FLUID AND ELECTROLYTE REQUIREMENTS IN SEVERE BURNS*

Everett Idris Evans, M.D., O. J. Purnell, M.D., P. W. Robinett, M.D.,
Alastair Batchelor, M.B., and Mary Martin, M.D.

Richmond, Va.

FROM THE DEPARTMENT OF SURGERY, MEDICAL COLLEGE OF VIRGINIA, RICHMOND

There is now general agreement that the principal cause of burn shock is loss of circulating plasma and red cell components into the burn zone. The logical prevention and treatment of burn shock comprises replacement of these substances in amounts adequate to permit effective blood flow to the brain, liver and kidney. A controversy exists as to the relative importance of salt in this therapy. Although there is a growing realization that adequate amounts of salt must be administered, the question remains: how *much* salt does the extensively burned patient need?[8, 11, 12]

Plasma administration in the burned patient is still largely regulated from estimates of the deficit in plasma volume according to hemoglobin or hematocrit determinations.[3, 9] Another method of estimating these requirements is the surface area formula improved by the observations of Cope and Moore.[4] Wallace[13] has used a similar formula with success in children.

Atomic warfare has significantly increased the hazards of thermal injury to civilian and military populations.[6] An atomic attack may result in thousands of burn victims. Proper care for them must necessarily include the administration of plasma, plasma substitutes or whole blood. Impressed with the need for a simple method of calculating these requirements, we have been searching for such a method for the past two years.

During this period the Burns Unit has admitted 252 patients, of whom 68 of the more extensively burned were selected for this study.

This paper, therefore, deals with the development and trial of a simple formula for the calculation of colloid and electrolyte requirements in the extensively-burned patient during the first 48 hours.

THE DEVELOPMENT OF A SURFACE AREA-WEIGHT FORMULA FOR FLUID THERAPY

A simple formula for intravenous fluid therapy of the burned adult during the first 24 hours was applied. This formula furnished 75 cc. of colloid and 75 cc. of electrolyte solution for each per cent of body surface burned. Smaller amounts than these were given on the second and third days respectively. We were not then sufficiently impressed with the warnings of Cope and Moore[4] that such surface formulas disregarded differences in the weights of patients and that the use of such formulas with burns of 50 per cent or more required great caution.

Table I indicates our experience with the surface area formula employing the

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amounts of plasma and saline cited above. In this Table it will be noted that four patients early developed severe pulmonary edema; this resulted in the death of two of these patients on the fourth and fifth day respectively. In B. C., the pulmonary edema was so severe as almost to result in death on the third day; however, he survived and left the hospital healed after grafting. Inasmuch as all four patients who developed pulmonary edema were admitted to the Burns Unit within a two-week period, this danger became apparent during that time. Accordingly, in the next patient, J. M., 84 years, the amounts of plasma and saline solution were limited because of his age. It will be noted from the Table that his urine output during the first 24 hours was only 100 cc. and he succumbed on the tenth day in uremia. Although this could be accounted for in part by his age, it probably was mainly due to inadequate shock therapy during the first 24 hours.

TABLE I.—*This Illustrates the Relationship Between the Incidence of Severe or Fatal Pulmonary Edema in Burn Patients Who Were Given, Intravenously, More Than the Apparently Optimal Quantities of Plasma or Saline (1.5 cc. Per Percent Burn Per Kilogram Body Weight).**

Patient (1)	Plasma and 0.9% NaCl Given First 72 Hours (2) cc. Plasma	(3) cc. ÷ Kg. x % Burn	(4) cc. 0.9% NaCl	(5) cc. ÷ Kg. x % Burn	Urine Output (6) Day 1	Day 2	Day 3	Remarks (7)
F. T., 34 years, 61 Kg. 92 per cent burn	5300	1.2	9160	3.0	1090	2682	2855	Pulmonary edema 6th day. Death from liver failure 32nd day.
G. L., 19 years, 57 Kg. 63 per cent burn	8500	3.0	7500	2.3	2457	6980	1318	Death from pulmonary edema on 4th day.
C. T., 31 years, 111 Kg. 46 per cent burn	4150	0.8	6300	1.4	1590	3985	2480	Death from pulmonary edema on 5th day.
B. C., 65 years, 72 Kg. 20 per cent burn	4100	2.8	2300	1.5	212	660	751	Severe pulmonary edema on 3d day; Lived and discharged after grafting.
J. M., 84 years, 77 Kg. 48 per cent burn	2500	0.7	2500	0.7	100	1300	1240	Urine output only 100 cc. 1st day; died in uremia on 10th day.
C. W., 17 years, 59 Kg. 36 per cent burn	2000	0.9	2550	1.2	2730	4250	2230	No pulmonary edema; discharged well. Good urine output.
F. J., 20 years, 57 Kg. 65 per cent burn	3900	1.4	4330	1.5	1800	900	1700	No pulmonary edema; aborted dead fetus 6th day; died 19th day from liver failure. Good urine output.
B. R., 15 years, 55 Kg. 24 per cent burn	1320	0.8	3500	2.5	965	3150	2605	No pulmonary edema; good urine output. Discharged well.
A. D., 13 years, 57 Kg. 23 per cent burn	3000	2.6	2750	2.2	2770	1140	2580	No pulmonary edema; good urine output. Discharged well.

* To be noted is the tendency for large urine outputs (above 50 cc. per hour), in those patients who received large amounts of plasma or saline.

It was recognized then that there were serious inherent dangers in the use of a surface area formula in estimating fluid and salt requirements, especially for the patient with an extensive burn. About this time, in our Experimental Laboratory, Dr. James Brooks was getting his first plasma volume data on the loss of plasma in a dog with a standard burn.[2] These data indicated that in the burned dog, by the sixth hour, approximately 1 cc. of plasma is lost for each per cent body surface burned per kilogram weight of the dog.

An analysis of plasma volume data in a series of burn patients indicated that approximately the same ratio of plasma deficit occurred in human burns involving 20 per cent of the body surface. Therefore, because pulmonary edema occurred when the surface area formula was used, and because the surface formula did not take into account differences in the weights of the patients, it was decided to test clinically a sim-

TABLE II.—*A 70 Kg. Man With a 35 Per Cent Body Surface Burn Would Require the Following During the First 24 Hours.*

1st days requirements	
Colloid	= 1 cc. per per cent body burn per Kg.
0.9 per cent NaCl	= 1 cc. per per cent body burn per Kg.
5 per cent glucose in water—2000 cc.	
A clinical example:	
Plasma, plasma substitute or whole blood.................	= 70x35x1 cc. = 2,450 cc.
Electrolyte solutions	= 70x35x1 cc. = 2,450 cc.
5 per cent glucose in water.......	= 2,000 cc.
	6,900 cc.

Half this amount of plasma and/or whole blood and electrolyte and the same amount (2000 cc.) of 5 per cent dextrose in water is given the second 24 hours. One should give no more than 4000 cc. of colloid or 4000 cc. of saline solutions in 24 hours, no matter how extensive the burns. When large amounts of saline are required, if available, ⅓ should be given as Ringer lactate and ⅔ as sanium chloride.

ple formula based on the administration of that amount of plasma which was found to have been lost in the standard burned dog, *i.e.*, 1 cc. per kilogram body weight per percentage of burn during the first 24 hours. Arbitrarily, the same quantity of electrolyte was given the first day, and only one-half these amounts of colloid and electrolyte were given on the second day. Two thousand cubic centimeters of non-electrolyte fluids were given intravenously to the more extensively burned patients to ensure an adequate urine output and take care of insensible fluid loss. The urine outputs reported by others and seen by us earlier were thought much too high (see Table I). In the adult a urine output of not more than 50 cc. and not less than 25 cc. per hour, were taken as clinical indication of adequate blood flow through the kidney. The upper limit of plasma and saline to be given the first day was placed at 4000 cc. of each for the average-sized adult, and one-half these amounts to be given during the second day. Because the weights of the burn patients varied, this upper limit was taken as those amounts calculated for a 50 per cent burn.

Table I (Columns 3 and 5) shows the difference in amounts of fluids calculated for those patients (who developed pulmonary edema on the surface area formula alone) between the weight-surface area formula and the surface area formula alone. All were given more than the calculated upper limit according to the surface area weight formula now in use. When lesser amounts were used, as in patient F. J. with a 65 per cent burn, an adequate urinary output was maintained and early pulmonary edema avoided.

TABLE III.—*This Indicates the Number of Patients in Each Category of Severity of Burn.**

Extent of Burn	Number of Patients	Recoveries	Number of Deaths	Remarks
10–20 per cent	10	10	0	This group was made up largely of children.
20–30 per cent	24	21	3	Two patients who died had associated severe pulmonary burn.
30–40 per cent	9	8	1	The one death in this group was in a patient over 50 years of age.
40–50 per cent	14	7	7	This group included patients (4) above 50 years of age and three (3) with associated pulmonary injury.
60 per cent or higher	11	0	11	We considered initial shock therapy adequate in all of these patients, as indicated by urine output of at least 25 cc. per hour.

* Of the 68 patients studied, with strict adherence to the surface area-weight formula, the fluid and electrolyte therapy presented in this paper, we considered shock therapy to be successful in all but two of the patients. In these two patients (with burns of above 60 per cent), we were not successful in maintaining a urine output of 25 cc. per hour.

THE USE OF THE SURFACE AREA-WEIGHT FORMULA IN CLINICAL PRACTICE

The age of the patient, the extent of the burn, the presence of respiratory burn and the general state of the patient on admission are the chief factors determining the recovery of the burn patient. These have been discussed in detail in a recent paper from this laboratory[7] and will be touched upon very briefly here.

In the burns of smaller extent (10 to 20 per cent) the baby or very young child suffers burn shock earlier and with more intensity than an adult with the same extent of burn. Consequently, all babies and children with burns more extensive than 10 per cent of the body surface are given shock therapy as soon as possible.

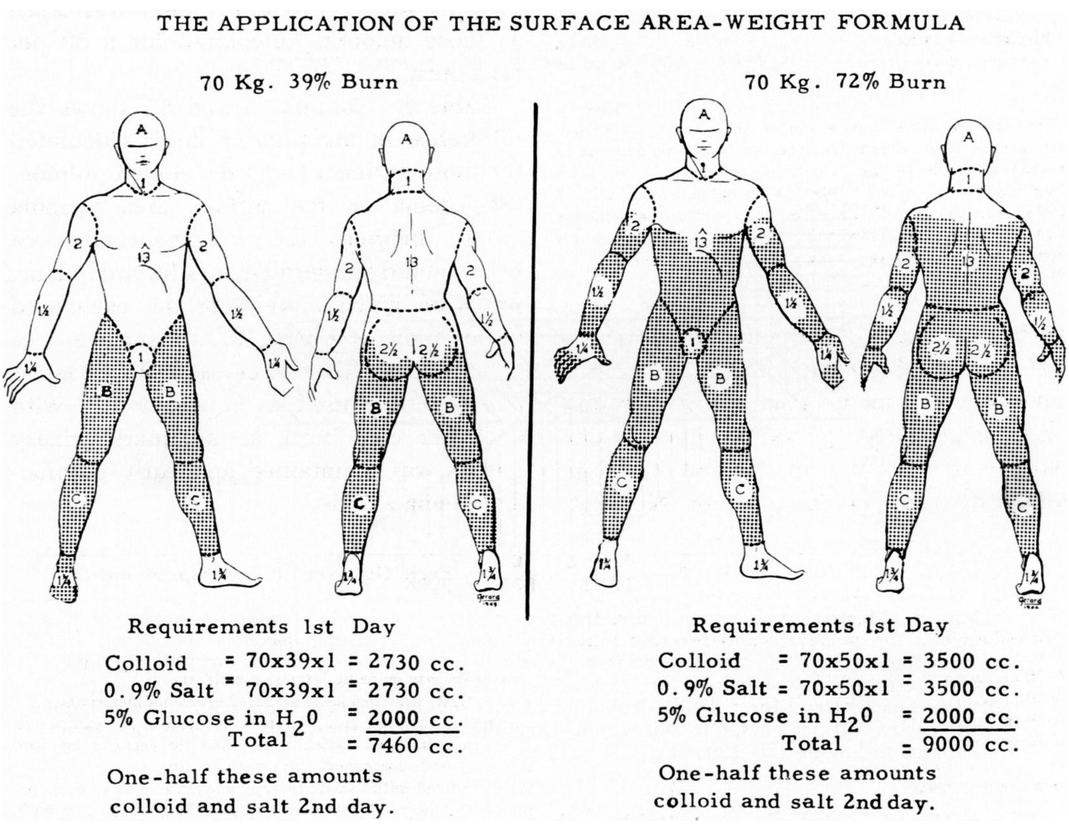

FIG. 1.—This illustrates the application of the surface area-weight formula for severe burns below and above 50 per cent. Note that 1 cc. of colloid or salt solution is given for each per cent body surface burned and this is multiplied by the weight in kilograms. One-half of these amounts of colloid and salt are given the second day. To be especially emphasized, note that in the patient with a 72 per cent burn only those amounts of colloid and salt are given which would be calculated for a 50 per cent burn.

A patient with a respiratory burn from inhalation of irritating gases may early show signs of pulmonary edema which can be fatal in itself, regardless of shock therapy. Colloid and salt administration in these patients is restricted because they develop pulmonary edema quite easily soon after, during, or even before intravenous infusions of large amounts of these fluids. Patients above 50 years of age must be examined carefully for cardiovascular renal disease, or overloading of the heart and kidneys may occur. Patients seen for the first time more than one or two hours after severe burning injury may be in a state of moderate to severe shock and prompt vigorous shock therapy is usually required. This is especially pertinent in babies and children.

THE MANAGEMENT OF BURN SHOCK

Immediately after admission the burned patient's clothing is removed and the extent of the burn mapped out on a chart according to the Lund and Browder modification of Brekow's Chart.[10] The tendency to overestimate the extent of burn injury is recognized, so care is taken not to include dubious first degree areas. An example of the use of this chart with a calculation of fluid requirements from our formula is shown in Figure 1.* burn. Admittedly, we have arbitrarily selected 50 per cent as the upper limit, but the wisdom of this selection has been borne out by clinical trial in truly extensive burns.

After the colloid and salt calculations have been made rapidly, an indwelling polyethylene tube is inserted under local anesthesia in an accessible vein. Before any fluid therapy is started a blood sample is secured for a hemoglobin or hematocrit estimation. The hemoglobin level is routinely employed because it is simpler to determine. If colloid or whole blood is available, it is given first; otherwise, an intravenous infusion of 0.9 per cent saline is started and a shift is made to colloid or whole blood as soon as it can be secured.

PLASMA SODIUM LEVELS IN BURNED PATIENTS

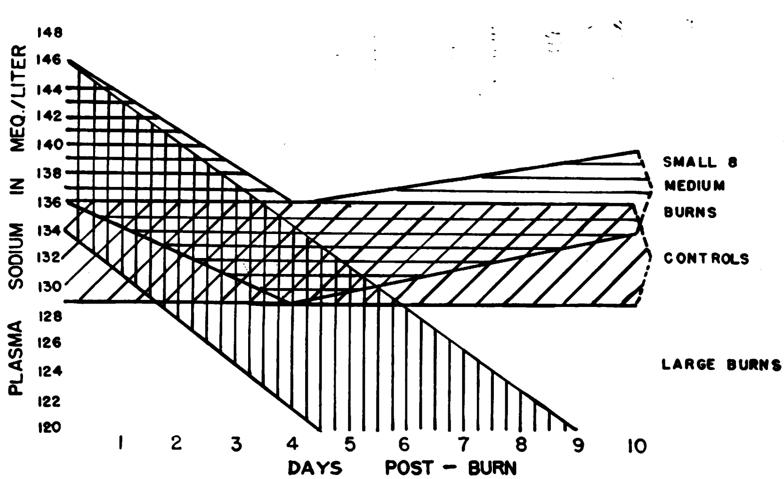

FIG. 2.—Illustrating diagramatically, the general trend of levels of sodium content of the plasma in the moderate and severely burned patients in this study. Note in the "small and medium burn group" the tendency for a decline in plasma sodium levels to 129–136 mEq. around the fourth day and the return to levels of 134–139 mEq. by the tenth day. In contrast, note the general trend for a steady decline of plasma sodium levels in those patients with large burns, (above 40 per cent.) In this group, from the fourth to the ninth day, plasma sodium levels were as low as 120–129 mEq.

The patient is weighed on a suitable scale or his weight learned by questioning. In Table II is shown the method for calculation of colloid and salt requirements for the first 24 hours. One-half of these amounts are given for the second 24 hours. If the burn is 50 per cent or more, an effort is made to restrict colloid and salt administration on the first and second days only to those amounts calculated for a 50 per cent

No anesthetic agent is ever employed, nor is any burn wound dressing applied until the condition of the patient is satisfactory. In the early management of the burned patient, adequate shock treatment takes preference over all other aspects of therapy.

* A handy diagram, adapted from Wallace's "Rule of 9," for a quick estimation of extent of burn is shown in Figure 7. Note that the different body areas are expressed as multiples of 9. This diagram is easily remembered and is accurate enough for most clinical use.

An indwelling Foley type catheter is then placed in the bladder for hourly measurement of urine. The hourly urine output* and a 4-hourly estimation of hemoglobin are the keystone of administering adequate shock therapy in the severely burned patient for the first 72 hours. If the initial hemoglobin is above 19 Gm. and the urine output below 25 cc. for the first hour, shock therapy has been inadequate and is speeded up, with reliance mainly on colloid and whole blood. The hemoglobin is kept a little below 19 Gm. for the first three days. If the urine output is below 25 cc. per hour concomitant with a rising hemoglobin, we believe inadequate colloid has been administered; on the other hand, if the urine output remains low and the hemoglobin is not rising, we believe inadequate salt and water have been administered. We try to maintain the urine output at no less than 25 and no more than 50 cc. per hour during the first two or three days.

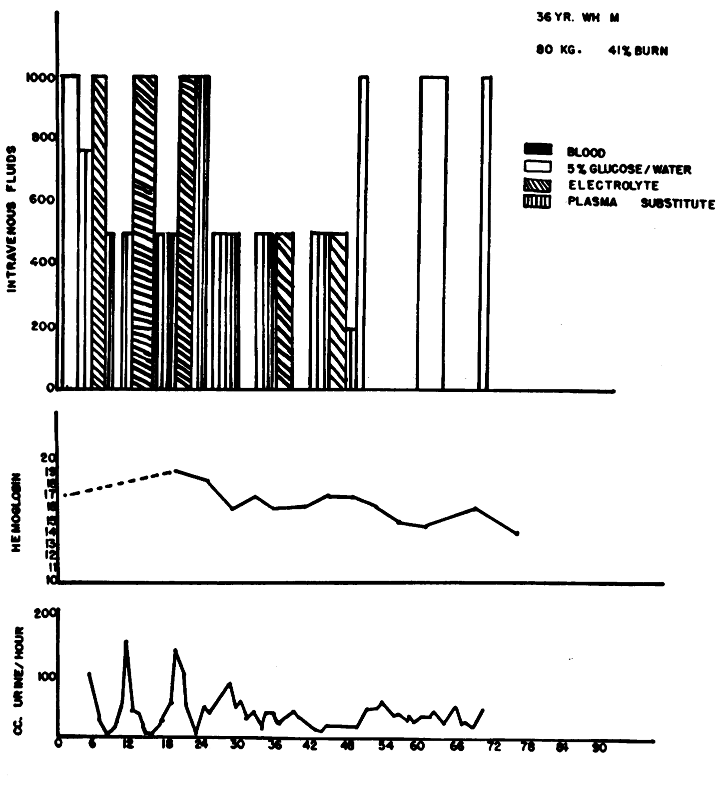

FIG. 3.—R. W. This illustrates the application of the surface area-weight formula in a severe burn.

The major portion of the estimated first day's calculated requirements of colloid and salt is given in the first 12 hours to 18 hours following severe burn injury. *It is emphasized strongly that the simple formula presented here for calculation of fluid and salt requirements is only a guide to therapy and not to be considered an infallible rule.* The adequacy of therapy is confirmed by the simple determination of adequate urine output and hemoglobin levels. The most important guide is the clinical response of the patient. Accordingly, if the patient is re-

* Special acknowledgement is accorded for the unfailing assistance of the nurses in our Burns Unit for their care in the hourly recording of urine output in all patients under study. They are: Louise Belfield, Constance Fields, Grace Walker and Norma Platt.

ceived late after the burning injury and is already in severe shock when first seen, intravenous requirement of the whole first day may have to be given in a few hours, and even the second day's requirement used up in the final hours of the first day. Additional colloid—whole blood, salt and water, *over and above that calculated from the formula,* is rarely required on the second day for the very extensively burned patient.

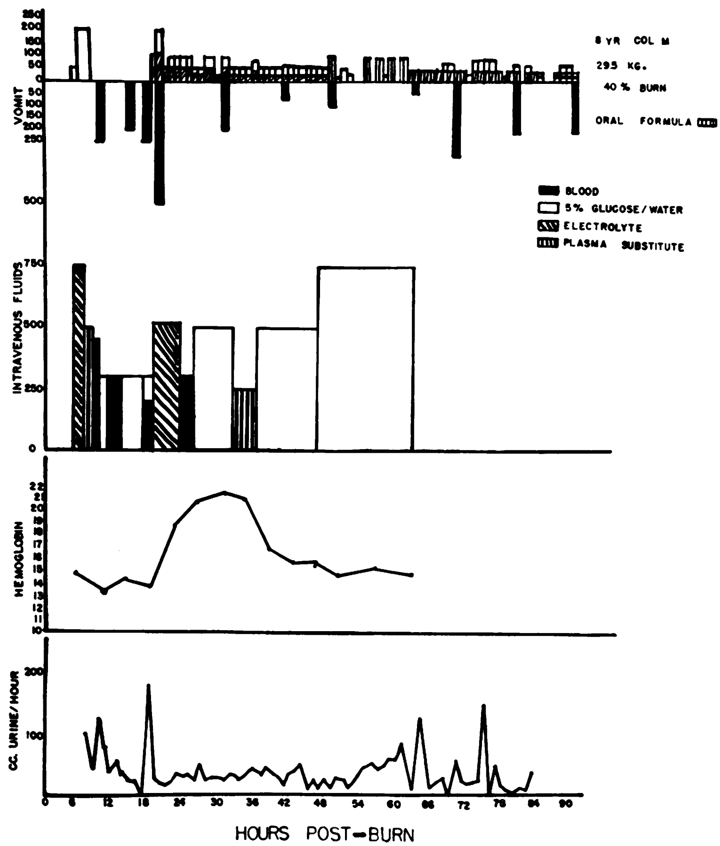

FIG. 4.—E. C. This illustrates the application of the surface area-weight formula in a severe burn.

In those patients with respiratory injury and/or serious cardiac disease, colloid and salt administration is limited to amounts which ensure minimal adequate urine output, that is, no more than 25 cc. per hour. Even when this plan is employed, serious pulmonary edema develops in the majority of patients with respiratory tract burns, and in several with cardiac disease alone. For the latter group of patients, unable to take oral fluids themselves, gavage with electrolyte and water is preferable to intravenous electrolyte.

A number of burned patients, grouped according to the extent of the burn, whose fluid management has been carried out by following our surface area-weight formula for the first 72 hours is shown in Table III. The numbers, the fatalities in each group, and remarks on the cause of death are shown for each. Sixty-eight patients are considered in that table. It will be noted there were 22 deaths but that of these 22 patients, 18 had burns more extensive than 40 per cent and that 11 of these had burns more extensive than 60 per cent. The three deaths in the 20 to 30 per cent category were mainly due to respiratory tract injury. The death rate in this series is approximately that to be expected from the probit analysis of Bull and Squire[3] for severely burned patients.

One troublesome feature of shock therapy, which has been noted when these guides are used, should be mentioned: An extensively burned patient has received apparently adequate therapy of fluid and salt, yet has a declining urine output, and shows signs of peripheral circulatory collapse; examination shows him to be troubled with serious gastric dilation; this form of "shock" is promptly relieved by decompression of the stomach, gastric lavage and electrolyte and water infusions. If vomiting occurs, replacement of the electrolyte loss must be made.

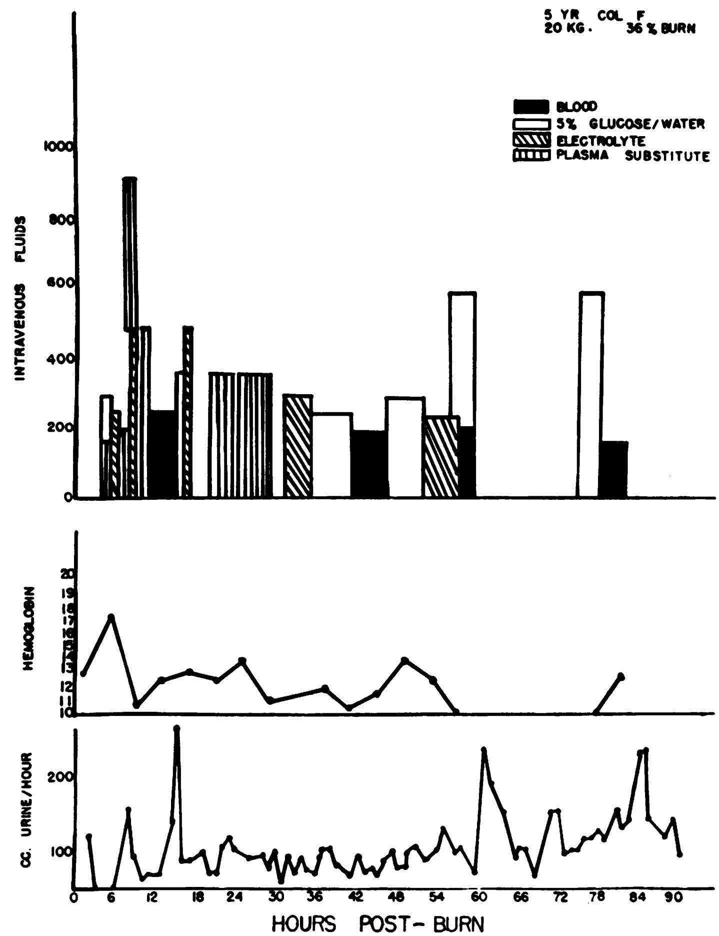

FIG. 5.—E. B. This illustrates the application of the surface area-weight formula in a severe burn.

THE "RULE OF 50"

We should like to emphasize what might be termed for ease of remembering, "the rule of 50." Great caution must be exercised in the management of shock in those patients over 50 years of age and in those patients of any age with burns more extensive than 50 per cent.

Since cardiac reserve usually lessens with increasing age, caution must be taken not to overload the burned patient of 50 years or over with what may be for him excessive amounts of colloid or salt. In these patients, careful and frequent observation is made of pulse rate, pulse volume, respiratory rate and fullness of neck veins. Where practicable, auscultation of the lung bases must be done often.

It will be recalled that we have recognized the danger of over-expansion of the extracellular space due to over-zealous therapy following extensive burns. The upper limit for use of the surface area-weight formula is arbitrarily taken as a surface burn of 50 per cent. For the average weight adult this corresponds quite well to the limit imposed by Cope and Moore in their studies. In the extensively burned patient, involving 60 to 90 per cent of the surface, if, after administration of the amounts of colloid and salt calculated at the upper limit of 50 per cent, the urinary output is considered too low or the hemoglobin level too high, the cautious administration of more colloid may be carried out, but this may not result in any remarkable improvement in such a patient. In several of these patients there was no clinical improvement but rather an earlier development of fatal pulmonary edema.

SELECTION OF COLLOID

In the patient, with a 20 to 25 per cent body burn, a suitable plasma substitute, such as gelatine or Dextran, appears as effective as plasma in the early treatment of burn shock. However, if sufficient quantities of properly pooled plasma were available at all times, this would be preferable. When 1 to 2 liters of a safe plasma substitute are used in the burn patient, almost inevitably on the third or fourth day a relatively low plasma protein level is found. The plasma protein level in extensive burns after plasma therapy is generally not so low during this period as when a plasma substitute is used, but it does fall from normal. This decrease is commonly less if whole blood has been used.

Our continuing interest in plasma substitutes in treating burn shock is based on establishing their safe use when supplies of plasma and whole blood may be very limited, as in many hospitals during peacetime, or after a major disaster or atomic attack.

In patients with severe burns of from 25 to 35 per cent, if adequate supplies of plasma and whole blood are available, we choose to give them in equal amounts according to calculations from our formula. When the burn is 35 per cent or more of the body surface we have found it advantageous to give whole blood in approximately 2 parts to 1 of plasma or whole blood alone. Whole blood may be administered in the presence of continued hemoconcentration. *Whole blood remains the bulwark of our plan of intravenous therapy for the treatment of shock in the extensively burned patient.*[1, 5]

SALT ADMINISTRATION IN SEVERE BURNS

The proper amount of salt to give to the severely burned patient during the first days after injury has not yet been clarified. For the extensively burned patient of average weight, our formula calls for the administration of approximately 90 Gm. of sodium chloride during the first two days. Analysis during this time indicates that the sodium content of the plasma has been maintained at an approximately normal level. After the first two days, because of fear of pulmonary and excessive wound edema, the amount of sodium chloride given is sharply curtailed to no more than 4 to 6 Gm. daily. This is usually given by mouth.

Figure 2 illustrates the general trend of the levels of sodium content of the plasma in the moderate and severely burned patients. The plasma sodium of the moderately burned patient and a series of control patients on the same salt intake remains at approximately normal levels, although at about the fourth to sixth day the plasma sodium falls to about 125 mEq. per liter in each group. In sharp contrast, a marked drop in plasma sodium occurs as low as 120 mEq. per liter by the fourth or fifth day in a group of extensively burned patients. Perhaps enough sodium chloride is not being administered on the third to eighth post-burn days in the extensively burned patient. Further observations will be made concerning this point in the future.

CLINICAL EXAMPLES OF THE USE OF THE SURFACE AREA-WEIGHT FORMULA FOR FLUID THERAPY

Case 1.—R. W., 100654. This 36-year-old white male was admitted November 27, 1950, 30 minutes after falling into a vat of hot lye (180°F). His burn covered the entire area from the waistline to the soles of the feet—approximating 41 per cent of the body surface. A phlebotomy was done and Dextran started immediately upon admission. A Foley catheter was inserted; burn pad dressings were applied. Fluid and electrolyte therapy was orally. The patient improved markedly on the fifteenth day, and began to take oral feedings without vomiting. The patient had six different grafting sessions between seventeenth day post-burn and the hundred and sixty-seventh day, when he had a very bad Pseudomonas infection, but all areas were healing well. By July 1 the patient could walk around by himself and remain up for 2 to 3 hours at a time. At the present time the patient is up and on his feet the whole day.

Case 2.—E. C., B113321. This 8-year-old colored male was admitted on May 9, 1951, after being burned in a gasoline explosion. He was seen

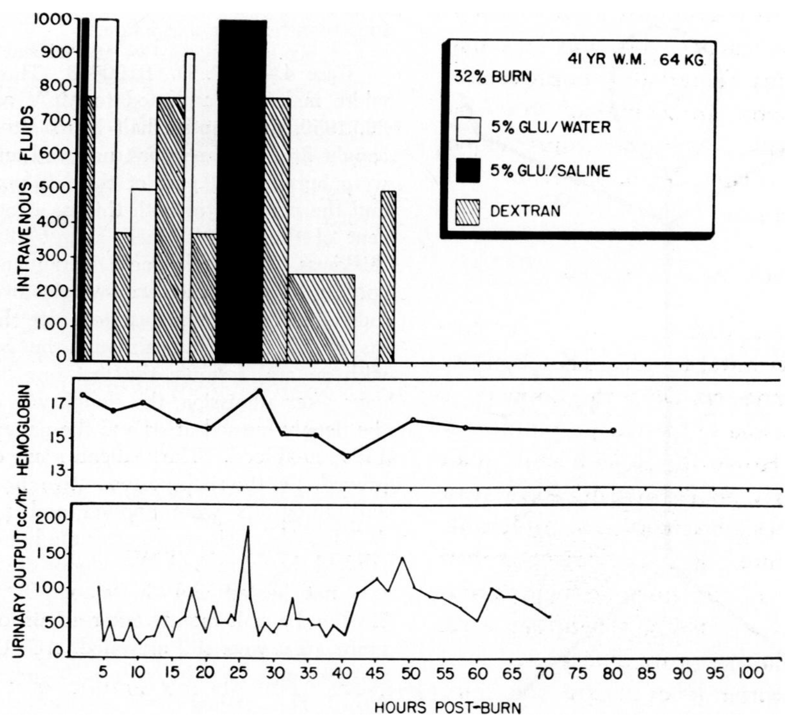

FIG. 6.—L. T. D. This illustrates the application of the surface area-weight formula in a severe burn.

carried out according to the amounts required by the surface area-weight formula. (See Fig. 3). Three days after admission, the patient's temperature was elevated to 105°F. His abdomen was distended. He was in respiratory distress. He was put on gastric suction which relieved his distension and respiratory distress. He was given terramycin, penicillin and 1000 cc. blood. On the first dressing, the burn was found to be entirely third degree. The patient then did fairly well until the fourteenth day, when patient became unusually lethargic. Blood plasma potassium was found to be 2.7 mEq. He was given 7 Gm. of potassium chloride intravenously and 10 Gm. potassium chloride 8 hours after the burn was sustained. The left arm, forearm, hand, left thigh, and leg, right upper thigh, mid-lower trunk and left lower back of trunk were deeply burned. It was estimated to be 40 per cent of his body surface. He was given saline intravenously immediately on admission, followed by 500 cc. of Dextran. Shock increased, however, and one pint of blood was given him rapidly before he came out of shock. His initial hemoglobin was only 13 Gm. and rbc. 8.0 million, indicating pre-existing hypochromic anemia. A Foley catheter was inserted. Fluid and electrolyte therapy was carried out according to the amounts required by the surface area-weight formula. (See

Fig. 4). He was dressed with dry pad dressings. He had been given Pantopon before being sent into the hospital, and had evidently been given an overdose, as shown by slow respiratory rate and tightly constricted pupils, after his circulation improved. Patient had difficulty with the oral formula and vomited or refused feedings for 2 or 3 weeks. On the nineteenth postburn day, grafting was begun. Five procedures were necessary up to July 9 to cover all three third-degree areas. Healing was complete on August 19. There was some limitation of knee, hip and elbow movement in the burned areas at discharge. When seen in follow-up clinic, on October 7, the patient had no limitation of joint movement and all areas were healed.

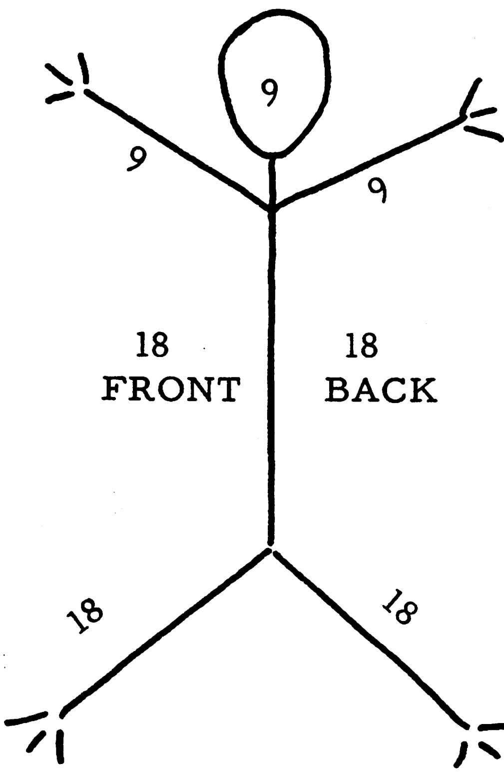

FIG. 7.—A simple diagram illustrating the easy, accurate, and quick method for estimating extent of body surface burned.

Case 3.—E. B., B102550. This five-year-old colored female was admitted on December 2, 1950, after having her clothing catch fire. She had deep and extensive burns of the back and abdomen, right thigh, and the inner aspect of both arms, involving 36 per cent of her body surface. She was in shock on admission. Fluids were started immediately. She was given Dextran, blood and Ringer's solution intravenously. Fluid and electrolyte therapy was given according to estimates made from the surface area-weight formula (Fig. 5). For 5 days her course was hectic. Her temperature rose to 105°F. and her pulse to 156. She was given massive antibiotic therapy. On the ninth hospital day her dressings were changed and her fever diminished. On the twentieth day, she was grafted. These took but became infected. There was still a large area of the back to be grafted with no adequate donor site, and homografts under ACTH therapy were applied. These sloughed in one and a half months, and then autografts were applied from the previously healed donor sites. These were slow to take and slow to heal due to the thick granulation tissue which had piled up under the homografts. She was discharged, healed, four months after admission.

Case 4.—L. T. D., B100636. This 41-year-old white male was admitted to MCV on November 26, 1950, three and a half hours after his clothes caught fire. His anterior trunk and anterior thighs were burned and part of the left posterior trunk and the posterior of both thighs; a total of 32 per cent of the body surface, almost all of this full thickness. He was given Dextran and blood according to our surface area-weight formula and an indwelling Foley was inserted. He did well after his initial treatment, although he had difficulty with an oral formula the first few days. Sixteen days after admission, the slough was excised from the deeply burned areas and the patient was given 1500 cc. blood. The patient seemed much improved. On the sixth postoperative day, homografts and autografts were applied and patient given ACTH. About six weeks after the homografts were applied they sloughed. The donor site for autograft was not healed and the autografts took poorly. Two and a half months after admission, all homografts areas were still unhealed. ACTH withdrawal was begun, and reduced from 25 mg. to 20 mg. q 6 hr. The patient became disoriented and the temperature rose to 104°. Blood chemical tests indicated acidosis and renal failure. The patient followed a downhill course and expired on his eighty-first hospital day. Autopsy showed acute pyelonephritis and lower nephron nephrosis. It was felt that septicemia accompanying withdrawal of ACTH therapy played a major part in his demise. (See Fig. 6.)

SUMMARY AND CONCLUSIONS

In this paper a simple, practical formula has been presented for the calculation of the fluid requirements of the badly burned patient during the first two days of shock phase. There is little difficulty in the man-

agement of fluid therapy following the use of almost any formula with burns up to 20 per cent, especially if the patient is not over 50 years of age. There is little difficulty in the care of the patient with a 20 to 25 per cent burn when the fluid therapy has adhered strictly to the formula. Moderately close clinical observation of the patient with a burn of 30 per cent of the body surface is required. When the area burned comprises 40 per cent or more, the problem of clinical management is so complicated that any formula for fluid estimates must be employed with caution and great care. Hourly clinical observation is exceedingly important. The decisions of clinical management of fluid therapy take precedence over the precise application of any formula.

Of greater import is what the clinician learns by careful bedside observation of the extensively burned patient. We emphasize this as strongly as possible lest some would conclude that by merely following our fluid formula in the extensively burned patient, close clinical observation is superfluous. The course of events in a seriously burned patient can change within a few minutes; at one instant his clinical condition may appear quite good, and then change radically in a very short time. This change requires most critical clinical examination and early institution of the appropriate therapy.

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DISCUSSION.—DR. M. E. DEBAKEY, Houston, Texas: Doctor Evans and his associates deserve considerable credit for providing us with a simple, practical formula for the calculation of the fluid requirements of the severely burned patient, particularly during the early shock period. In our burn unit, which along with others was established through the co-ordinated efforts of the N.R.C. Subcommittee on Burns under Doctor Evans' chairmanship, particular emphasis has been placed upon a study of the role of the kidney in this problem.

It is immediately apparent from Doctor Evans' presentation that successful fluid and electrolyte therapy in severely burned patients is largely dependent upon adequate kidney function. In the measurement of the urinary output, an accurate index of renal function and, indirectly, circulatory function and circulating blood volume, is obtained. We have recently reported a series of severely burned patients with detailed studies of the glomerular filtration rate, the effective renal plasma flow and the maximal tubular excretory capacity (Ann. Surg., 134: 617, 1951). These cases were adequately treated from the fluid and electrolyte standpoint, and in no case was renal failure a problem. These studies reveal that there is a fairly consistent pattern of response in this group, characterized by an increased glomerular filtration