Adjusting Oxygen Availability to Tissues
(By use of hypothermia during total hemodilution)

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INTRODUCTION

Utilizing partial hemodilution near normal hemoglobin ranges can be maintained. However, employing total hemodilution may present problems since the hemoglobin count usually falls below acceptable limits even though flow is somewhat increased through the capillaries due to the hemodilution. Because of the pronounced drop in hemoglobin count it was beneficial to plot the standard adult patient oxygen requirements/Kg. against temperatures below 37°C. Decreasing temperatures reduce the oxygen requirement of the body. From this information it was possible to determine just how far hypothermia must be carried out in order for a reduced hemoglobin count to provide adequate oxygen requirements.

METHODS

The table which reflects the combining of O₂ to hemoglobin at various gram concentrations and the graph which charts oxygen required per Kilogram against temperature, were constructed using the following information:

One gram of hemoglobin carries 1.34cc O₂ and 0.30cc O₂ will also be dissolved in each 100cc blood at 150 mm Hg (1) (2). Since the number of grams of hemoglobin is calculated from 100cc blood and approximately one-fourth of oxygen bound with hemoglobin is actually delivered to the tissues, the following calculations can be derived using hemoglobin count as the only variable. (3)(Table). (If the hematocrit is more available divide it by 3 to find the approximate hemoglobin factor).

Calculation:

\[
\frac{(1.34cc \text{ O₂/gm. Hb.} \times \text{Hb. count}) + 0.30}{4} \text{ for each 100mm Hg.}
\]

Each kilogram of body weight requires approximately 4cc O₂/min. at 37°C in adults (4). This requirement will decrease in the following manner as the body temperature is reduced (5) (Graph).

<table>
<thead>
<tr>
<th>Body temperature (O₂ Requirements compared to normal temperature)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>29°C</td>
<td>50%</td>
</tr>
<tr>
<td>22°C</td>
<td>25%</td>
</tr>
<tr>
<td>16°C</td>
<td>12%</td>
</tr>
<tr>
<td>10°C</td>
<td>6%</td>
</tr>
</tbody>
</table>

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3. BODY TEMPERATURE VS. OXYGEN CONSUMPTION

This information can be used in conjunction with pump flows to find the amount of oxygen absorbed by the tissues at various stages of hypothermia. The following example should help to understand how the table and chart should be used:

A 70 Kg patient is being perfused at a rate of 4200cc hemodilution/min. A hemoglobin count of 8 would supply 2.98cc O$_2$/100cc blood (Table) or

$$4200\text{cc blood/min.} \times \frac{2.98\text{cc O}_2/100\text{cc blood}}{100} = 125.16\text{cc O}_2/\text{min.}$$

By dividing 125.16cc O$_2$/min. by 70 Kg, we find that we are supplying 1.79cc O$_2$/Kg./min. This is below body requirements at 37°C and we find we must cool to 27.5°C (Graph) to provide adequate oxygen to the tissues with the given hemoglobin count of 8. This example assumes a $pO_2$ tension of approximately 100-150 mm Hg.

DISCUSSION

A $pO_2$ above 150 mm Hg would change oxygen availability to the tissues by allowing more oxygen to become dissolved in the blood (6). As can be seen from the Table, an increased $pO_2$ from 150 mm Hg to 350 mm Hg with a Hemoglobin count of 8 gm/100cc of blood will increase oxygen availability from 2.98cc O$_2$/100cc blood to 3.58cc O$_2$/100cc blood. By using the same blood flow (4200cc/min.) and body weight (70 Kg) as in the aforementioned example it is found that hypothermia must be carried out to 29.7°C at 350 mm Hg assuming that the tissue picks up all the dissolved oxygen. However, it is recommended that the $pO_2$ of arterial blood be kept closer to 100-120 mm Hg in the bubble oxygenator with more hypothermia than less hypothermia and higher $pO_2$'s. Increasing the blood-gas interface with higher $pO_2$'s produces increased hemolysis, protein denaturation, microemboli, cellular damage, etc., especially on cases of long duration.
SUMMARY

One reliable system has been discussed which will allow the perfusionist to measure more adequately the amount of hypothermia necessary to meet an adult patient's metabolic demands for oxygen when hemoglobin counts are low. By determining the blood flow (in hundreds cc) and multiplying by the hemoglobin factor (Table) and dividing by the patient's weight (in Kg) it is possible to determine the cc O2/Kg./min. available.

Calculation:

\[
\text{blood flow in 100 cc's x Hg factor} \div \text{Weight (Kg.)}
\]

If oxygen availability is less than the 4cc O2/Kg. deemed necessary at normothermic temperature, use the accompanying Graph to determine the extent of hypothermia. In children or adults below 50 Kg. progressively higher O2 requirements/Kg. will be required. As a result, the Graph depicting cc O2/Kg. vs decreasing body temperature will not be valid.

TABLE

The use of the hemoglobin count to determine O2 availability to tissues.

Calculation:

\[
\frac{(1.34 \text{ cc } O_2/\text{gm. Hb.} \times \text{Hb. count}) + 0.30 \text{cc dissolved } O_2}{100 \text{ mm Hg.}}
\]

Add 0.30 for each 100 mm Hg of O2.

<table>
<thead>
<tr>
<th>Gm. Hg</th>
<th>pO2 at 150 mm Hg</th>
<th>pO2 at 250 mm Hg</th>
<th>pO2 at 350 mm Hg</th>
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</thead>
<tbody>
<tr>
<td>14</td>
<td>4.99</td>
<td>5.29</td>
<td>5.59</td>
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<td>13</td>
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<td>4.96</td>
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<td>1.98</td>
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</tr>
</tbody>
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REFERENCES