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A Method For the Determination of Exchanged Blood Volume During Exchange Transfusion in Newborn Infants*

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After the classical study of Allen, Diamond and Vaughan on the importance of exchange blood transfusion in cases of hiperbilirubinemia,[1] exchange blood transfusion has been accepted as one of the most effective treatments of hiperbilirubinemia.[2] At present, exchange blood transfusion has also been used succesfully in the treatment of some poisonings, hepatic coma and hypermagnesemia.[3,5]

It is a proven fact that the efficiency of exchange blood transfusion is greater when the absolute amount of original blood is reduced to a low level in the infants circulation.[6] For this reason it would be very convenient if the exchanged volume of blood was known at any time during exchange blood transfusion. This information would be especially valuable in cases of poisoning.

The purpose of this study is to present an easy method for the accurate measurement of the exchanged blood volume at any time during exchange blood transfusion. Our study was performed in newborns who underwent exchange blood transfusions for the treatment of hiperbilirubinemia.

Material and Method

Our material was selected from patients who needed exchange transfusions due to hiperbilirubinemia. Because of the 10 minute prolong-

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ation of exchange transfusion time for the additional study, only 19 newborns were accepted for the study, all of whom had had normal gestational periods, normal birth weights and were in good general condition.

It is well known that the ^{51} Cr- labelled red cells have been used for newborns and infants in the determination of total blood volume, total red cell mass and red cell survival studies without any considerable radiation hazard to the patient.[7, 9]

The method used for ^{51} Cr - labcling of red cells has been described by Gray and Sterling and recently modified by Ebaugh.[10, 11]

Freshly drawn O Rh(–) blood (obtained from the blood bank), with ACD solution was used for labeling. (It was suitable for labeling for a period of 10 days.[12]

Radioactivity counts were done with a "Picker" well-type gamma counting system. The instrument was adjusted to the 321 Kev photo peak of chromium-51.

In this study ^{51} Cr - labeled and saline washed red cell suspension was used and the following steps were taken for the completion of studies:

1. 0.1 ml of ^{51} Cr - labeled red cell suspension was transfused into 4 ml counting tubes. These were then diluted to 4 ml with water. These samples were used as standards.
2. Exchange transfusion was started from the umbilical vein and 20 ml of infants' blood were taken. Chromium - 51 labeled red cells (1 ci/Kg body weight) were injected via the umbilical vein and the 20 ml of blood which had been withdrawn earlier were immediately replaced by doner blood. Thus, the radioactivity was washed from the catherter.
3. A period of 5 to 10 minutes was allowed to pass for the thorough mixing of the labeled red cells in the circulating blood.
4. Two 4 ml samples were taken into counting tubes and hematocrit values were determined from these.
5. Exchange blood transfusion was continued.
6. Step 4 was repeated.
7. Samples and standards were counted in well-type gamma counters.

CALCULATIONS:

Exchanged blood volume, (as percent of original blood volume). = 100 – percent of original blood left in the infants circulation.

$$\text{Percent of original blood left in the infants circulation.} = \frac{\text{Total net counts in 4 ml of post exchange transfusion whole blood sample.}}{\text{Total net counts in 4 ml of pre-exchange 5–10 minutes whole blood sample.}} \times 100$$

Total Blood volume = Total red cell volume ÷ Hematocrit. (as decimal).

$$\text{Total red cell volume} = \frac{\text{Total net counts injected.}}{\text{Net counts in 1 ml of red cells in 5–10 minute sample.}}$$

Total net counts injected = Counts in Standard sample x 10 x amount of red cell suspension injected (in ml).

Net counts of 1 ml red cells = counts in 4 ml 5–10 minutes sample ÷ 4 ÷ Hematocrit (as decimal).

Results

Pre-exchange total blood volume, weight and blood volume per Kg/ body weight of the 19 patients are listed in Table 1. The total blood

TABLE I

TOTAL BLOOD VOLUME, WEIGHT AND BLOOD VOLUME PER KG OF BODY WEIGHT

Patient	Weight (in grams)	Total Blood Volume (in ml)	Blood Volume per kg of Body Weight (in ml)
1	2650	225	84
2	3400	215	63
3	2780	190	71
4	2665	176	66
5	3440	201	59
6	3340	205	63
7	3220	256	80
8	3240	337	104
9	3100	332	107
10	2650	278	105
11	2850	225	80
12	2500	276	110
13	2980	278	92
14	3400	327	96
15	3350	326	97
16	2400	232	97
17	3150	310	98
18	2900	334	115
19	3080	442	140

volume of patient 19 is not included in the evaluation of the results because of a technical error in performing the total blood volume of this patient.

As can be seen in Table I the highest total blood volume was 331 ml (patient 8). In this patient blood volume per Kg/body weight was 66 ml. The mean value of the total blood volume per Kgr/body weight on 81 patients was found to be 87 ml I 17 ml. These values correlate well with the findings in other studies in literature.[13]

Table II pertains to information about the exchanged blood volume as percent of total blood volume and the amount of blood used per Kg/body weight for exchange transfusion.

TABLE II

EXCHANGED BLOOD VOLUME (AS PER CENT OF TOTAL BLOOD VOLUME) AND AMOUNT OF BLOOD USED PER KG OF BODY WEIGHT.

Patient	Exchanged Blood volume as percent of Total Blood Volume	Amount of Blood Used per kg of Body Weight (in ml)
1	84	400
2	85	440
3	82	440
4	85	380
5	64	480
6	66	460
7	78	420
8	85	480
9	85	470
10	89	410
11	88	472
12	81	390
13	88	440
14	84	480
15	80	500
16	80	380
17	83	455
18	81	440
19	87	460

Among 19 patients the highest exchange was made in Case 10. In this case 89 % of the original total blood volume was replaced by doner blood. This patient received 154 ml blood per Kg/body weight for exchange blood transfusion.

The lowest exchange was for Patient 5. This case received 139 ml of blood per Kg/body weight for exchange blood transfusion and only 64 % of the original blood was replaced by doner blood.

Thus it can be seen that if the blood used per Kg/body weight for exchange transfusion exceeds 150 ml, the amount of exchange blood is increased. Despite this we were not able to use this amount of blood in all our cases because of technical difficulties or the inavailability of the desired amount of blood. In our cases the mean value of exchanged blood was 82 % of the original total blood volume with a one standard deviation of S = 13 ml.

Discussion

Calculation of exchanged blood volume during exchange blood transfusion by a mathematical approach has been described by Pochedly.[14] It is an indirect estimation and the final result is dependent upon the assumption that the newborn has 85 ml blood per kilogram of body weight, which is not always correct. The procedure is cumbersome to perform, as one must count the number of syringes, removed and replaced, and must be very careful about the proper filling and emptying of the syringes.

In our study exchanged blood volumes were directly measured from the rate of dilution of the original amount of radioactivity which was injected into the patient.

In addition to the information about the exchanged blood volume, it is also possible to obtain the total blood volume and the total red cell volume of the patient at the end of the study. This additional information could be of further use in the treatment of the patient.

In this study the average exchanged blood volume has been found as 82 percent of the total blood volume with a one standard deviation of S = 13 ml. In infants in whom 150 ml or more blood per kilogram of body weight was given for exchange blood transfusion, this value reached 88 percent. In cases to which less than 150 ml of blood per kilogram of body weight was given, exchanged blood volume decreased accordingly. These findings are closely correlated with the mathematical estimations.

Summary

A method has been described for the exchange blood volume during exchange transfusion and the advantages of the method described. The method can be performed without difficulty in cases where exchange transfusions are necessary.

In this study the average exchanged blood volume was found to be 82 percent of the total blood volume with a one standard deviation of S = 13. Exchanged blood volume was found to be related to the amount of blood used per kilogram of body weight. This finding is in accordance with the mathematical estimations.

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