taken by mouth, water is derived from food. On the average, one-half to two-thirds of the contents of solid food is water.[1] Water is also derived from oxidation processes in the body, each gram of solid food furnishes about 0.9 cubic centimetres of water.[1] During fasting, oxidation of body materials continues.

Besides the urinary output, a very small amount, 100 to 200 cubic centimetres of water is lost in the feces. The insensible loss of water, i.e., by vaporization, is continuous and takes precedence over that which might be used to excrete waste products in the urine. About 1500 cubic centimetres are lost through the respiratory system and normally, a constant though

much smaller amount, by the skin.[16] This loss of water is intimately associated with maintaining a normal body temperature. More water is vaporized under conditions in which metabolism is raised.

At all times, there must be sufficient water to enable physiological functions of the body to proceed normally.

MAINTENANCE OF CHLORIDE BALANCE:

The daily diet contains 2 to 20 grams of sodium chloride. The salt excreted in the urine practically equals the intake except when excessive sweating occurs. Under normal conditions, about 1 gram of salt is excreted through the skin daily, but this is increased to 10 grams or more when perspiration is profuse.[1]

MAINTENANCE OF BLOOD VOLUME:

Normally the blood volume remains constant despite variations in intake and output. The tissue spaces act as reservoirs into which fluid passes when there is an excess in the blood and from which fluid can be withdrawn when the blood volume is decreased. Dehydration is a decrease in the amount of fluid in the tissue spaces.

WATER AND ELECTROLYTIC BALANCE IN SURGICAL CASES

Post-operatively, the patient requires approximately the same quantities of salt and water as he does under normal conditions. The fluid intake should be 2500 to 3000 cubic centimetres to insure that the daily urinary output amounts to 1000 to 1500 cubic centimetres.[16]

On the day of the operation very little fluid and no food is taken. The only source of water is the small amount tolerated by mouth and 300 to 500 cubic centimetres obtained by oxidation of body materials.[1]

The work of Coller and Maddock has formed the basis for estimating the daily volume of fluid required by surgical patients.

This can be calculated as follows:-

1.	Water for vaporization	1500 to 2000 cubic centimetres
2.	Water for urine	1000 to 1500 cubic centimetres
3.	Water to replace abnormal losses	? to ?
4.	Water to overcome dehydration	(an amount equal to 6 per cent of body weight)

WATER FOR VAPORIZATION:

This varies from 1500 to 2000 cubic centimetres. There are several conditions in which vaporization is increased. These include hyperthyroidism, fever and anaesthesia. This loss is continuous, regardless of the supply.

WATER FOR URINE:

A daily output of 500 cubic centimetres is sufficient provided the kidney has a normal concentrating power. However, Coller and Maddock recommend allowing 1500 cubic centimetres for this purpose, to provide for all degrees of function. Wangensteen feels that 700 cubic centimetres is enough for the majority of cases.

WATER FOR ABNORMAL LOSS:

This is calculated by measuring the fluid lost by suctions, fistulae, discharging wounds, and diarrhoea. Normally about 7000 to 10000 cubic centimetres of fluid are secreted into the gastro-intestinal tract daily. Only 150 to 200 cubic centimetres are lost in the feces. The salt content of these fluids is about 5 grams per litre. To maintain the water and electrolytic balance, the amount of salt and water given parenterally should slightly exceed the quantity lost by these abnormal routes.

WATER TO OVERCOME DEHYDRATION:

In most emergencies and in some chronic surgical conditions the body is dehydrated. This should be corrected pre-operatively. Coller and Maddock have estimated that fluid equal to 6 per cent of the body weight is required to overcome dehydration.

By a consideration of these factors, an estimation of the theoretical requirements for water and electrolytic balance can be made.

THE DANGERS OF EXTREMES OF WATER AND SALT THERAPY

Dehydration is a very serious post-operative complication. It is present to some extent following every major operation. Should it progress, it will lead to anhydremia and death. Cutting states that in a surgical patient, dehydration should never be allowed to develop to the point where it is clinically recognizable.

Hyperhydration is produced with difficulty in a normal individual, but care must be taken to avoid over administration of fluids in patients with chest complications or cardiac embarrassment.

If the intake is limited, the sodium chloride reserve is reduced when excessive fluid is lost from the gastro-intestinal tract. This may produce a clinical state similar to uremia. To counteract this, sodium chloride as well as water must be given, even though the urinary output is quantitatively sufficient.[11] Estimation of urinary chlorides may aid in gauging the amount of salt required.[13] It is known that when the chloride reserve is low, the body will abruptly reduce the output.

Overdosage of sodium chloride may cause retention of fluid in the tissues. This may produce edema of the ankles, pulmonary edema and cardiac failure. Because parenteral therapy is usually not prolonged this occurs infrequently.

It is better to give not quite enough salt and water than to give too much.

ESTIMATION OF WATER BALANCE

In estimating the degree of hydration pre and post-operatively the following criteria may be used:

1. Clinical dehydration is shown by a burning, dry, inelastic skin and a dirty dry tongue.
2. A comparison of the fluid intake and output may be calculated according to the method of Coller and Maddock. This is ideal, but time-consuming and difficult.
3. The amount and specific gravity of the urine is commonly used. It is subject to error as there is often a definite lag in the urinary output for the first few days post-operatively, even when the intake has been adequate.[23]
4. The hemoglobin percentage and red blood cell count are easily estimated but are misleading in many instances.[2 17]
5. The estimation of the level of plasma proteins is technically difficult and of doubtful value.
6. There is some evidence that a daily record of body weight is of value in estimating the degree of hydration.[23]

From the foregoing it can be seen that there is still a need for a simple, reliable test for water balance. An investigation of the McClure-Aldrich test was undertaken with this in view.

DATA

A study of ninety operative cases was undertaken to determine the value of the McClure-Aldrich test as an index of hydration and as a guide for optimal fluid administration.

APPARATUS:

This consists of a tuberculin syringe, a number 26, half inch intradermal needle and sterile normal saline.

METHOD:

Using aseptic technique, the syringe is filled with normal saline and the needle is adjusted with the bevel on the same side as the centimetre graduations of the syringe. The skin is spread by the fingers and the needle is pressed in, until the lumen just disappears. The bevel should be sufficiently superficial as to be seen through the skin. 0.2 cubic centimetres of the solution is then injected slowly. This raises a clearly circumscribed wheal with accentuation of the pores. Three wheals are made, one to two inches apart, and the average time of disappearance noted.

The volar surface of the forearm at the junction of the upper and middle thirds was used except in those individuals receiving intravenous therapy. In these cases the anterior chest wall was used midway between the sterno-clavicular joint and the anterior axillary fold.[14]

As the saline is injected slowly, a round white wheal, with accentuated pores is formed. It then becomes red for a few minutes and then slowly fades in colour. The disappearance of the elevation is best appreciated by the tip of the finger passed lightly over it.

The first reading was made at 30 minutes and then at 10 to 15 minutes intervals until the wheal was not palpable or until 70 minutes had elapsed.

The test was done 12 to 24 hours pre-operatively in all cases, except emergencies, in order to insure sufficient time for parenteral therapy, should it be considered necessary. It was repeated 4 hours after the operation and at the same time on subsequent days or as indicated, until a normal fluid balance was established.

All tests were made and interpreted by one individual, with the exception of ten cases investigated independently as a control, by an associate, S. Dubo.

A full blood count was done pre-operatively and repeated if considered necessary. Fluid intake and output were estimated as well as the salt content of the parenteral fluids.

RESULTS

GROUP 1

This group consisted of 10 male patients ranging from 20 to 52 years of age. They were operated on for inguinal hernia, under spinal anaesthesia. The average operating time was 40 minutes. Each individual appeared well hydrated clinically but the test showed very slight dehydration for the first few days.

Graph 1 shows the average disappearance time of the wheals of 5 of the patients. Routine orders regarding fluid intake were carried out.

GROUP 1

Graph 2 shows the average disappearance time of the second 5 cases. Water was administered as need was indicated by the test. The disappearance time of the wheal returned to normal in a shorter period of time than in the first 5 of this group.

GROUP 11

This group consisted of 10 cases. The first 5 cases were simple appendectomies, performed under ether anaesthesia, all for chronic appendicitis, and all in young adults. A McBurney incision was made in each case and the average operating time was under 25 minutes.

Graph 3 represents the average disappearance time of the wheals in these 5 cases. On the first post-operative day, they all appeared to be slightly dehydrated clinically. The test indicates a more severe degree of dehydration and also more than occurs under spinal anaesthesia.

GROUP 11

The second 5 cases were emergency appendectomies, performed under ether anaesthesia, all for acute appendicitis with perforation, and all in older adults. A McBurney incision was made in each case and the average operating time was under 35 minutes.

Graph 4 shows the average disappearance time of the wheals in a typical case of this group. This patient had a localized peritonitis. The appendix was removed and the pelvis drained with gauze. Clinically the patient was never more than slightly dehydrated, but according to the disappearance time of the saline, he was dehydrated pre-operatively, and this persisted until the third post-operative day, when fluids were increased up to 3000 cubic centimetres per day and food was taken by mouth. The gauze pack was moistened twice daily with saline to prevent dehydration by this means.

GROUP 11

Graph 5 shows the average disappearance time of the wheals in an adult patient, who had a generalized peritonitis due to a perforated appendix. The operation was performed under ether anaesthesia and through a McBurney incision. At the operation the appendix was removed, an appendicostomy performed and the pelvis packed with gauze.

Post-operatively a gastric suction was used and a suction was put on the appendicostomy tube, as well.

The patient clinically was dehydrated before the operation and for about 4 days thereafter.

According to the disappearance time of the wheal, the patient was moderately dehydrated pre-operatively and was on the verge of severe dehydration for several days, post-operatively.

Fluids were given parenterally in large amounts as need seemed to be indicated by the disappearance time of the wheal. Even though 4000 to 5000 cubic centimetres were given intravenously and with a urinary output of 1500 to 2500 cubic centimetres daily, the disappearance time of the wheal did not return to normal, until the fluids were increased to 5500 cubic centimetres, and until the gastric suction was removed.

GROUP 111

This group consisted of 5 patients ranging from 26 to 40 years of age, who had laparotomies for gynaecological conditions. Operation was performed under ether anaesthesia. The average time was 40 minutes. Post-operative treatment was routine and consisted of fluids by mouth as tolerated, and food was taken by mouth on the second post-operative day.

Graph 6 shows the average disappearance time of the wheals in these cases. The patients looked slightly dehydrated on the first day post-operatively, but were always hydrated clinically after that.

The McClure-Aldrich test indicates a slightly greater degree of dehydration and for a longer period of time.

GROUP IV

This group consisted of 5 female patients ranging from 18 to 34 years of age who had subtotal thyroid resections. They had symptoms and signs of mild hyperthyroidism. The operations were performed under gas and local anaesthesia, with an average operating time of forty minutes. Blood loss was slight to moderate.

Graph 7 shows the average disappearance time of the wheals of these 5 patients. They did not show dehydration either clinically or by the test.

GROUP V

This group consisted of 10 adult patients ranging from 22 to 56 years of age. All operations were performed under nupercaine spinal anaesthesia.

The first 5 cases were simple cholecystectomies. The average operating time was 35 minutes.

Graph 8 represents the average disappearance time of the wheals in these cases. The patients were never clinically dehydrated to any extent, while the McClure-Aldrich test showed slight dehydration for several days. The patients were treated routinely, with fluids allowed by mouth as desired.

GROUP V

Graph 9 represents the average disappearance time of the wheals in 5 cholecystectomies with common duct drainage, as well. The average operating time was 50 minutes. By observation alone, these cases were slightly dehydrated for the first post-operative day. The test shows a greater degree of dehydration than suspected clinically. This returned to normal when fluids were forced and the diet increased.

GROUP V1

This group consisted of 3 patients ranging from 36 to 57 years of age. Gastric resections, 1 for carcinoma of the pylorus and 2 for benign ulcers, were performed under nupercaine spinal anaesthesia. The average operating time was 90 minutes. Post-operatively, gastric suction was used for 4 days and fluids were given parenterally, as appeared to be needed by the disappearance time of the wheal.

Graph 10 shows the average disappearance time of the wheals in these cases. Clinically the patients were never more than slightly dehydrated. The test showed a moderate dehydration for several days, especially when the suction was being used. This improved when fluids were given intravenously up to 4300 cubic centimetres per day.

GROUP V11

This group consisted of 2 cases. The first case was a male patient aged 50 years. The operation was a cholecystectomy with a common duct drainage, performed under nupercaine spinal anaesthesia, for obstructive jaundice. Post-operatively, gastric suction was used for 8 days. On the third day, his heart started to fibrillate. Clinically he was always dehydrated, but yet fluids could not be forced to any great extent on account of the chest complication and cardiac failure. He died on the eighth post-operative day.

Graph 11 shows the disappearance time of the wheals, which indicates only a slight to moderate dehydration and never a severe one, which the patient undoubtly had.

GROUP VII

In the second case, the patient was a female aged 56 years. The operation was a simple cholecystectomy performed under ether anaesthesia. She died suddenly on the third post-operative day.

Graph 12 represents the disappearance time of the wheals in this case. Neither clinically nor by the test did she show much dehydration until the day of her death.

GROUP VIII

In this group, there were 9 patients. Most of them were elderly men. It included various types of operations.

Graph 13 represents the average disappearance time of the wheals in these cases. Though the patients appeared clinically dehydrated, the disappearance time was well above normal. A record of the intake and output indicates that the patients could not have been well hydrated.

DISCUSSION

In July 1923, W.M. McClure and C.A. Aldrich injected normal saline intracutaneously in cases of nephritis with obvious edema and pre-clinical edema. By noting the time of disappearance of the wheal, they hoped to have a guide as to the severity, progress and prognosis of the disease. In the majority of cases, the disappearance time was from 2 to 20 minutes. In normal adults it varied from 60 to 80 minutes.

Since then, the test has been used in the study of peripheral vascular disease, cardiac decompensation, the toxaemias of pregnancy and infectious fevers.[8 9 15 21] Favourable results in these conditions have been reported.

The physiological basis of the test is disputed. It is probable that disappearance of the saline is due almost wholly to dispersement of the fluid in the tissue spaces; the length of time required for this to take place, as calculated by the subsidence of the wheal, is inversely proportional to the thirst of the tissues for water.

It therefore seemed logical that the test would furnish a practical, accurate and quantitative means by which water balance could be estimated in the surgical patient.

McClure and Aldrich suggested application of the test in cases of dehydration. However, Appel and Brill, in 1927, first

used it in surgical cases and in 1930, Andrews and Reuterkiold reported a similar investigation. In November 1939, Hopp and Christopher renewed interest in the procedure by reporting a further series of cases.

It must be emphasized that the McClure-Aldrich test is a means of measuring tissue avidity for water, whether this is due to dehydration, or because the water present is bound by sodium and unavailable for use.

Various solutions were tried experimentally before the series was started. Distilled water, when injected intradermally was very painful. 1 per cent novocaine was used, as well as a solution of 1:1500 adrenalin in normal saline and Ringer's solution.[19] However, as little advantage could be found, normal saline was used for this series of cases.

To determine the best site of injection, wheals were made on various parts of the body. It was found that the forearm was most convenient and wheals were more easily interpreted in this situation. Since the disappearance time varied with the site of injection, the same place must be used routinely in order to obtain comparable results.

The findings of other observers in vascular disturbances of the extremities, cardiac failure and nephritis with edema were confirmed.

The majority of investigators have found that the average disappearance time of the wheal in normal individuals is 60 to 80 minutes.

In this investigation, the minimal limit of normal time was found to be somewhat lower, 50 to 55 minutes.

A fallacy was encountered in certain individuals. Although they appeared well hydrated clinically, the disappearance time of the wheal was greatly prolonged; even though it was clearly defined. This occurred most commonly in elderly people and may be due to the texture of the skin and the absence of subcutaneous fat.

While other observors have taken readings every 5 minutes, no difference in size of the wheal was appreciated by palpation in an interval of less than 15 minutes. Kunde found the tactile method of such questionable delicacy that she used an elastometer. S. Dubo reached a similar conclusion. Because of these difficulties, a wheal was raised on the forearm of the interpreter immediately after injecting the solution into the patient. Comparison of the wheals facilitated interpretation, since the observer was always well hydrated as evidenced by a normal measured intake and output of urine.

CONCLUSIONS

1. The McClure-Aldrich test was used in a series of 90 surgical cases, in an effort to determine its value as a guide to the state of hydration.
2. In the majority of the cases, the McClure-Aldrich test is a better index of the degree of hydration than clinical judgement. However, since it is subject to error in certain cases, it cannot in its present form, entirely supercede the other methods of estimating water balance.

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