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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Table 1. Variables used and how derived for CPB-HUD

Variable Symbol	Variable	How Derived
CI	Cardiac index	Blood flow rate/body surface area
SVR	Systemic vascular resistance	(Mean arterial pressure/ blood flow rate) × 80
HCT	Hematocrit	Entered value
DOL	Dynamic operating level	(Operating volume/blood flow rate) × 60
SvO2	Venous oxygen saturation	Entered value
MAP	Mean arterial pressure	Entered value

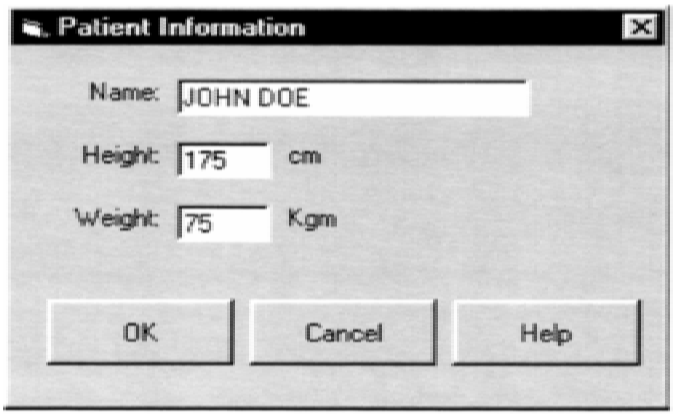

Figure 1: Patient information window, patient's name, height, and weight are inputted for each new patient.

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.

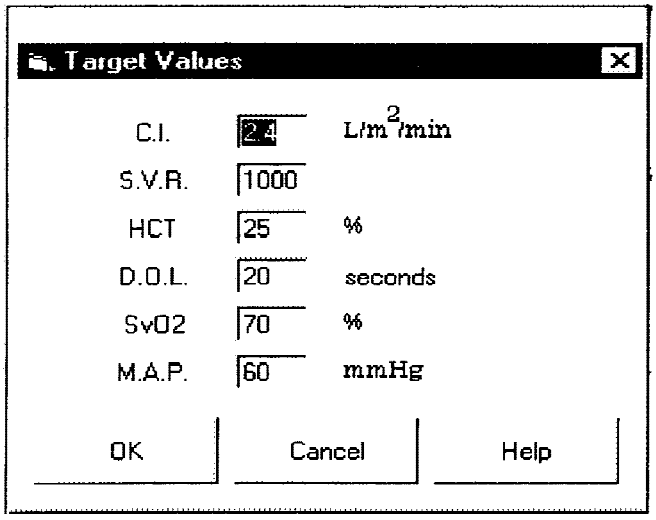

Figure 2: Target values are input; default values may be used or changed to values more specific for the patient or technique.

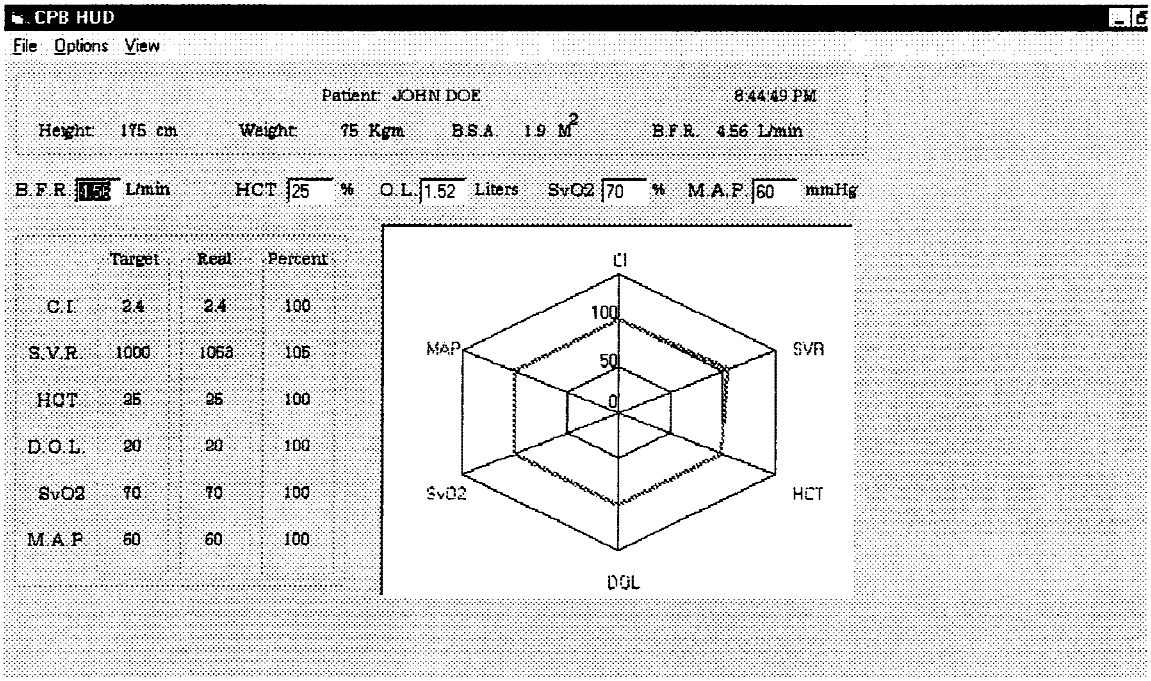

Figure 3: CPB-HUD window, numeric and graphic, real-time input of values of blood flow rate, hematocrit, operating volume, venous oxygen saturation, and mean arterial pressure.

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

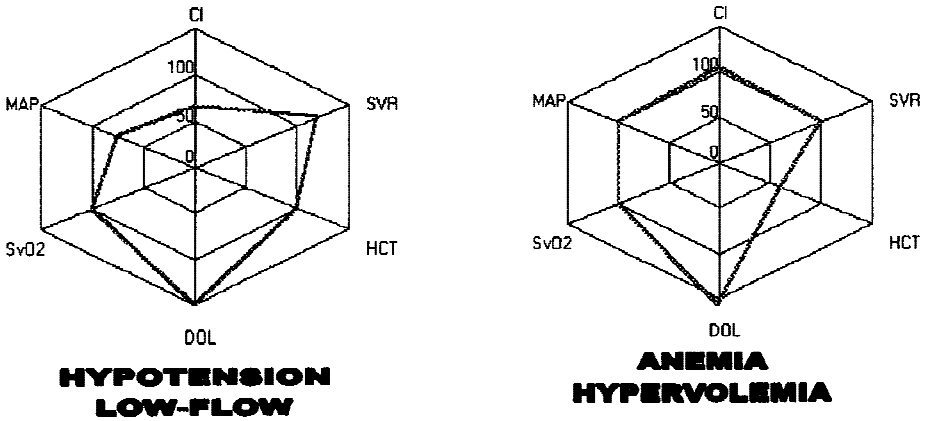

Figure 4: Patterns on the CPB-HUD polygon have proved valuable to recognize conditions such as hypovolemia, vasoconstriction, and vasodilitation rapidly.

volume, venous oxygen saturation, and mean arterial blood pressure are input then compared to targeted values and expressed as a percentage. If all targeted values are achieved, the real values are 100% of the targeted values. The resultant graphical representation is a hexagon (Figure 3).

The computer program is written in Microsoft® Visual Basic,® and it runs on Microsoft® Windows® Operating System.[a] A computer stand was constructed from a sheet of stainless steel and attaches to the heart–lung machine console with a clamp. A standard laptop computer is used. A plastic cover protects the laptop from liquids. After initial set-up, the program may be operated with a ten-key pad for numeric input. A computer monitor is placed adjacent to the anesthesiologist where the CPB-HUD is viewed on a real-time basis.

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

1. Siegel JH, Farrell EJ, Fichthorn J, et al. The use of multivariable trajectories in defining normal and abnormal time courses of recovery and coronary bypass surgery. J Surg Res. 1975;18:341–56.
2. Shoemaker WC, Charles CJ, Demetriades D, et al. Early physiologic patterns in acute illness and accidents: Toward a concept of circulatory dysfunction and shock based on invasive and noninvasive hemodynamic monitoring. New Horizons. 1996;4: .
3. Rubsamen DS. Continuous blood gas monitoring during cardiopulmonary bypass—How soon will it be the standard of care? J Cardiothorac Vasc Anesth. 1990;4:1–4.
4. Ferries LH. Standards of care in perfusion: Should not continuous in-line blood gas monitoring be one? J Extra-Corp Technol. 1992;23:45–8.
5. Bashien G, Townes BD, Nessly BS, et al. A randomized study of carbon dioxide management during hypothermic cardiopulmonary bypass. Anesthesiology. 1990;72:7–15.
6. Philbin DM, Inada E, Sims N, et al. Oxygen consumption and on-line blood gas determinations during rewarming on cardiopulmonary bypass. Perfusion. 1987;2:127–29.
7. Swan H, Sanchez M, Tyndall M, Koch C. Quality control of perfusion: Monitoring venous blood oxygen tension to prevent hypoxic acidosis. J Thorac Cardiovasc Surg. 1990; 99:868–72.
8. Baraka A. Continuous venous oximetry should be used routinely during cardiopulmonary bypass. J Cardiothorac Vasc Anesth. 1992;6:105–8.
9. Baraka A, Baroody M, Harmon SX, et al. Predictor of postcardiopulmonary bypass cardiac output by venous oximetry. J Extra-Corp Technol. 1992;24:86–9.
10. Justinson GA, Parsons S. Improved quality control utilizing continuous blood gas monitoring and computerized perfusion systems. J Extra-Corp Technol. 1989;21:83–7.
11. Alston RP. Clinical evaluation of the CDI system 400 blood gas monitor. Perfusion. 1994;9:373–75.
12. Bolen GZ, Anderson GE, Huddleson JR, et al. Clinical accuracy of continuous hemoglobin oxygen saturation monitoring devices. J Extra-Corp Technol. 1990;22:61–6.
13. Mark JB, Fitzgerald D, Fenton T, et al. Continuous arterial and venous blood gas monitoring during cardiopulminary bypass. J Thorac Cardiovasc Surg. 1991;102:431–39.
14. Iatridis A, Chan T. An evaluation of the Cobe Sat/Hct monitor. Proceed Am Acad Card Perf. 1992;13:86–90.
15. Baris RR, Wagner BK, Amory DW. Clinical comparison of jugular venous saturation and the CDI 100 saturation monitor on cardiopulmonary bypass. Proc Am Acad Card Perf. 1993;14:34–40.
16. Riley JB, Bishop DG. The current status of ECC inline hemoglobin, hematocrit, and oxygen saturation monitor accuracy. Proc Am Acad Card Perf. 1993:34–40.
17. Brown ME, Rawleigh ID, Gallagher JM. In vitro evaluation of continuous mixed venous oxygen saturation and hematocrit monitors. J Extra-Corp Technol. 1994;26:189–93.
18. Svenmarker S, Lindholm R, Haggmark S, Janson E, Berze S. Clinical evaluation of the CDI System 400 blood gas monitor. Perfusion. 1994;9:71–8.
19. Stammers AA. Monitoring controversies during cardiopulmonary bypass: How far have we come? Perfusion. 1998; 13:35–43.
20. Berger EC. The Physiology of Adequate Perfusion. St. Louis: C.V. Mosby; 1979.

a Microsoft Corp. Redmond, WA

21. Reed CC, Kurusz M, Lawrence AE. Safety and Techniques in Perfusion. Stafford, Texas: Quali-Med Inc.; 1988.
22. Taylor KM. Cardiopulmonary Bypass, Principles and Management. Baltimore: Williams & Wilkins; 1986.
23. Galletti PM, Brecher GA. Heart–Lung Bypass. New York: Grune & Stratton; 1966.
24. Austin JW, Harner DL. The Heart–Lung Machine and Related Technologies of Open-Heart Surgery. Phoenix: Phoenix Medical Communications; 1990.