A COMPARATIVE STUDY OF FLUID VOLUMES IN HEART-LUNG BY-PASS OPERATIONS IN OPEN-HEART SURGERY

WALTER F. SCOTT, M.D. (RAND), M.R.C.P. (LOND.), *Johannesburg*

Those concerned with the management of patients undergoing open-heart operations in Johannesburg have had to find their own solution for the control of fluid volume in heart-lung by-pass operations, on account of the particular climatic conditions prevailing in this city. Johannesburg is situated 6,000 feet above sea level. During the mid-winter month of July 1960, the mean noon humidity mixing ratio was 4·5 G. of water in 1 kg. of air. The minimum temperature was 4·5°C. and the maximum temperature 16°C. During the mid-summer month of January the mean noon humidity mixing ratio was 12 G. of water in 1 kg. of air. The minimum temperature was 16°C. and the maximum temperature 24°C.[1] Although the operating theatre was air-conditioned, the room in which the patient was nursed was not so controlled.

It was hoped to develop a régime for our climate with which all who were concerned with the care of patients could become conversant. The advantages of such a régime were felt to lie in the formulation of a normal course of events that would enable abnormalities to be readily detected.

Two series of consecutive patients were studied to test the reproducibility of results and to bring out the differences produced by the administration of different quantities of fluid. The first series consisted of 25 patients and the second of 40 patients. In the first series the average size of the patients was 1·27 square metres body surface area (sq. m. BSA).[2] The volumes of blood and 5% dextrose in water administered were restricted to a minimum in an attempt to establish what advantages, if any, lay in stringent fluid restriction. In the second series the average size of the patients was 1·19 sq. m. BSA and larger quantities of blood and 5% dextrose in water were administered.

BLOOD LOSS

In the first series, during operation the average volume of blood lost per sq. m. BSA was 995 ml. This included 707 ml. lost into the suction sump, 111 ml. removed for tests, 119 G. lost on the swabs and 58 G. lost in spillage. The volume of blood replaced was 1,156 ml. per sq. m. BSA, giving a positive balance of 162 ml. per sq. m. BSA at the end of the operation.

In the second series the average volume of blood lost during the operation was 1,040 ml. per sq. m. BSA. 778 ml. were lost into the suction sump. Since fewer tests were done, only 70 ml. were removed for tests. The quantity lost on the swabs was 125 G. and that spilt was 67 G. The average volume of blood replaced was 1,388 ml. per sq. m. BSA, giving a positive blood balance of 348 ml. per sq. m. BSA at the end of the operation.

It had become apparent that mere replacement of the blood lost did not always result in a satisfactory postoperative state. The volume of blood replaced must ensure a systemic blood pressure, as near as possible to the pre-operative pressure, and a satisfactory venous pressure in the neighbourhood of 15 cm. of water. It is desirable that the venous pressure be maintained at 15 cm. of water irrespective of whether the volume of blood in the patient is greater or less than before operation. There is no relationship between the size of the patient and the volume of blood lost during the operation (Fig. 1).

Nearly all the blood lost in the postoperative period was lost in the first postoperative 24 hours. In series 1 the average volume of blood lost was 865 ml. per sq. m. BSA in the first 24-hour period, and 126 ml. per sq. m. BSA in the second 24-hour period. The total postoperative blood loss was 991 ml. per sq. m. BSA. The volume of blood replaced in the corresponding postoperative period was 1,153 ml. per sq. m. BSA, showing a postoperative positive balance of 162 ml. per sq. m. BSA.

In series 2 the average blood loss was 763 ml. per sq. m. BSA in the first postoperative 24-hour period. The average blood loss in the second postoperative 24-hour period was 105 ml. per sq. m. BSA. The total postoperative blood

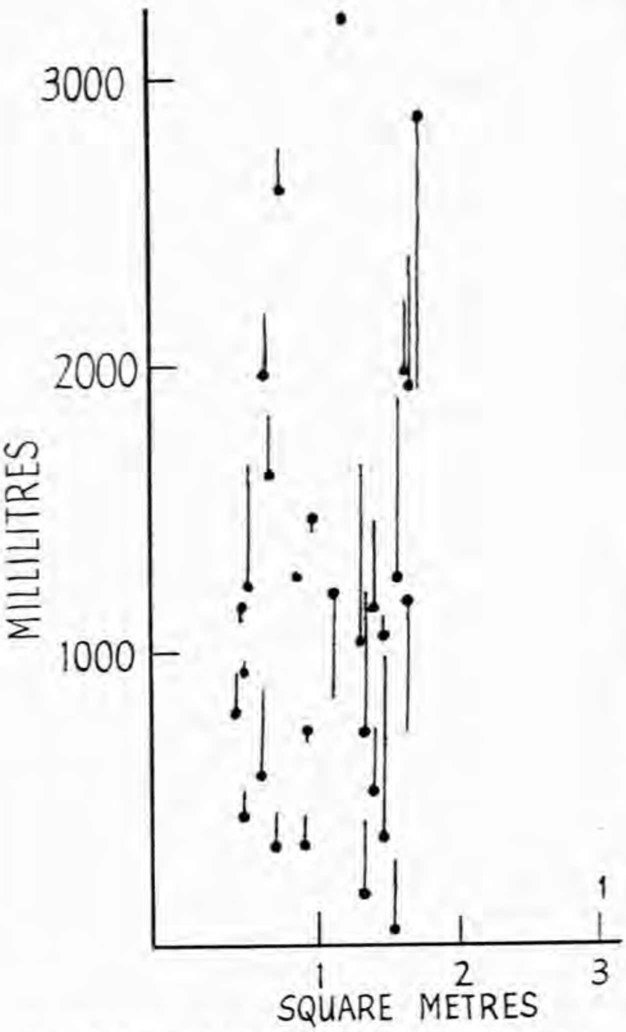


Fig. 1. Volumes of blood lost and replaced in each patient during heart-lung operations. The dot denotes the volume of blood lost and the point at the end of the vertical line the volume replaced.

loss was 868 ml. per sq. m. BSA. The distribution of this loss in the individual patients is illustrated in Fig. 2. The average volume of blood replaced in the first 24-hour period was 956 ml. per sq. m. BSA and in the second postoperative 24-hour period 128 ml. The average volume of blood replaced in the postoperative period was 1,084 ml. per sq. m. BSA, showing a postoperative positive blood balance of 216 ml. per sq. m. BSA.

The average positive blood balance during the postoperative period showed an increase from 162 ml. per sq. m. BSA in series 1, to 216 ml. per sq. m. BSA in series 2. Two possible explanations exist for the smaller blood loss in the second series. These are, increased experience in the surgical procedure and the substitution of polybrene for protamine to reverse the effect of heparin.[5]

Although the blood loss during the operation is unrelated to the patient's size, the blood loss during the postoperative period increases with the size of the patient. The greater blood loss in the bigger patients, noted over the whole operative and postoperative period is, therefore, ascribable to the greater loss by the bigger patients during the postoperative period.

The average total volumes of blood lost during the combined operative and postoperative periods in series 1 and 2 showed a remarkable constancy at 1,986 ml. per sq. m. BSA and 1,908 ml. per sq. m. BSA respectively. The average total volumes of blood replaced in series 1 and 2 were 2,309 ml. per sq. m. BSA and 2,472 ml. per sq. m. BSA respectively. Conforming to the principle of maintaining the arterial and venous blood pressures, besides replacing blood loss, the positive average balance of 323 ml. per sq. m. BSA in series 1 was increased to 564 ml. per sq. m. BSA in series 2 over the whole procedure. The final blood balance is nearly always positive and is not related to the patient's size.

FLUID BALANCE

Intravenous Fluid

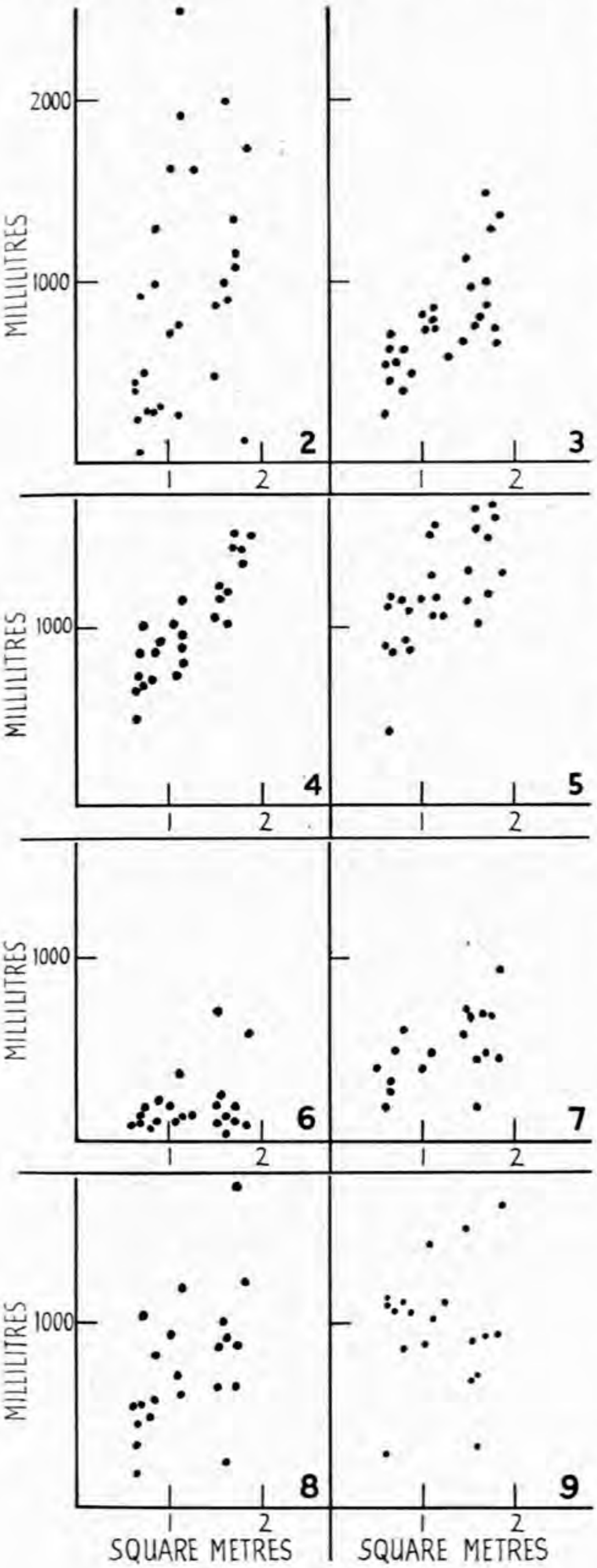
In series 1 the average volume of 5% dextrose in water administered during the operation was 125 ml. per sq. m. BSA. The average volumes of 5% dextrose in water administered per sq. m. BSA for the first, second and third postoperative 24-hour periods were 524 ml., 690 ml., and 727 ml. respectively. The distribution of these volumes in relation to the sizes of the patients was described previously.[4] The average total volume of 5% dextrose in water administered per sq. m. BSA during the operative and postoperative 72 hours was 2,066 ml.

In series 2 the average volume of 5% dextrose in water administered per sq. m. BSA during the operation was 430 ml. During the first, second and third postoperative 24 hours the volumes per sq. m. BSA were 692 ml., 892 ml., and 1,048 ml. respectively. The distribution of these volumes in relation to the sizes of the patients is illustrated in Figs. 3, 4 and 5. The average total volume administered during the period of operation and the ensuing postoperative 72 hours was 3,062 ml. per sq. m. BSA. Thus a total of 996 ml. per sq. m. BSA more was administered in series 2 than in series 1.

Urine

Immediately before going for operation each patient was made to pass urine. In series 1 the average volumes of urine passed per sq. m. BSA in the first, second and third postoperative 24-hour periods were 505 ml., 562 ml., and 505 ml. respectively, giving an average total urine output from the beginning of the operation to the end of the 72nd postoperative hour of 1,572 ml. The distribution of these volumes in relation to the sizes of the patients has been described previously.[4] The average volume of 5% dextrose in water administered during this same period was 2,066 ml. per sq. m. BSA. The positive balance of 5% dextrose in water above the urine excreted was 494 ml. per sq. m. BSA.

In series 2 the patients were catheterized at the end of the operation, and the average volume of urine obtained was 145 ml. per sq. m. BSA. The distribution of these volumes in relation to the sizes of the patients is illustrated in Fig. 6. The volume of urine excreted during the operation bears no relation to the size of the patient. The aver-



age volumes of urine secreted per sq. m. BSA in the first, second, and third postoperative 24-hour periods were 430 ml., 688 ml., and 865 ml. respectively. The distribution of these volumes in relation to the sizes of the patients is illustrated in Figs. 7, 8 and 9. The volume of urine passed from the beginning of the operation to the end of the 72nd postoperative hour was 1,983 ml. per sq. m. BSA. The volume of 5% dextrose in water administered during this period was 3,062 ml. per sq. m. BSA. The positive balance of 5% dextrose in water administered above the urine excreted was 1,079 ml. per sq. m. BSA.

In series 1 the average specific gravity of the urine during the first, second, and third postoperative 24-hour periods was 1023, 1023, and 1019 respectively. In series 2 the corresponding average specific gravity was 1020, 1016, and 1012 respectively.

No attempt has been made to assess the quantity of fluid produced by metabolism in the patients. On account of the many difficulties involved no attempt has been made to evaluate the insensible fluid loss.

COMMENT

In series 1 the positive blood balance at the end of the operation was 162 ml. per sq. m. BSA. In series 2 this figure was raised to 216 ml. per sq. m. BSA, which resulted in more satisfactory venous and systemic blood pressures. In series 1 at the end of the 72nd postoperative hour the total positive blood balance was 323 ml. per sq. m. BSA, and in series 2, 564 ml. per sq. m. BSA. The condition of the patients in series 2 gave rise to much less anxiety during the postoperative period. In series 1 the average total of 5% dextrose in water administered from the beginning of the operation to the end of the 72nd postoperative hour was 2,066 ml. per sq. m. BSA. The corresponding volume in series 2 was 3,062 ml. per sq. m. BSA, an increase of 996 ml. per sq. m. BSA.

The increase in blood administered and the 5% dextrose in water increase of 996 ml. per sq. m. BSA in series 2 was sufficient to reduce the average specific gravity of the urine in the first postoperative 24 hours from 1023 to 1020, in the second postoperative 24 hours from 1023 to 1016 and in the third postoperative 24 hours from 1019 to 1012.

The fact that in series 1 the volume of urine remained more or less constant at about 500 ml. per sq. m. BSA

Fig. 2. Total postoperative blood loss, per patient.
Fig. 3. Fluid intake (5% dextrose in water), per patient, in first postoperative 24 hours.
Fig. 4. Fluid intake, per patient, in second postoperative 24 hours.
Fig. 5. Fluid intake, per patient, in third postoperative 24 hours.
Fig. 6. Catheter urine, per patient, obtained at the end of operation.
Fig. 7. Urine output, per patient, during operation and in first postoperative 24 hours.
Fig. 8. Urine output, per patient, in second postoperative 24 hours.
Fig. 9. Urine output, per patient, in third postoperative 24 hours.

Figs. 2 - 9 refer to patients from series 2. Although this was a series of 40 unselected cases, some of the patients died, some of the patients were incontinent, and some of the urines collected were accidentally spilt; therefore data were not available for all patients in the series. Thus, the number of patients represented in the various graphs is not constant.

for the first 3 periods of 24 hours, would indicate that the patients were excreting an obligatory urine and were, therefore, being dehydrated. In series 2 the volume of urine showed an increase in each of the successive 3 periods of 24 hours, indicating that they were receiving sufficient fluid to allow them to excrete a volume of urine in excess of an obligatory urine. The fact that the average specific gravity did not fall below 1012 suggests that the patients were not being overhydrated. It appears that the balance struck was satisfactory. Fewer of the patients in series 2 complained of thirst than in series 1.

SUMMARY

The control of blood and fluid volumes in 2 series of 25 and 40 consecutive patients undergoing open-heart surgery on the heart-lung oxygenator are compared. Volumes which have been found to give satisfactory postoperative results have been established.

I wish to thank the thoracic surgeons Mr. D. I. Adler, Mr. L. A. du Plessis, Mr. L. Fatti, Mr. D. N. Fuller and Mr. P. E. Marchand for allowing access to their patients; also the physicians, Dr. J. L. Braudo, Dr. M. M. Zion, and Dr. J. Barlow; the anaesthetists, Dr. F. J. Durham, Dr. C. Frost, Dr. K. B. Meaker, Dr. J. Pitcher and Dr. C. H. van Hasselt; the pathologists, Dr. H. B. W. Greig and Dr. A. Walker; and Sister H. du Preez, for their help.

REFERENCES

1. African Climatology Unit, University of the Witwatersrand, Johannesburg: Personal communication.
2. du Bois, E. F. (1936): *Basal Metabolism in Health and Disease*, 3rd ed. London: Ballière, Tindall and Cox.
3. Rothnie, N. G and Kinmonth, J. B. (1960): Brit. Med. J., **1**, 73.
4. Scott, W. F. (1960): S. Afr. Med. J., **34**, 249.