THE AMOUNT OF BLOOD TO BE TRANSFUSED IN ANEMIA OF CHILDREN (BLOOD DOSAGE) *

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Rapidly as the advance in blood transfusion has taken place, and brilliant as the results have been, it must be admitted that some details have been more or less neglected.

A study of the literature shows that one of the simplest questions still remains unanswered, viz., the exact amount of blood to be transfused. It is very important that this be determined in every case as exactly as is possible; because if too much is given, danger of hypertransfusion becomes imminent; if too little is given, the result will be nil.

Until now no method has been known by means of which one could determine beforehand how much blood was needed to cause a definite increase in the number of red blood cells. Nor could one foretell the degree of increase after the transfusion of a known quantity of normal blood. In fact, the question of blood dosage is a very vague one. While one author advocates a dose for infants up to 150 c.c., another says that a safe limit is to give up to 15 c.c. for each pound of body weight.

It is evident that neither can be right; for it is clear that the amount will depend on more factors than age or weight alone. In the first place, the state of the patient's blood has to be considered. A child with 800,000 red blood cells will need more blood than one with 2,800,000 cells, both being anemic. Secondly, the weight of the patient is of importance; a newly born infant needs less blood than a full grown man. Thirdly, the desired result is a factor—the higher the blood counts desired, the more blood is needed. Fourthly, the kind of anemia is also a determining factor whether the blood forming organs are impaired functionally, or whether the spleen and other blood reservoirs are hyperfunctioning, or whether there is an hydremia, or an oligemia.

It is generally known that after transfusion the red blood cell values usually are increased. Investigators who have studied this effect, and who have tried to discover a constant rule in the changes following this

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procedure, always were discouraged by the fact that in certain cases the blood count showed the same values after transfusion as before, or were even found to be decreased. Their final conclusion was that the counts did not show any constant changes (Huck¹). I wish to emphasize that in nearly all these cases the patient suffered from a serious disease of the blood forming organs (often there existed pernicious anemia) which distorted the results. In other cases in which this abnormal condition was not present, there can be found a constant change. I hope to prove in this paper that the change in the blood count is, in the main, parallel with (1) the body weight of the patient, and (2) the amount of blood transfused.

My interest in the question of blood dosage arose from observations made on two little patients with anemia that were transfused at Leiden in 1919, and who received the same amount of blood (500 c.c.). One of them, a boy, aged 4 years, weighing 13.75 kg., showed after transfusion of 500 c.c. an increase in the number of red blood cells from 1 million to 3.3 millions—an increase of 2.3 millions. The red blood cells of the other boy, aged 2½ years, weighing 11.5 kg., rose from 2.2 to 4.7 millions—an increase of 2.5 millions. These two boys, of nearly the same weight, showed after transfusion of an equal amount of blood a nearly equal rise in the number of red blood cells—the larger boy showing the smaller rise.

I received the impression that in these cases the two bloods had been mixed, just as though they had been mixed in a vessel outside the body, with the restriction that the volume after the procedure was reduced to the volume of the patient's blood before. I believe that the mechanism was as follows: After the blood of the donor has entered the patient's vessels, a dilatation of these vessels takes place and the two bloods are mixed. Within from twenty-four to forty-eight hours the vessels get back their original volume, and the blood bulk is reduced to the volume present before the transfusion, the surplus disappearing. In this volume now is circulating the sum of the recipient's corpuscles plus the corpuscles from the donor.

How many corpuscles has the patient now? To answer this question it is necessary to estimate the blood volume of the patient. We know that the number varies considerably, even in the same patient, and therefore, it cannot be determined with great accuracy. I believe it is possible to base an estimation on a figure approximating one thirteenth of the body weight (7 per cent.) of the patient. This keeps the average between the figures of Haldane and Smith² (1/20) and Lucas and Dearing³ (14.7 per cent. = 1/7).

1. Huck: Johns Hopkins Hosp. Bull. **30**:63, 1919.

2. Haldane and Smith: J. Physiol. **25**:330, 1900.

3. Lucas and Dearing: Am. J. Dis. Child. **21**:96 (Jan.) 1921.

My argument at first was as follows: Supposing that a child weighing 13 kg. (containing 1 kg. of blood) needs to have the number of red blood cells raised from 1 million to 3 millions. This could be done by giving the number of red blood cells present in 1 kg. of blood with 2 millions of red blood cells, which equals 0.4 kg. of normal blood. We have to transfuse 0.4 liter, or 400 c.c. As such calculations proved to work out correctly, I formulated the problem as follows: How much of normal blood do we need for each kilogram of body weight to make the number of red blood cells increase one million?

CONCURRENCE BETWEEN OBSERVED RISE OF RED BLOOD CELLS AND
THEORETICAL RISE IN TWENTY TRANSFUSIONS

No. of Case	Diagnosis	Weight in Kg.	Amount of Blood in C.c.	Red Blood Cells in Millions		Rise of Red Blood Cells in Millions	Theoretical Rise of Red Blood Cells in Millions
				Before Transfusion	After Transfusion		
1	Anemia, hypoplastic ?	13.75	500	1.0	3.3	2.3	2.4
2	Anemia, secondary	11.5	500	2.2	4.7	2.5	2.8
3	Von Jaksch (syphilis)	5.8	150	1.7	3.4	1.7	1.7
4	Von Jaksch (sepsis)	6.2	150	2.3	3.5	1.2	2.4
5	Anemia, secondary	7.11	300	1.5	3.9	2.5	2.8
6	Anemia, secondary	8.25	350	2.1	6.2	4.1	2.8
7	Von Jaksch	3.7	63	2.0	3.0	1.0	1.1
8*	Von Jaksch	3.8	85 ?	2.3	3.1	0.8	1.5
9	Anemia, secondary	10.7	170	2.4	3.6	1.2	1.5
10*	Anemia, secondary	9.7	175	3.7	4.7	1.0	1.2
11	Anemia, secondary	2.3	72	2.9	5.1	2.2	2.0
12	Anemia, secondary	6.28	250	1.2	4.7	3.5	2.7
13	Von Jaksch	4.55	130	2.6	4.4	1.8	1.8
14	Von Jaksch	8.5	160	3.4	4.6	1.2	1.3
15	Von Jaksch	5.77	180 ?	3.1	4.6	1.5	2.0
16	Anemia, secondary	19.5	380 ?	3.3	5.0	1.7	1.3
17	Anemia, secondary	7.62	230	1.6	3.6	2.0	2.0
18	Anemia, secondary	3.9	85	2.8	4.5	1.7	1.7
19	Anemia, secondary	7.9	150	3.9	4.3	1.4	1.3
20	Anemia, secondary	4.6	150	1.2	3.8	2.6	2.1

* Second transfusion in same patient.

Considering that each kilogram of a child contains 1/13 kilogram of blood, and supposing that normal blood contains 5 million red blood corpuscles, it is evident that this quantity will be $1/5 \times 1/13 \times 1,000$ c.c., or 15 c.c. per kilogram. Thus we come to the thesis: In cases of simple anemia in which we wish to make the red blood cells increase 1,000,000, we have to transfuse 15 c.c. per kilogram of body weight.

To prove this, I have put together in a table the blood counts of all patients who were transfused at the Leiden pediatric clinic and have compared the rise of their red blood cells with the theoretical rise. Beginning with about case 6 I have even used my method to fix the amount of blood to be transfused, and with rather good results.

It is obvious from this table that in most cases the number of red blood corpuscles nearly approached the estimated number. In only three cases was there any great difference.

In Case 4 the blood counts were too low, which may have been caused by the blood destruction that resulted from the septic process (patient died, spleen was greatly enlarged). In Case 6 the blood counts were too high (hydremia?). In Case 8 the blood counts were too low. This patient had an enlarged spleen, and possibly the dose of blood transfused had not rightly been committed, as there had been trouble in this transfusion.

In all other cases the difference was less than 25 per cent. In thirteen cases it was even less than 0.3 million.

It appears to me that the method may be of practical value for those who are employing blood transfusion as a therapeutic agent in cases of chronic anemia. In acute hemorrhages it is not necessary to make an estimation by this method, because the blood findings in these cases are without great value. Small differences always will be seen, as the normal blood count varies within fairly wide limits. Too low a count may be due to an abnormal condition of the bone marrow, or an enlarged spleen and liver, when the blood corpuscles are prevented from entering the circulation, or to a rapid destruction in these organs of the introduced blood.

Too high counts possibly may be caused by a watery condition of the blood of the recipient (hydremia) in combination with bad vasotonus, the normal tonus returning after transfusion, which gives concentration of the blood and relative rise of red corpuscles.

It is obvious that pernicious anemia will give capricious results, as all these conditions may be present.

In adults the method may serve as a guide. A person weighing about 70 kg. needs $70 \times 15 = 1$ liter of blood to make his red blood cells increase one million.

CONCLUSION

In cases of simple anemia, there exists a correlation between the amount of blood transfused, the body weight and the rise of red blood cells. A rise of one million corresponds with an amount of 15 c.c. of blood per kg. of body weight. This gives a method to estimate beforehand the amount of blood to be transfused, as shown in twenty cases from the Leiden pediatric clinic.