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# Proposed Formulae for Determining Blood Transfusion Requirements in Children with Severe Anaemia

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**Summary**

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**Background**: Blood replacement remains a crucial component of the treatment of severe anaemia irrespective of the cause. The transfusion of an adequate amount of blood is important to prevent under- or over-transfusion. Existing formulae used for the calculation of blood transfusion requirements, while being useful, still have deficiencies. The current study aims to evolve simple formulae that can be used in calculating the volume of packed red blood cells (PRBC) required for attaining a specific packed cell volume (PCV) level.

**Method**: A total of 172 patients with severe anaemia [PCV of <20] were recruited for the study. They all received 15 ml/kg of PRBCs irrespective of their pre-transfusion PCV. Post-transfusion PCV was determined at least, six hours after the completion of blood transfusion. The three simple formulae were subsequently derived by using the blood volume transfused, the mean weight of the patients and their mean pre- and post-transfusion PCVs.

**Result**: The three formulae obtained in determining the volume of PRBC required in transfusions were as follows: (a) 1ml/kg of packed cells would increase PCV by 0.9 percent, (b) 1.1 ml/kg of packed cells would increase PCV by one percent, and (c) (target PCV x weight x k (0.55) / pre-transfusion PCV).

**Conclusion**: The three formulae should aid the calculation of required volume of PRBCs transfusion in severe anaemia aiming at a target PCV. The maximum target PCV should however, not exceed 30 percent and the PCV differential should not exceed 13.3 when using these formulae.

**Keywords**: Formulae; Blood transfusion; Severe anaemia.

## Introduction

ANAEMIA remains a common life threatening condition of children in the tropics.[1-3] It is caused by various diseases, commonest of which is malaria.[4] It results in varied levels of hypoxaemia and lactic acidosis depending on its severity. These metabolic complications affect the function of virtually every organ in the body. A delay in accurate intervention in terms of blood replacement may result in an unfavourable outcome. Blood replacement is not just essential but the accurate determination of the amount needed is also crucial. Any miscalculation is capable of leading either to an inadequate or to excessive transfusion. These potential problems call for an accurate formula to calculate the required volume of blood in patients with severe anaemia and a review of existing formulae. The current formulae in use in local emergency rooms, while still useful, do not adequately correct the severe anaemia in some cases. The formula of giving 15 ml of packed red blood cells/kg[5] to anaemic patients does not take into consideration the target PCV to be attained. The other formula [Desired PCV – Observed PCV x Blood Volume x Weight in Kg/PCV of transfused blood] that addresses the issue of target PCV sometimes results in large volume requirement which is capable of causing congestive cardiac failure. In the light of this, the current study aims to evolve other simple formulae that can be used

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in calculating blood transfusion requirements, taking into consideration the PCV to be attained.

## Materials and Methods

A total of 172 patients admitted to the Emergency Children's Unit (ECU) of the University of Ilorin Teaching Hospital (UITH) and diagnosed as having severe anaemia based on a PCV <20 percent, were recruited into the study. Patients with anaemia caused by loss of whole blood from any cause were excluded from the study. Similarly, any patient that required whole blood transfusion was excluded.

The PCV was determined by collecting blood from the eligible patient in a capillary tube and subsequently spinning it in a centrifuge to allow the red cells to settle. The PCV was obtained by reading off the level of the red cell sediment on a microhaematocrit scale. Blood transfusion was given to patients who met the inclusion criteria. All the patients received 15ml/kg of packed red blood cells (PRBC) irrespective of their pre-transfusion PCV; in addition, 1ml/kg of frusemide was given intravenously during transfusion to prevent hypervolemia. The post-transfusion PCV was determined at least six hours after the completion of the transfusion. The mean pre and post-transfusion PCVs were determined and the PCV differential between the pre and post transfusion PCVs was determined by subtracting the mean pre-transfusion PCV from the mean post-transfusion PCV.

The three formulae were derived from the blood volume transfused, the mean weight of the patients and the mean pre and post-transfusion PCVs.

## Results

The 172 patients studied, comprised 95 males and 77 females. They were aged from three months to 15 years, with a mean of 4.6 years. One hundred and eight [62.8 percent] of the patients were aged three months to four years, 36 [20.9 percent] were >4 to nine years, and the remaining 28 [16.3 percent] were aged >9 to 15 years [Table I]. The mean weight of the patients was 14.4 kg with a standard deviation [SD] of 8.9

**Table I**

*Age Groups of the Patients Transfused*

| *Age Group (years)* | *Number (%)* |
|---|---|
| 0 – 4 | 108 (62.8) |
| >4 – 9 | 36 (20.9) |
| >9 – 15 | 28 (16.3) |
| Total | 172 (100) |

**Table II**

*Pre-Transfusion PCV of the Patients Studied*

| *Pre-Transfusion PCV(%)* | *Number of Patients (%)* |
|---|---|
| 0 – 5 | 1 (0.6) |
| 6 – 10 | 26 (15.1) |
| 11 – 15 | 77 (44.8) |
| 16 – 19 | 68 (39.5) |
| Total | 172 (100) |

**Table III**

*Post-Transfusion PCV of the Patients Studied*

| *Post-Transfusion PCV (%)* | *Number of Patients (%)* |
|---|---|
| 11 – 20 | 15 (8.7) |
| 21 – 30 | 109 (63.4) |
| 31 – 40 | 48 (27.9) |
| Total | 172 (100) |

**Table IV**

*Presumed Causes of Anaemia in the Patients Studied*

| *Causes* | *Number of Patients(%)* |
|---|---|
| Malaria | 124 (72.1) |
| Sickle cell disease | 18 (10.5) |
| Sepsis | 13 (7.5) |
| Others | 17 (9.9) |
| Total | 172 (100) |

The pre-transfusion PCV ranged from 5-19 percent with a mean of 14.6 and SD of 3.9. The PCV in 77 (44.8 percent) patients ranged from 11 to 15 percent; in 68 [39.5 percent] others, it ranged from 16-19 percent, in 26 [15.1 percent] it varied from 6 to10 percent, while only one patient had a PCV of five percent [Table II]. The range of post-transfusion PCV was 11-40 percent with a mean of 27.9 and SD of 6.1. The PCV increased to 21-30 percent in 109 [63.4 percent] patients; in 48[27.9 percent], the increase ranged from 31-40 percent, while in the remaining 15 [8.7 percent] patients it ranged from 11-20 percent [Table III].

Anaemia in 124 [72.1 percent] patients was presumed to be due to malaria in view of a quick recovery after anti-malaria chemotherapy and blood transfusion. The presumed cause of anaemia in 18 [10.5 percent] was sickle cell disease [SCD], sepsis in 13 [7.6 percent], while the causes in the remaining 17 [9.8 percent] included glucose-6 phosphate-dehydrogenase deficiency, pneumonia, malnutrition, and auto-immune haemolytic anaemia [Table IV].

Eight deaths, constituting 4.7percent mortality, were recorded. Fifty percent of the deaths were recorded among patients who presented with anaemia due to malaria while the rest occurred among those with sepsis and SCD.

### Derivation of the formulae

Since each of the 172 patients received 15ml/kg of PRBCs and this resulted in a mean post-transfusion PCV of 27.9 percent in patients whose mean weight was 14.4 kg, the following inferences or deductions could be made:

1. It may be implied that 15ml/Kg of packed cells was able to raise the PCV by [mean post-transfusion PCV [27.9] - mean pre-transfusion PCV [14.6] = 13.3. Therefore, if 15ml/Kg of packed cells raised the PCV by 13.3, then, 1ml/kg of packed cells would raise it by 13.3 ÷ 15 = 0.9. The 0.9 is a constant K.

*Example*

If for instance, one wants to raise PCV by 9 percent in a patient with a given pre-transfusion PCV, it means the target PCV differential [post-transfusion PCV – pre-transfusion PCV] = 9. The blood volume in ml/kg required for the target PCV differential of

$$9 = \frac{\text{Target PCV differential}}{\text{Constant}} = \frac{9}{0.9} = 10\text{ml/kg}$$

2. It may also be implied that 15ml/kg of PRBC was able to raise the PCV by [mean post transfusion PCV (27.9) – mean pre-transfusion PCV (14.6) = 13.3] supposedly in a child with a weight of 14.4 kg since that was the mean weight of all the patients. Therefore, that child with a weight of 14.4 kg received 15 x 14.4 ml of PRBC = 216 ml. It therefore implies that 216 ml of PRBC was able to raise the PCV by 13.3. Therefore, in order to raise PCV by 1, [216 divided by 13.3] ml = 16ml of packed cells will be required. Since the weight of the patients under consideration is 14.4, [16 divided by 14.4] ml/Kg = 1.1 ml/Kg of packed cells will be needed to raise the PCV by 1.Thus, 1.1 becomes a constant K

***Example:***

If for instance, one wants to raise PCV by 9 in a patient with a given pre- transfusion PCV, it means the target PCV differential is 9. The blood volume in ml/kg required to achieve this target PCV differential of 9 is K, which is 1.1 x PCV differential of 9 = 9.9 ml/kg.

3. It is also feasible to derive a constant K from an equation involving the mean pre-transfusion PCV, post-transfusion PCV, mean weight, and the transfused volume of 15 ml/kg. The equation goes thus:

$$\frac{\text{Mean pre-transfusion PCV [14.6] x blood volume transfused [15ml/kg]}}{\text{Mean post-transfusion PCV [27.9] x mean weight [14.4Kg]}} = 0.55$$

The blood volume to be transfused in ml/kg becomes the derivable variable Y, while the constant K is 0.55.

***Example:***

If a child weighing 10 kg presenting with a PCV of 10 requires that his PCV be raised by 10 to bring it to a post transfusion PCV of 20, then Y, which is the blood volume to be transfused would be calculated from the equation:

$$\frac{\text{Pre-transfusion PCV [10] x [Y]}}{\text{Post-transfusion PCV [20] x weight [10 kg]}} = 0.55$$

$$Y = \frac{20 \times 10 \times 0.55}{10} = 11\text{ml/kg}$$

The hypothetical patients used in the three examples are similar; therefore, blood volume required were expected to be as close as possible to each other, which was the case [P <0.05].

### Discussion

These three formulae were derived using the administration of 15ml/kg as reference point. The administration of 15ml/kg [5] to all patients irrespective of their PCV seems to be inappropriate as the blood requirement of patients with different pre-transfusion PCVs will obviously differ. Another formula [Desired PCV – Observed PCV, x Blood Volume x Weight in kg/ PCV of transfused blood] did take into account desired PCV, but the addition of the PCV of the transfused blood to the formula, while probably appropriate, makes the calculation more complex especially under emergency situations where the survival of the child is a priority consideration before any other. Furthermore, transfused blood is not expected to be anaemic for any reason as anaemic blood donors are automatically disqualified. Anecdotal observations from calculations of blood requirements of several anaemic children revealed that a much higher volume requirement that raises the fear of possibility of volume overload is obtained on certain occasions.

The mean PCV differential of 13.3 obtained following transfusion with 15 ml/kg [5] of packed cells indicates that the maximum possible increase of PCV that could be obtained is 13.3. The implication of this is that the attainment of a higher PCV differential would necessitate a closer monitoring of vital signs because of the probable higher volume that would be required for transfusion.

The three derived formulae were based on simple deductions from our findings of mean PCV differences between pre- and post-transfusion PCV in children with a mean weight of 14.4 kg. It is pertinent to note that any proposed formula on blood requirement in anaemia should take into account the weight of the child because blood volume is relative to weight, in addition to the desired PCV to be attained. The PCV of the transfused blood is also relevant since it reflects its haemoglobin content that would ultimately determine the rise in the level of PCV in the patient. However, this should not be an issue since blood transfusion facilities do not, as a rule, obtain blood from anaemic donors.

These three formulae should be useful at the bedside. They have the advantage of helping to attain a target PCV, they do not need any complex calculations, physicians can easily be trained to use them and there is no fear of excessive transfusion. However, in using these formulae, the maximum PCV attainable should not exceed 30 and the PCV differential should not exceed 13.3. If for any reason, any of these figures needs to be exceeded, the vital signs should be closely monitored for signs of volume overload. In addition, all patients on blood transfusions should also receive a diuretic, usually frusemide, to prevent hypervolaemia.

In conclusion, we recommend that these three formulae should be used in calculating blood requirements in children with anaemia requiring packed red blood cells transfusion. We also strongly recommend a validation of these propositions with a view to improving on them, if necessary. Furthermore, we suggest that volumes of blood transfusion should always aim at a desired or target PCV.

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