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Review

# Mathematics of apheresis

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ABSTRACT

Mathematics is related to apheresis medicine. The safety of donor and patient in taking blood components is utterly important. Knowledge of total blood and plasma volume is needed and have to be calculated. By increasing quality, the safety of not only the donor and patient, but also the operator will increase, as well as the efficiency of operating an apheresis collection facility. Various concepts, formulas and calculations methods and their significance in apheresis are given in this paper.

## 1. Introduction

For working as an apheresis nurse doing apheresis procedures, specific calculations for the safety of your donor or patient are needed. In this paper we will share some mathematics that might be important in your apheresis work, e.g. calculation of the total blood volume, the total plasma volume and how to calculate the extra corporeal volume. Besides that, we will discuss the collection efficiency of the apheresis machines, and in relation to that, how to calculate the number of total blood volumes to process to achieve a specific number of cells. And in the end we will discuss the AC ratio and the hematocrit in relation to hemoglobin levels.

## 2. Total blood volume (TBV)

The total blood volume of an human being is not the same in every person. For example, a very obese man will have a totally different blood volume than a tiny women. Also for babies and young children you can't say that they have a TBV of approximately 5 liters. For a more precise estimation of the TBV, various formulas are published. Well known are Nadler's formula and Gilcher's rule of fives, but there are also other formulas. Nadler's formula is a very complicated formula (see Table 1), taking into account the gender, height and bodyweight of a person.

It should be noted that this formula can not be used for children with a bodyweight of 25 kilogram or less. It's also important to know that most apheresis equipment is using this formula to calculate the TBV in the parameter setting of the machines.

In Gilcher's rule of fives [2], you make a choice for male, female or pediatric persons, after that you need to take into account the physics of the person. Depending on the group the patient is belonging too, the total blood volume will be calculated by multiplying the patient's bodyweight with the number given in the table.

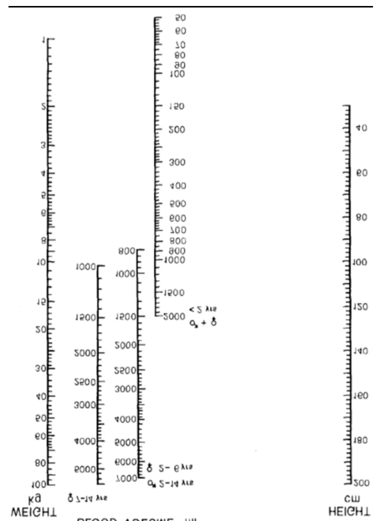

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**Table 1**
Nadler's formula [1].

| |
|---|
| For Males = (0.3669 * $Ht^3$) + (0.03219 * Wt) + 0.6041 |
| For Females = (0.3561 * $Ht^3$) + (0.03308 * Wt) + 0.1833 |
| Note: |
| * Ht in M = Height in Meters |
| * Wt in kgs = Body weight in kilograms |

(*continued*)

| Gilcher's Rule of Fives | | | | |
|---|---|---|---|---|
| | Blood Volume (mL/kg of Body Weight) | | | |
| Patient | Obese | Thin | Normal | Muscular |
| Male | 60 | 65 | 70 | 75 |
| Female | 55 | 60 | 65 | 70 |
| Infant/Child | - | - | 80/70 | - |

As mentioned above, Nadler's formula can't be used in children below 25 kgs. Based on research work in dozens of children of varying ages, Linderkamp, et al. [3], composed a so-called nomogram for the calculation of the TBV in children, which gives rather accurate outcomes.

### 2.1. Extra Corporeal Volume (ECV)

When somebody is talking about the ECV, he or she is talking about the volume of blood which is outside of the body. This is not only the blood in the disposable, but also the volume of the collected blood components and the volume in the test tubes. For the safety of the donor or patient, it is advised that the ECV should be maximally 15% of the TBV. Working with Spectra Optia® (Terumo BCT), it should be realized that the cMNC set is having a volume of 285 mL, while the standard MNC set has a volume of 151 mL. Assume that you will collect 300 mL using the MNC set of Spectra Optia, the patient or donor will have an ECV of at least one 151 mL of the disposable plus 300 mL of the collected volume which is 451 mL, and 585 mL with the other sets. So you need to take care of children or smaller patients.

### 2.2. Extra Corporeal Red Blood Cell Volume (ECRV)

Another way of looking at the ECV is looking at the extra corporeal RBC volume, so the RBCs in the disposable and the collected tubes. Similar to the ECV, it is advised that this should be maximally 15%. To calculate the RBC volume of the donor or patient, you need to know besides the total blood volume also the hematocrit.

Calculation of the red blood cell volume can be of extreme importance to decide whether for apheresis procedures in children priming of the disposable with red blood cells is needed. For example: a 6 year old child with a calculated blood volume of 1800 mL needs a Plasma Exchange. It should be taken into account, that with connecting the disposable to the patient, the TBV of the child will increase with the volume of the disposable and blood warmer from 1800 to almost 2000 mL. With a saline or albumen disposable prime, the RBC volume remains the same, so the hematocrit will drop during the procedure. In case of starting with a hematocrit of 20%, the child decreases during the procedure to a hematocrit of 18% and have an ECRV of almost 20%. Based on the clinical condition of the child, a blood prime could be considered.

### 2.3. Plasma volume and hematocrit

The hematocrit is the volume percentage of RBCs in the blood volume. Using the TBV in combination with the hematocrit (Hct), a total plasma volume (TPV) can be calculated: TPV= TBV * (1-Hct).

Typically in plasma exchange procedures, 1–1.5 times a plasma volume needs to be exchanged by plasma, colloids or crystalloids. Calculation of the TPV is important to orders the correct volume of replacement solutions prior to the procedure.

### 2.4. Weight and volume

There is a relation between the volume and the weight of fluids. Knowing the weight of a specific fluid the volume can be calculated. Every blood component has its own specific weight. You need to take the weight of the collection bag (without the weight of the empty bag) and divide this with the specific weight of the fluid. The other way around, knowing the volume collected, also the weight of the collected component can be calculated. For this calculation, you multiply the volume with the specific weight of the fluid.

### 2.5. Collection efficiency

It's good to know the collection efficiency of the machines you are using, because this can be used for quality aspects of your collection and also for logistic reasons within your collection facility. You can compare the various collection machines, but also the various operators. In principle the collection efficiency is the number of cells that we collect of the total number of cells processed by the apheresis machine.

There are two formula's that can be used for all different blood cells.

Collection efficiency 1 = T product.

T precount 2 * processed volume without AC * 100.

Collection efficiency 2 = T product.

T precount + T postcount / 2 * processed volume without AC * 100.

In the formula of CE2 you take the collected number of cells in the collection bag and you divide that number with the pre-count plus the post- count (divide by two) and multiply that with the processed absolute blood volume, this is the processed volume without the anticoagulant volume. When you don't know the post count of the platelets, you only use the pre-count in the calculation (CE1). However, since the cell count during a procedure can change, this collection calculation is less accurate. With all these data, the efficiency with this machine for this procedure can be calculated accurately. Doing this for all your collections, you can calculate the mean collection efficiency for this procedure in your center.

Knowing the mean collection efficiency in your center, you can also calculate what volume of blood must be processed to collect a specific number of cells. It's totally not needed to process always three times the total blood volume or always standard fifteen liters and sometimes you can see that one procedure will not be sufficient and that a second day will follow.

TBV = $CD34_{needed}$ x body weight patient

$CD34_{donor}$ x collection efficiency

Making the calculation you will see how much of uncoagulated blood we need to process to achieve the request number of cells. This exercise can be helpful in the logistics of your apheresis center. You maybe avoid a procedure on the second day or have information on a volume to process when a second day is needed.

Hemoglobin levels.

Depending on the center or country your working, the units your working with can vary. For instance, the hemoglobin level. Some work with g/dl and others with mmol/l. It's not that difficult to know what the hemoglobin level will be when the for you usual unit is not used:

1 g/dL = 0·62 mmol/L and 1 mmol/L = 1·61 g/dL

Sometimes you only know the hemoglobin level of a patient. However, the apheresis machine needs to know for a variation of calculations the Hct. Of course, hematocrit and hemoglobin are two different items. The hematocrit is the percentage of red blood cells in your blood.

Approximately 90% of the red blood cell is covered by the hemoglobin protein. However, with knowing the hemoglobin level, a rough calculation of the hematocrit can be made:

g/dL: Hct is roughly 3x Hb.

mmol/L: Hct is roughly (Hb x 10): 2) – 2.

## References

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