Math in Donor Apheresis

Marleen Neyrinck\textsuperscript{1}, Hans Vrielink\textsuperscript{2}

\textsuperscript{1}AZ DELTA, ROESELARE, BELGIUM
\textsuperscript{2}SANQUIN BLOOD SUPPLY, AMSTERDAM, THE NETHERLANDS
Disclosure of Relevant Financial Relationships

• Marleen Neyrinck  None
• Hans Vrielink    None
- TBV
- ECV
- TPV
- CE
- Volume to process
Total blood volume

- 5 liter
• Nadler’s formula
• Gilcher’s rule of fives
• Other calculations
Nadler's Formula

For Males = (0.3669 * Ht$^3$ in M) + (0.03219 * Wt in kgs) + 0.6041

For Females = (0.3561 * Ht$^3$ in M) + (0.03308 x Wt in kgs) + 0.1833

Note:
# Ht in M = Height in Meters
# Wt in kgs = Body weight in kilograms

### Gilcher’s Rule of Fives

<table>
<thead>
<tr>
<th>Patient</th>
<th>Blood Volume (mL/kg of Body Weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obese</td>
</tr>
<tr>
<td>Male</td>
<td>60</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
</tr>
<tr>
<td>Infant/Child</td>
<td>-</td>
</tr>
</tbody>
</table>

### Others

<table>
<thead>
<tr>
<th>Age group</th>
<th>Approximate blood volume (mL/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature infant, at birth</td>
<td>90-105</td>
</tr>
<tr>
<td>Term newborn infant</td>
<td>80-90</td>
</tr>
<tr>
<td>Children &gt; 3 months</td>
<td>70-75</td>
</tr>
<tr>
<td>Adolescents and adults</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>70</td>
</tr>
<tr>
<td>Female</td>
<td>65</td>
</tr>
<tr>
<td>BMI</td>
<td>Blood volume</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>BMI &lt; 18.5</td>
<td>80 mL/kg</td>
</tr>
<tr>
<td>BMI 18.5-24.9</td>
<td>70 mL/kg</td>
</tr>
<tr>
<td>BMI 25-29.9</td>
<td>65 mL/kg</td>
</tr>
<tr>
<td>BMI &gt;30</td>
<td>55 mL/kg</td>
</tr>
</tbody>
</table>

\[
\text{BMI} = \frac{\text{Wt}}{H^2}
\]

Wt = 75 kg  
H = 1.70 m

\[
\text{BMI} = \frac{75}{(1.7 \times 1.7)} = 26 \text{ kg/m}^2
\]

C van Bree. Abstract  Ned Tijdschrift Bloedtransfusie 2010
### Others

<table>
<thead>
<tr>
<th>BMI</th>
<th>&lt; 18.5</th>
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<table>
<thead>
<tr>
<th>Total n=261</th>
<th>N=19</th>
<th>N=117</th>
<th>N=89</th>
<th>N=36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>78.3 mL/kg</td>
<td>66.7 mL/kg</td>
<td>61.7 mL/kg</td>
<td>56.2 mL/kg</td>
</tr>
</tbody>
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## Gilcher’s Rule of Fives

<table>
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<tr>
<th>Patient</th>
<th>Obese</th>
<th>Thin</th>
<th>Normal</th>
<th>Muscular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
</tr>
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### Blood Volume (mL/kg of Body Weight)

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<tr>
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TBV in children

Rule of thumb:
• Premature infant, at birth • 90-105 mL/kg
• Term new born infant • 80-90 mL/kg
• Children (>3 months) • 70-75 mL/kg

Nadler’s formula is not usable
TBV in children

Boy 3 yrs of age
Height 88 cm
Weight 16 kg
Girl 6 months of age
Height 58 cm
Weight 6 kg

“Volume of blood removed from the donor at any time. It includes all blood and plasma in collection packs and contained within the machine harness....”

Important to know:

- Volume harness
- Volume to collect
- Volume taken for tests
- TBV patient / donor
Most patients without significant cardiovascular or pulmonary disease will tolerate an ECV and an ERCV of up to 15%.

If the ECV or ERCV of a standard procedure will exceed 15%, or if the patient has significant cardiovascular disease, measures such as priming the circuit with a colloid or red cells should be considered.
- USA: No limits

- Europe: “The maximal ECV must never be higher than 20%.”
“The maximal ECV must never be higher than 20%.”

“In any apheresis procedure involving collection of plasma, platelets and/or red cells in one apheresis procedure, the total volume of all components collected (plasma, platelets and red cells) must not exceed 16% of total blood volume, with a maximum of 750 mL (exclusive of anti-coagulant), unless fluid replacement is undertaken.”
ECV and apheresis

- USA: No limits

- Europe: “The maximal ECV must never be higher than 20%.”

- UK Red Book: “During apheresis procedures the ECV should not exceed 15% TBV (excluding anticoagulant).”
ECV in children

- Volume disposable 150 – 250 mL
- Less variance in ECV in case of continuous systems
- (RBC) priming needed:
  - Depletion of >15% because of filling disposable
  - In case threatening the oxygen-carrying capacity by reduction of RBC volume
  - Usually if bodyweight is <20 kg
Total plasma volume

TPV = TBV * (1 – Hct)

TPV = \( \frac{TBV \times (100 - Hct)}{100} \)
Hematocrit

• The volume percentage of red blood cells in blood

• Females 0.36 – 0.46 L/L (36 – 46%)

• Males 0.41 – 0.53 L/L (41 – 53%)
Total plasma volume & Hct

TPV = TBV * (1 – Hct)

Casus

Patient 1:  - Female
- Height: 160 cm
- Weight: 91 kg
- Hct: 0.35 L/L

TBV: 91 x 55 = ± 5000 mL
TPV: 5000 x 0.65 = ± 3250 mL

Patient 2:  - Male
- Height: 175 cm
- Weight: 72 kg
- Hct: 0.50 L/L

TBV: 72 x 70 = ± 5000 mL
TPV: 5000 x 0.5 = ± 2500 mL
Reservoir for temporarily storage of cells $\to$ 200 mL of Hct = 80% $\to$ In reservoir 160 mL cells

**Per cycle**

- Hct = 50% $\to$ Processing of 320 mL $\to$ Collection of 120 mL of plasma
- Hct = 35% $\to$ Processing of 460 mL $\to$ Collection of 260 mL of plasma

Higher Hct $\to$ more donor blood needs to be processed for plasma collection
Calculation Hb into Hct

Note: Hb and Hct are two different things
- Hct is percentage of RBCs in blood
- 90% of RBC content is Hb

• g/dL $\Rightarrow$ Hct is roughly 3x Hb
• mmol/L $\Rightarrow$ $((\text{Hb} \times 10) : 2) - 2$
Calculation Hb into Hct

- g/dL → Hct is roughly 3x Hb
- mmol/L → ((Hb x 10) :2) -2

Hb = 16.1 g/dL = 10 mmol/L

- g/dL → Hct = 3 x 16.1 = 48%
- mmol/L → Hct = ((10 x 10) :2) - 2 = 48%
Collection efficiency

How many of the by the machine processed cells are collected in the bag

e.g. platelets

\[
\frac{T_{\text{product}}}{(\frac{T_{\text{pre}} + T_{\text{post}}}{2}) \times (\text{Processed volume} - \text{AC volume})} \times 100
\]

\[
\frac{T_{\text{product}}}{T_{\text{pre}} \times (\text{Processed volume} - \text{AC volume})} \times 100
\]
Collection efficiency

e.g. platelets

\[
\frac{T_{\text{product}}}{((T_{\text{pre}} + T_{\text{post}}) / 2) \times (\text{Processed volume} – \text{AC volume})} \times 100
\]

Case:

<table>
<thead>
<tr>
<th>T product</th>
<th>350 x 10^9/unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>T pre</td>
<td>280 x 10^9/L (280,000 / µL)</td>
</tr>
<tr>
<td>T post</td>
<td>200 x 10^9/L (200,000 / µL)</td>
</tr>
<tr>
<td>PV – AC</td>
<td>2,000 mL</td>
</tr>
</tbody>
</table>

\[
\text{CE} = \frac{350 \times 100}{((280+200)/2) \times 2} = 72.9\%
\]
Collection efficiency

\[
\frac{CD34_{\text{product}}}{(CD34_{\text{pre}}) \times (\text{Processed volume} - \text{AC volume})} \times 100
\]

Case:
CD34\text{pre} \quad 30 \times 10^6/L
We processed \quad 15 \text{ L without ACD-A}
Collected CD34 \quad 4 \times 10^6 / \text{kg of the recipients’ body weight}
Body weight patient \quad 70 \text{ kg}

Therefore CE = \frac{280}{30 \times 15} \times 100 = 62.2\%
<table>
<thead>
<tr>
<th>Clinic</th>
<th>Mean CE (CD34 +ve)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinic 1</td>
<td>54.6%</td>
<td></td>
</tr>
<tr>
<td>Clinic 2</td>
<td>57.7%</td>
<td></td>
</tr>
<tr>
<td>Clinic 3</td>
<td>56.7%</td>
<td></td>
</tr>
<tr>
<td>Clinic 4</td>
<td>53.5%</td>
<td></td>
</tr>
<tr>
<td>Clinic 5</td>
<td>52.0%</td>
<td>2 vs 5: p=0.2</td>
</tr>
<tr>
<td>Disease</td>
<td>Mean CE (autologous donors)</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>AML</td>
<td>57.7%</td>
<td></td>
</tr>
<tr>
<td>Amyloidosis</td>
<td>40.3%</td>
<td></td>
</tr>
<tr>
<td>Lymphoma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Follicular Lymphoma</td>
<td>33.5%</td>
<td></td>
</tr>
<tr>
<td>- Hodgkin Lymphoma</td>
<td>56.8%</td>
<td></td>
</tr>
<tr>
<td>- Mantle-Cell Lymphoma</td>
<td>47.0%</td>
<td></td>
</tr>
<tr>
<td>- Non-Hodgkin Lymphoma</td>
<td>57.1%</td>
<td></td>
</tr>
<tr>
<td>Multiple Myeloma</td>
<td>58.6%</td>
<td></td>
</tr>
</tbody>
</table>
Collection efficiency

**CD34 CE in donors by gender**

- Male donor
- Female donor

**CD34 CE in MM donors by gender**

- Male donor
- Female donor

P = 0.20

P = 0.0003
Collection efficiency

Auto vs Allo CD34 collection

P<0.004
Collection efficiency

CE different co-workers

#1 vs #2: P = 0.02
Remainder: NS
Calculating TBV to be processed

• Don’t process standard volumes e.g. 15 liter or always 3x TBV

• Be aware of CD34 count in donor / patient
Calculating TBV to be processed

\[
TBV = \frac{CD34_{\text{needed}} \times \text{body weight patient}}{CD34_{\text{donor}} \times \text{collection efficiency}}
\]

- \(CD34_{\text{donor}} = 35 \times 10^6 / \text{L} = 35 / \mu\text{L}\)
- \(CD34_{\text{needed}} = 3 \times 10^6 / \text{kg}\)
- \(\text{BW patient} = 65 \text{ kg}\)
- \(\text{Mean Collection efficiency} = 45\%\)

\[
TBV = \frac{3 \times 65}{35 \times 0.45} = 12.5 \text{ Liter uncoagulated blood}
\]
Product yield $\rightarrow$ 3x TBV processing

$$\frac{\text{CD34}_{\text{donor}} \times \text{TBV}_{\text{donor}} \times 3 \times \text{CE}_{\text{mean}}}{1000} = \text{CD34}_{\text{product}}$$

**Case:**

- CD34\textsubscript{donor} $= 35 \times 10^6$/L $= 35 / \mu$L
- BW donor $= 80$ kg
- TBV donor $= 80 \times 70 = 5,600$ mL
- Mean Collection efficiency $= 45$

$$\frac{35 \times 5600 \times 3 \times 0.45}{1000} = 265 \times 10^6 / \text{unit}$$

or for patient 65 kg $= 265 : 65 = 4 \times 10^6 / \text{kg}$
In summary

• TBV
• TPV
• ECV
• Collection efficiencies
• Total processed volume
Acknowledgment

Dries Deeren, MD

Hematologist
AZ Delta
Roeselare
Belgium