Technique

Evaluation of a “Heads-up” Display for Cardiopulmonary Bypass

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ABSTRACT

Multiple variables must be analyzed during cardiopulmonary bypass in order to judge the adequacy of perfusion. Variables when viewed singly can be confusing and lead to inaccurate representation of the physiological status of the patient. Communication between the perfusionist and members of the surgical team requires accuracy and complete presentation of pertinent data. Toward this goal of improving the assimilation and processing of information during cardiopulmonary bypass, a multivariable computer-aided “Heads-up Display” (HUD) was developed.

Modern jet pilots use heads-up display for rapid assimilation of information when making judgments about the performance of their aircraft and weapons systems. Heads-up display is an electronically generated display that is superimposed upon a pilot’s forward field of view. An analogy between a jet pilot and a perfusionist can be made.

A geometric form, a hexagon, is used as part of the heads-up display for cardiopulmonary bypass (CPB-HUD). The polygon represents a performance evaluation graph. Each of the six “spokes of a wheel” represents a physiological parameter. The represented variables are: cardiac index, peripheral vascular resistance, hematocrit, dynamic operating blood level, venous saturation, and mean arterial pressure. The perfusionist inputs target values. Target values are then compared to actual values and expressed as a percentage. If all targeted values are achieved, the graphical representation is a hexagon.

The surgical team rapidly recognizes abnormal patterns that are outside individual target values. They include, but are not limited to, patterns of: vasoconstriction, vasodilatation, hypovolemia, decreased oxygen carrying capacity, and several others.

The CPB-HUD has proved to be of value for planning, real time evaluation, retrospective analysis of cardiopulmonary bypass benchmark data, and as an aid in the teaching of new personnel concerned with cardiopulmonary bypass.

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INTRODUCTION

The aim of the present study is to explore methods, concepts, and techniques to display multivariables during cardiopulmonary bypass. Parameters, when viewed singly, can be confusing and can lead to inaccurate interpretation of the physiological status of the patient. Other authors have previously graphed physiological multivariables (1, 2). Thousands of individual physiological values are evaluated during the time that a patient is on cardiopulmonary bypass (3–24). Often perfusionists are overwhelmed with the amount of physiological data to analyze and present to the surgical team.

Perfusionists and anesthesiologists work closely to maintain the patient’s optimal physiological status, while also providing conditions to accomplish the surgical repair. It is the combined task of the perfusionist and the anesthesiologist to interpret and maintain the adequacy of perfusion. “The anesthesiologist and perfusionist can be each other’s best friend or worst enemy in the achievement of adequate perfusion.” (20).

To improve the assimilation and processing of information during CPB and to judge the adequacy of perfusion, a multiple variable heads-up display for cardiopulmonary bypass has been developed. (CPB-HUD) The multivariable graphic polygon display presents a simple geometric form to the surgical team to aid in the assimilation and processing of information. The vertices and “hub of the wheel” of the polygon present a pictorial indication of current variable values. The geometric shape displayed is a hexagon. The variables are simultaneously displayed in numeric fashion. Geometric shapes are used as roadside warnings and regulatory signs, because they can be recognized rapidly without detailed reading.

Modern jet fighter pilots use heads-up display for rapid assimilation of information when making judgments about the performance of their aircraft and weapons systems. A heads-up display is an electronically generated display that is superimposed upon a pilot’s forward field of view. An analogy between a jet pilot and a perfusionist can be made in several respects. First, the need for guidance and the advisory relationship between the perfusionist and anesthesiologist can be compared with a pilot and a control tower. Second, take-off and landing can be compared to going on cardiopulmonary bypass and weaning the patient from cardiopulmonary bypass; these phases are the most critical and problematic. Third, level flight for the pilot and the middle of bypass for the perfusionist are, by in large, periods of time when their respective “machines” are monitored and kept on course. Fourth, the continuous minute-to-minute interpretation of conditions for the safety of the pilot and plane are similar to the need for quick interpretation of perfusion conditions for the safety of the patient on the heart–lung machine.

<table>
<thead>
<tr>
<th>Variable Symbol</th>
<th>Variable</th>
<th>How Derived</th>
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<tbody>
<tr>
<td>CI</td>
<td>Cardiac index</td>
<td>Blood flow rate/body surface area</td>
</tr>
<tr>
<td>SVR</td>
<td>Systemic vascular resistance</td>
<td>(Mean arterial pressure/blood flow rate) × 80</td>
</tr>
<tr>
<td>HCT</td>
<td>Hematocrit</td>
<td>Entered value</td>
</tr>
<tr>
<td>DOL</td>
<td>Dynamic operating level</td>
<td>(Operating volume/blood flow rate) × 60</td>
</tr>
<tr>
<td>SvO2</td>
<td>Venous oxygen saturation</td>
<td>Entered value</td>
</tr>
<tr>
<td>MAP</td>
<td>Mean arterial pressure</td>
<td>Entered value</td>
</tr>
</tbody>
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Figure 1: Patient information window, patient’s name, height, and weight are inputted for each new patient.

Figure 2: Target values are input; default values may be used or changed to values more specific for the patient or technique.
METHODS

A geometric form, a hexagon, is used as part of the computer-generated CPB-HUD. The polygon represents a performance evaluation graph. Each of the six "spokes of a wheel" represents a physiological parameter. Represented variables are cardiac index, peripheral vascular resistance, hematocrit, dynamic operating level, venous oxygen saturation, and mean arterial pressure (Table 1). Dynamic operating level is defined as the time, in seconds, that a given blood flow rate will empty a given volume. Calculations of peripheral vascular resistance assume the venous pressure of the patient is zero.

The patient’s name, height, and weight are input into the patient information window (Figure 1). Targeted values are input into the target value window. Default target values can be changed to meet the needs of the patient. Values appearing in the CPB-HUD initial window reflect input target values. These values are used in determining the initial blood flow rates and safe operating level of the patient at hand (Figure 2).

Real values of blood flow rate, hematocrit, operating blood

![Figure 3: CPB-HUD window, numeric and graphic, real-time input of values of blood flow rate, hematocrit, operating volume, venous oxygen saturation, and mean arterial pressure.](image)

![Figure 4: Patterns on the CPB-HUD polygon have proved valuable to recognize conditions such as hypovolemia, vasoconstriction, and vasodilitation rapidly.](image)
DISCUSSION

The CPB-HUD has proved to be of value in a number of respects. The initial prebypass values provide a benefit in planning the perfusion. In consultation with the anesthesiologist, the CPB-HUD provides the perfusionist a format to discuss and adjust target values before bypass.

Real time monitoring provides a performance evaluation of the patient’s conditions. Since all the vital signs, hemodynamic as well as metabolic, are closely interdependent in a perfused organism, there is no need to measure them all. The monitoring of a few key factors is, for practical purposes, sufficient to infer the behavior of the others” (23). Patterns on the CPB-HUD polygon, when outside of target values, have proven valuable to rapidly recognize conditions such as hypovolemia, vasoconstriction, and vasodilatation (Figure 4).

Data can be downloaded to a database computer program where benchmark data can be compared statistically, and reports may be generated. CPB-HUD has been found to be of particular value in teaching new perfusionists and anesthesia residents the physiology and pathophysiology of cardiopulmonary bypass.

REFERENCES