USE OF A PROGRAMMABLE CALCULATOR IN CARDIOPULMONARY PERFUSION

J. DAVID MILLS, B.A., C.C.P., P.A.* AND
JEROME H. TALLENT, B.S., C.C.P., P.A.**

This study describes a hand-held, battery-powered, programmable instrument (Calculator Model SR-52) that can be taken directly into the operating room by cardiopulmonary perfusionists. Three programs are described in detail: 1) Cardiopulmonary perfusion parameters and estimated blood volume; 2) blood gas parameters and saturations, with temperature corrections; and 3) cardiopulmonary oxygen transfer and oxygenator efficiency. This inexpensive calculator allows perfusion personnel to manipulate easily-derived data into values which heretofore have required elaborate nomograms or special slide rules—or were not available within a reasonable computational time.

As the art of cardiopulmonary bypass approaches that of an exact science, more specific and accurate data must be used to assess the adequacy of perfusion. With the advent of a readily programmable, battery-powered calculator, the availability of relatively inexpensive, high-level computational power can be taken directly into the operating room for the use of virtually every perfusion team.

The technologist responsible for making perfusion decisions must have clinical information fairly rapidly accessible in order to make valid judgments concerning the patient's well-being. Programmability gives the perfusionist the advantage of freedom from the need to recall complex formulae and numerical constants, plus eliminating lengthy manipulations of data which are always subject to operator error. In addition, less time spent on calculations means more time spent in actually monitoring the conduct of the bypass.

This "artificial intelligence" allows perfusion personnel to manipulate easily-derived data into values which heretofore have required either elaborate nomograms or special slide rules, or were not available within a reasonable computational time. Accurate blood gas values, corrected for temperature and hemoglobin content, oxygen transfer, oxygenator efficiency, circulating blood volume and computed flow rates aid in the decision making process. With this information available, proper adjustments can usually be instituted before a potentially critical situation develops.

*Clinical Cardiopulmonary Perfusionist and Physician's Assistant, Cardiovascular and Thoracic Surgeons, Associated, Chattanooga, Tennessee.

**Chief Cardiopulmonary Perfusionist and Physician's Assistant, Baroness Erlanger Hospital, Chattanooga, Tennessee.

MATERIALS

Calculator Model SR-52* is a hand-held, battery powered, programmable instrument. It features 224 program storage locations with 20 addressable memory registers and 10 logical decision functions. These 224 program steps can be stored for subsequent repetitive use on magnetic cards; thus providing repeatable instruction for the manipulation of new data entered. A separate AC power adapter is included, which also serves as a battery recharging unit when the calculator is turned off. Cost of the unit is approximately $250.

There is an optional printing unit, Model PC-100A,* which provides AC power conversion and serves as a security cradle as well as producing permanent records of calculations or simply printing results. The printer is also useful in listing the programming sequence for trouble shooting purposes. Cost of the printer is approximately $200.

Program I—Cardiopulmonary Perfusion Parameters + Estimated Blood Volume

Of the various parameters used to assess the adequacy of cardiopulmonary perfusion, the most common yardstick is the rate of perfusion, either in cubic centimeters per kilogram (cc/kg) or in liters per square meter of body surface area (L/m^2).

Given the patient's height in inches and weight in pounds, this program will convert these measurements to centimeters and kilograms respectively. These values are utilized to determine the body surface area (BSA) via the DuBois Equation.

Various flow parameters are calculated at rates of 35 cc/kg, 45 cc/kg, 50 cc/kg, and 2.2 L/m^2.

Estimation of circulating blood volume is then determined, based on the sex of the patient, by the method of Allen et al.[1]

Programming notes:

This program uses 179 of the 224 program steps and three of the twenty data registers. Six of the user definable functions are employed.

The program card is entered; only the first half (side A) of the program need be entered if estimated blood volumes are not desired. The height in inches is entered via the keyboard. The program defined by function A is executed. The calculator display reveals the height in centimeters. If the printer is used, the height in inches is printed. The height in centimeters is stored in data register 01.

The weight in pounds is then entered and user defined function B is depressed. The result on the display is the equivalent in kilograms. The printer prints the weight in pounds. The weight in kilograms is stored in data register 02.

*Texas Instruments, Dallas, Texas

Height and weight may be entered in any order.

User defined function C results in computation of the body surface area, which is displayed. Printed results include the height in cm, the weight in kg, followed by the body surface in m^2.

Flows are calculated by recalling the value from data register 02 (kg). This is multiplied by 35 and printed (35 cc/kg). This value is multiplied by 1.2857, resulting in a value for 45 cc/kg, which is printed. Multiplication by 1.111 is continued for a value for 50 cc/kg and printed. Multiplication by 1.5 yields a value for 75 cc/kg with printing and a halt command. If the program is used without a printer, the print commands are replaced by halt commands.

Estimated blood volume is calculated by depressing the A′ function for males, and the B′ function for females. Results are displayed and printed in cubic centimeters (cc).

Equations:

$$BSA_{m^2} = Ht_{(cm)}^{0.725} \times Wt_{(kg)}^{0.425} \times 0.007184$$

$$EBV_{male} = [0.417\ (Ht_{(m)})^3 + 0.045\ (Wt_{(kg)}) - 0.03] \times 10^3$$

$$EBV_{female} = [0.414\ (Ht_{(m)})^3) + 0.0328\ (Wt_{(kg)}) - 0.03] \times 10^3$$

Program Listing:

Table I: User Instructions, Program I
Table II: Program Listing, Program I

TABLE I. User Instructions, Program I. Cardiopulmonary Bypass Parameters and Estimated Blood Volume.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Enter Program*			
2.	Enter Height in Inches	Ht	A	cm equivalent prt inches
3.	Enter Weight in Pounds	Wt	B	kg equivalent prt pounds
4.	Compute Body Surface Area		C	prt cm, kg prt and display BSA
5.	Compute Flows		D run run run run	35 cc/kg 45 cc/kg 50 cc/kg 75 cc/kg 2.2 L/m2
6.	Compute Estimated Blood Volume		A' B'	Male EBV Female EBV

*For Steps 2-5 only: Enter only Side A
For Step 6 also, both sides must be entered.

TABLE II. Program Listing, Program I—Cardiopulmonary Perfusion Parameters and Estimated Blood Volume.

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY
000	46 11	*Lbl A	057	04 95	4 =	120	65 53	x (
002	98	*Prt	059	42 00 03	Sto 03	122	43 00 01	Rcl 01
003	65 02	x 2	062	98 81	*Prt Hlt	125	55 01 00	÷ 1 0
005	93 05 04	. 5 4	064	46 14	*Lbl D	128	00 54 45	0) y^x
008	95	=	066	99 57 00	*Pap *Fix	131	03 85 04	3 + 4
009	42 00 01	Sto 01	069	43 00 02	Rcl 02	134	05 65	5 x
012	81	Hlt	072	65 03 05	x 3 5	136	43 00 02	Rcl 02
013	46 12	*Lbl B	075	95 98	= *Prt	139	75 03 00	- 3 0
015	98	*Prt	077	65 01 93	X 1 .	142	95 98 81	= *Prt Hlt
016	65 93 04	x . 4	080	02 08 05	2 8 5			
019	05 03 06	5 3 6	083	07 95 98	7 = *Prt	145	46 17 99	*Lbl *B'
022	95	=	086	65 01 93	X 1 .			*Pap
023	42 00 02	Sto 02	089	01 01 01	1 1 1	148	57 00	*Fix 0
026	81	Hlt	092	95 98	= *Prt	150	04 01 04	4 1 4
027	46 13	*Lbl C	094	65 01 93	X 1 .	153	65 53	X (
029	57 02	*Fix 2	097	05 95 98	5 = *Prt	155	43 00 01	Rcl 01
031	43 00 01	Rcl 01	100	43 00 03	Rcl 03	158	55 01 00	÷ 1 0
034	98	*Prt	103	65 02 93	X 2 .	161	00 54 45	0) y^x
035	45 93 07	y^x . 7	106	02 95	2 =	164	03 85 03	3 + 3
038	02 05 65	2 5 X	108	57 03	*Fix 3	167	02 93 08	2 . 8
041	43 00 02	Rcl 02	110	98 81	*Prt Hlt	170	65	X
044	98	*Prt				171	43 00 02	Rcl 02
045	45 93 04	y^x . 4	112	46 16 99	*Lbl *A'	174	75 03 00	- 3 0
048	02 05 65	2 5 X			*Pap	177	95 98	= *Prt
051	93 00 00	. 0 0	115	57 00	*Fix 0	179	81	Hlt
054	07 01 08	7 1 8	117	04 01 07	4 1 7			

NOTES: This programming is written for use with the printer. When using a computer without a printer:

A) Change the following locations from *Prt to Hlt
- LOC 076 from Prt to Hlt
- LOC 085 from Prt to Hlt
- LOC 093 from Prt to Hlt
- LOC 099 from Prt to Hlt

B) Delete the following steps:
- LOC 002 Prt
- LOC 015 Prt
- LOC 034 Prt
- LOC 044 Prt
- LOC 062 Prt
- LOC 066 Pap
- LOC 110 Prt
- LOC 114 Pap
- LOC 143 Prt
- LOC 147 Pap
- LOC 178 Prt

Program II—Blood Gas Parameters and Saturations, with Temperature Corrections

Given the pH, the pCO_2, the pO_2, the patient's temperature (°C), and the patient's hemoglobin content (gm%), this program will calculate the base excess, bicarbonate level (mMol/L), the Carbon Dioxide content (mMol/L), and the oxygen saturation (%), all of which are corrected for the patient's hemoglobin level.

After reprogramming with the second card of this two-card program, calculation of temperature corrected values of the pH, pCO_2, pO_2, base excess, bicarbonate level and oxygen saturation is accomplished.

Programming notes:

This program is contained on two magnetic cards and encompasses 446 program steps. All 20 data memory registers are used. Seven of the user defined functions are employed.

Card I, sides A and B are entered. pH, pCO_2, and the pO_2 are entered via the user-defined functions A, B, and C respectively. Patient temperature (°C) is entered through function D. Function A′ allows the entry of hemoglobin content. These may be entered in any sequence.

Function E produces the hemoglobin corrected values for base excess, bicarbonate level, carbon dioxide content and oxygen saturation. With the printer oriented program, these are printed without halts. The program designed to be used without the printer requires the depression of the "run" command after recording each value.

The program position indicator must be reset by pressing the second function key and the reset command (rset). Card II, sides A and B, is then loaded.

Function E′ calculates and prints the temperature and hemoglobin corrected values for pH, pCO_2, pO_2, base excess, bicarbonate level, and oxygen saturation. As with Card I, the programming designed for use without the printer requires depression of the "run" command for the next value. The display for the corrected oxygen saturation is flashing due to lack of a terminal halt command in the program. The Clear Entry (CE) command will return the display from the error mode.

Equations:[2]

$$\text{Base Excess} = \Delta \overline{HCO_3} + 9.5\Delta pH + 1.49 Hgb\Delta pH - 0.0143 Hgb\Delta \overline{HCO_3} - 0.0233 Hgb^2 \Delta pH + 0.2 Hgb/(1.36 \times 10^{-4} \times pO_2^{2.71} \times 10^{1.31\Delta pH} + 1)$$

$$\text{Bicarbonate Level} = 2.41 \times 10^{-8} \times pCO_2 \times 10^{pH}$$

$$\text{Carbon Dioxide Content} = \overline{HCO_3} + 0.0306\, pCO_2$$

$$\text{Oxygen Saturation} = 100/(1 + ((7.34 \times 10^3)/(pO_2^{2.71} \times 10^{1.31\Delta pH})))$$

Temperature Corrections:[3,4]

$$pH_{corrected} = pH_{37} - 0.0147\Delta T$$

Accuracy ± 0.003 pH units ± 0.0005 pH/°C from 37°C.

$$pCO_{2\,corrected} = pCO_{2\,37} \times 10^{0.0185\Delta T}$$

Accuracy ± 1.0 mm Hg ± 1% ± 0.1%/°C from 37°C.

$$pO_{2\,corrected} = pO_{2\,37} \times 10^{0.0247\Delta T}$$

Accuracy ± 2%.

$$\Delta \overline{HCO_3} = \overline{HCO_3} - 24.2 \qquad \Delta pH = pH - 7.40$$

$$\Delta T = \text{Patient Temperature} - 37°C$$

Program Listing:

Table III: User Instruction, Program II
Table IV: Program Listing, Program II, Card 1
Table V: Program Listing, Program II, Card 2

TABLE III. User Instructions—Program II. Blood Gas Parameters and Saturation with Temperature Corrections.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Enter Card I, Sides A and B.			
2.	Enter pH	pH	A	pH - 7.40 prt pH
3.	Enter pCO_2	pCO_2	B	* pCO_2
4.	Enter pO_2	pO_2	C	* pO_2
5.	Enter Temperature	Temp	D	Temp - 37 prt Temp
6.	Enter Hemoglobin Level	Hgb	A'	* Hgb
7.	Calculate Parameters		E (run) (run) (run) (run) (Without Printer)	(Base Excess) (Bicarbonate Level) (CO_2 Content) *Saturation
8.	Reset Program Indicator		2nd Rset	
9.	Load Card II, Sides A and B.			
10.	Calculate Hemoglobin and Temperature Corrected Values →→ Display is flashing at end of printing due to lack of Hlt command; PRESS KEY CE.		E' (run) (run) (run) (run) (run) (Without Printer)	(pH corr) (pCO_2 corr) (pO_2 corr) (B.E. corr) (HCO_3^- corr) *Saturation corrected

Program III—Cardiopulmonary Oxygen Transfer and Oxygenator Efficiency

Given the arterial and venous oxygen saturations, the blood flow, and the hemoglobin content, this program calculates the oxygen transferred in cc/min and vol%.

If the amount of oxygen supplied to the oxygenator is entered, the efficiency as a percentage of transfer is determined. Gas to blood flow ratio can also be determined.

Programming notes:

This program utilizes only 110 program steps and six of the data registers. Only side A of the magnetic program card need be entered.

Arterial and venous oxygen saturations are entered through functions A and B respectively. These are stored in data registers 10 and 11. Blood flow (cc) and hemoglobin content (gm%) are both entered through functions C and D. These are stored in data registers 12 and 13. Data may be entered in any sequence.

TABLE IV. Program Listing, Program II—Card 1. Blood Gas Parameters and Saturation, with Temperature Corrections.

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY
000	46 11	Lbl A	070	43 01 02	Rcl 12	147	43 01 09	Rcl 19
002	42 01 06	Sto 16	073	54 95	) =	150	40 54 85	x²) +
005	98 75	Prt -	075	42 00 08	Sto 08	153	93 02 65	. 2 X
007	07 93 04	7.4	078	02 93 04	2 . 4	156	43 01 09	Rcl 19
010	95	=	081	01 52 08	1 EE 8	159	55 53 93	÷ (.
011	42 01 02	Sto 12	084	94 65	+/- X	162	00 00 00	0 0 0
014	81	Hlt	086	43 01 07	Rcl 17	165	01 03 06	1 3 6
015	46 12	Lbl B	089	65 01 00	x 10	168	65	X
017	42 01 07	Sto 17	092	45	y^x	169	43 00 08	Rcl 08
020	98 81	Prt Hlt	093	43 01 06	Rcl 16	172	85 01 54	+ 1)
022	46 13	Lbl C	096	95 22 52	= INV EE	175	95 99 98	= Pap Prt
024	42 01 08	Sto 18	099	42 01 00	Sto 10	178	42 01 01	Sto 11
027	98 81	Prt Hlt	102	75 02 04	- 24	181	43 01 00	Rcl 10
029	46 14	Lbl D	105	93 02 95	. 2 =	184	98 85 93	Prt +
031	42 01 05	Sto 15	108	65 53 01	X (1	187	00 03 00	0 3 0
034	98 75	Prt -	111	75 93 00	- . 0	190	06 65	6 X
036	03 07 95	37 =	114	01 04 03	143	192	43 01 07	Rcl 17
039	42 01 04	Sto 14	117	65	X	195	95	=
042	81	Hlt	118	43 01 09	Rcl 19	196	42 00 09	Sto 09
043	46 16	Lbl A'	121	54 85	) +	199	98 01 00	Prt 1 0
045	42 01 09	Sto 19	123	43 01 02	Rcl 12	202	00 55 53	0 ÷ (
048	98 81	Prt Hlt	126	65 53	X (	205	01 85 07	1 ÷ 7
050	46 15	Lbl E	128	09 93 05	9.5	208	03 04 00	3 4 0
052	43 01 08	Rcl 18	131	85 01 93	+ 1 .	211	55	÷
055	45 02 93	y^x 2 .	134	04 09 65	4 9 X	212	43 00 08	Rcl 08
058	07 01 65	7 1 x	137	43 01 09	Rcl 19	215	54 95	) =
061	01 00 45	1 0 y^x	140	75 93 00	- . 0	217	42 00 07	Sto 07
064	53 01 93	(1 .	143	02 03 03	2 3 3	220	98 99 81	Prt Pap Hlt*
067	03 01 65	3 1 x	146	65	X			

*Comment: Prt SO_2

NOTES: This programming is written for use with the printer. When using a computer without a printer, the following changes should be made:

LOC 005 delete Prt
LOC 020 delete Prt
LOC 027 delete Prt
LOC 034 delete Prt
LOC 048 delete Prt
LOC 176 delete Pap
LOC 177 change Prt to Hlt
LOC 184 change Prt to Hlt
LOC 199 change Prt to Hlt
LOC 220 delete Prt
LOC 221 delete Pap

Function E then computes oxygen in cc/min, then computes oxygen transfer in volumes percent.

Entering oxygen supplied to the oxygenator (L/min) and depressing function A′ yields oxygenator efficiency. Oxygen flow is stored in data register 14.

If the gas supplied to the oxygenator is 100% oxygen, Function B′ will calculate gas to blood flow (Qb) ratio.

Equations:

$$\text{Oxygen Transfer}_{(cc/min)} = (Q_b \times \text{Hgb} \times 1.34 \times (SaO_2 - SvO_2))/10{,}000.$$

TABLE V. Program Listing, Program II—Card 2. Blood Gas Parameters and Saturation, with Temperature Corrections.

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY
000	46 10	Lbl E'	076	93 07 01	. 7 1	154	09 65	9 X
002	43 01 06	Rcl 16	079	65 01 00	X 1 0	156	43 01 09	Rcl 19
005	75 93 00	- . 0	082	45 53 01	y^x (1	159	75 93 00	- . 0
008	01 04 06	1 4 6	085	93 03 01	. 3 1	162	02 03 03	2 3 3
011	65	X	088	65	X	165	65	X
012	43 01 04	Rcl 14	089	43 00 01	Rcl 01	166	43 01 09	Rcl 19
015	95	=	092	54 95	) =	169	40 54 85	x^2) +
016	42 00 04	Sto 04	094	42 00 03	Sto 03	172	93 02 65	. 2 X
019	98 75 07	Prt - 7	097	02 93 04	2 . 4	175	43 01 09	Rcl 19
022	93 04 95	. 4 =	100	01 52 08	1 EE 8	178	55 53 93	÷ (.
025	42 00 01	Sto 01	103	94 65	+/- X	181	00 00 00	0 0 0
028	43 01 07	Rcl 17	105	43 00 05	Rcl 05	184	01 03 06	1 3 6
031	65 01 00	X 1 0	108	65 01 00	X 1 0	187	65	X
034	45 53 93	y^x (.	111	45	y^x	188	43 00 03	Rcl 03
037	00 01 08	0 1 8	112	43 00 04	Rcl 04	191	85 01 54	+ 1)
040	05 65	5 X	115	95 22 52	= INV EE	194	95	=
042	43 01 04	Rcl 14	118	42 00 02	Sto 02	195	42 00 00	Sto 00
045	54 95	) =	121	75 02 04	- 2 4	198	98	Prt
047	42 00 05	Sto 05	124	93 02 95	. 2 =	199	43 00 02	Rcl 02
050	98	Prt	127	65 53 01	X (1	202	98 01 00	Prt 1 0
051	43 01 08	Rcl 18	130	75 93 00	- . 0	205	00 55 53	0 ÷ (
054	65 01 00	X 1 0	133	01 04 03	1 4 3	208	01 85 07	1 + 7
057	45 53 93	y^x (.	136	65	X	211	03 04 00	3 4 0
060	00 02 04	0 2 4	137	43 01 09	Rcl 19	215	55	÷
063	07 65	7 X	140	54 85	) +	215	43 00 03	Rcl 03
065	43 01 04	Rcl 14	142	43 00 01	Rcl 01	218	54 95	) =
068	54 95	) =	145	65 53 09	X (9	220	42 00 08	Sto 08
070	42 00 06	Sto 06	148	93 05 85	. 5 +	223	98	Prt*
073	98 45 02	Prt y^x 2	151	01 93 04	1 . 4			

*Comment: Prt SO_2

NOTES: This programming is written for use with the printer. When using a computer without a printer, the following changes should be made:

LOC 019 change Prt to Hlt
LOC 050 change Prt to Hlt
LOC 073 change Prt to Hlt
LOC 198 change Prt to Hlt
LOC 202 change Prt to Hlt
LOC 223 change Prt to Hlt

Oxygen transfer $_{(vol\%)}$ = (Oxygen transfer $_{(cc/min)}$)/Q_b
Efficiency = (Oxygen transferred)/(Oxygen supplied)

Program Listing:

Table VI: User Instructions, Program III.
Table VII: Program Listing, Program III.

DISCUSSION

Program I

This program was designed to be run before the initiation of bypass to determine approximate projected flow rates and basic data about the patient.

The program originally contained a provision for total red cell volume (in cc) based upon the patient's hematocrit. With this value, the amount of pump prime,

TABLE VI. User Instructions, Program III—Cardiopulmonary Oxygen Transfer and Oxygenator Efficiency.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Enter Program, Side A Only	SaO_2	A	SaO_2
2.	Enter Arterial Saturation	SaO_2	A	SaO_2
3.	Enter Venous Saturation	SvO_2	B	SvO_2
4.	Enter Bloof Flow (cc/min)	Q_b	C	Q_b
5.	Enter Hemoglobin (gm%)	Hgb	D	Hbg
6.	Calculate Oxygen Transfer (cc/min)		E (Run)	(cc/min)*
7.	Enter Oxygen Flow Rate (L/min)	Q_{02}	A'	Prt Q_{02}**

*(Vol%)

**Q_{02}: Q_b

TABLE VII. Program Listing, Program III—Cardiopulmonary Oxygen Transfer and Oxygenator Efficiency.

LOC	CODE	KEY	LOC	CODE	KEY
000	46 11	Lbl A	055	03 04 95	3 4 =
002	42 01 00	Sto 10	058	99 98	Pap Prt
005	98 81	Prt Hlt	060	42 01 05	Sto 15
007	46 12	Lbl B	063	55	÷
009	42 01 01	Sto 11	064	43 01 02	Rcl 12
012	98 81	Prt Hlt	067	65 01 00	X 1 0
014	46 13	Lbl C	070	00 95 98	) = Prt
016	42 01 02	Sto 12	073	81	Hlt
019	98 81	Prt Hlt	074	46 16 99	Lbl B' Pap
021	46 14	Lbl D	077	98 65 01	Prt X 1
023	42 01 03	Sto 13	080	00 00 00	0 0 0
026	98 81	Prt Hlt	083	95	=
028	46 15	Lbl E	084	42 01 04	Sto 14
030	57 02 53	Fix 2 (	087	20 65	1/x X
033	43 01 00	Rcl 10	089	43 01 05	Rcl 15
036	75	-	092	65 01 00	X 1 0
037	43 01 01	Rcl 11	095	00 95	0 =
040	54 65	) X	097	98 81	Prt Hlt
042	Rcl 01 02	Rcl 12	099	46 17	Lbl B'
045	65	X	101	43 01 04	Rcl 14
046	43 01 03	Rcl 13	104	55	÷
049	65 93 00	X . 0	105	43 01 02	Rcl 12
052	00 00 01	0 0 1	108	95 98 81	= Prt Hlt

NOTES: This programming is written for use with the printer. When using a computer with a printer, the following changes should be made:

LOC 005 delete Prt
LOC 012 delete Prt
LOC 019 delete Prt
LOC 026 delete Prt
LOC 058 delete Pap
LOC 059 change Prt to Hlt
LOC 072 delete Prt
LOC 076 delete Pap
LOC 077 delete Prt
LOC 097 delete Prt
LOC 109 delete Prt

and the estimated blood volume, we tried to project our initial on-pump hematocrit value. This lead to some erroneously high readings in our clinical situation and can be attributed to time of initial hematocrit determination, amount of pre-operative and pre-pump parenteral fluid administration, urine output and operative blood loss. We are currently working on a program to account for the variables involved.

Other areas of program development relative to this program include the conversion of pump calibrations to flow based on weight or body surface area and the determination of rate flow in terms of cc/kg or L/m^2 based on actual established flow.

Program II

The need for laboratory results derived from readily available data is a luxury not always economically practical at some smaller hospitals and clinics. Even with automated gas analysis equipment, temperature correction still requires the conscious effort of a technologist to register the patient temperature with each sample. Oftentimes, this is neglected and as a result, the blood gas values are based on the pre-set 37°C.

Many automated analyses also assume a patient hemoglobin content of 15 gm%, thus very few print the percentage oxygen saturation accurately. As most perfusionists will agree, this is rarely the clinical situation for a patient undergoing extracorporeal circulation. In fact, there are many clinical variations where this program will be of value; anytime the patient temperature and/or the hemoglobin differ from the "normal", this program can be used to reflect accurate clinically significant data. Variations might include anemia, fever, polycythemia, environmental hypothermia, etc.

It is not to be inferred that this program is designed to replace the clinical laboratory in the area of blood gas analysis, but rather to be an adjunct in modifying laboratory conditions to fit clinical situations through mathematical manipulations.

Program III

Program III was developed in response to repeated determinations of oxygen transfer and is particularly helpful in cases where oxygenation capacity is questioned.

By the same token, when oxygenation is occurring to maximal saturation levels, the amount of oxygen utilization is directly related to the amount of oxygen extraction. Therefore, this provides the team with a relative index to anesthesia depth and adequacy of perfusion.

This program may also be adapted to use with Swan-Ganz balloon flotation catheters as mixed venous saturation and arterialized saturations may be determined, thereby estimating the oxygen transfer by the lungs.

Conduction of cardiopulmonary bypass with bubble oxygenators requires the maintenance of gas to blood flow ratios within certain ranges to minimize hemolysis. This ratio is rapidly calculated as the end result of this program B′).

REFERENCES

1. Allen TH, et al: Prediction of blood volume and adiposity in man from body weight and cube of height. Metabolism 5:328-345, 1956
2. Operator's Manual, IL-813, Instrumentation Laboratories, Inc. Lexington, Massachusetts
3. Severinghaus JW: Blood gas calculator. J Appl Physiol 21(3): 1108-1116, 1966
4. Bradley AF, Stupfel M, Severinghaus JW: Effects of Temperature on pCO_2 and pO_2 of blood in vitro. J Appl Physiol 9:201, 1956