The Effect of a Real-Time Computer System on Patient Morbidity and Mortality in Cardiac Surgery

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ABSTRACT

Computer systems, manufactured by large corporations or assembled by individual hospitals, have recently been incorporated into the practice of perfusion. However, no study has been undertaken to determine whether these systems are effective in reducing patient mortality or morbidity. This study compares 72 CABG patients (36 before the implementation of a real-time computer monitoring system and 36 using the Providence Perfusion Software Package). No statistically significant differences (p<.05) were found in the pre-operative comparison of the two groups. Since no real time surgical data was recorded on the control group, evaluation of intraoperative data was not attempted. Post-operative data showed no statistical difference between the two groups. Subsequently a third group of 54 patients was compared to the control with similar results and to the intraoperative data of group two where several minor differences were noted. In light of this information, the cost effectiveness of a prepackaged system must be examined and other alternatives should be explored.

INTRODUCTION

Computers and computer systems are rapidly becoming an integral part of routine cardiac surgery [1,2,3], yet to date, there has been no objective study conducted comparing computer assisted bypass to traditional perfusion methodology. Claims have also been made by major manufacturers of perfusion computers and software that their systems will improve patient care and decrease patient complications justifying the moderate capital investment required for the systems.[4,5,6] The purpose of this study is to examine the impact of computer usage during cardiopulmonary bypass on patient morbidity and mortality in coronary artery revascularization cases and to examine the intraoperative effects observed and recorded when using a real time computer system.

MATERIALS AND METHODS

This retrospective study was undertaken using two groups consisting of 36 coronary artery revascularization patients each. The controlled variable was the use of an IBM AT[a] computer equipped with an Adalab A to D converter running the Providence Perfusion Software Package 1. Group One did not have the computer system. Group 2 was made up of the next 36 cases performed with the aid of the computer. The 72 cases were all performed in a time block starting in February 1987 and ending in December 1987. All cases had the author as primary perfusionist. The perfusionist in these cases was also the designer and programmer of the computer system and software.[1] The equipment used on all of the cases consisted of a Shiley[b] M-2000 membrane oxygenator, a Shiley hard shell venous reservoir-cardiotomy, Tygon[c] S50HL Class VI tubing, a Shiley forty micron arterial filter and a Stockert heart lung machine.

Subsequently, additional data was acquired by selecting a third group of 54 coronary artery revascularization patients from the second and third quarter of 1988 to see if the intra-operative computer data was consistent and to evaluate cardiopulmonary bypass statistical trends. All the variables listed above in this third patient group remained unchanged from that of the first two groups. Statistical analysis for the pre and post operative data was preformed using the Dendrite Patient Analysis and Tracking System. Intra-operative data was analyzed with the shareware program Kwikstat by Alan C. Elliot. The t-test for independent groups was employed and a p-value less than .05 was the cutoff point for establishing independence between the groups.

RESULTS

Table 1 lists a breakdown of the descriptive pre-operative statistics between the pre- and post-computer usage groups and gives the statistical analysis. **Table 2** gives the morbidity and mortality breakdown along with statistical analysis for the various categories. **Table 3** compares pre-computer values against the second and third quarter 1988 (Group Three) descriptive statistics. **Table 4** analyses the morbidity and mortality values between the pre-computer usage group and the 1988 patients. **Table 5** compares intra-operative perfusion statistics between the early computer usage group and the second and third quarter 1988 patients. This analysis could not be conducted on the pre-computer group due to lack of recorded data. All values reported were within the acceptable range

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a. IBM
b. Shiley, Irvine, CA
c. Tygon

TABLE 1: PRE OPERATIVE AND DESCRIPTIVE STATISTICS

CATAGORY	PRE COMPUTER	POST COMPUTER	P VALUE
AGE	64.47	62.17	0.8225
SEX (% MALE)	77.8	58.3	0.0696
HX OF MI (% NEG)	50	44.4	0.5738
NU OF VESSLES DISEASED	4.222	3.444	0.1695
BSA	1.921	1.9	0.3648
BYPASS TIME	121.8	109.39	0.3377
XCLAMP TIME	51.63	47.17	0.1854
NU OF GRAFTS	3.47	3.17	0.9231
CHAR OF OPER (% ELECT)	38.9	58.3	0.3522
TOTAL OPER TIME	256.6	240.1	0.6008
SURGEON			0.0886
PREV CARDIAC SURG (% NONE)	88.9	86.1	0.6839

TABLE 2: POST OPERATIVE MORBIDITY AND MORTALITY STATISTICS

CATAGORY	PRE COMPUTER	POST COMPUTER	P VALUE
INTRAOP COMP (% NEG)	77.5	71.1	0.3245
IABP USAGE (% NOT USED)	86.1	97.2	0.4197
ECG CHANGES (% NEG)	69.4	68.4	0.8936
CPK MB (% INDIC NO MI)	55.6	55.6	0.7531
BLOOD USAGE	2.64	2.4	0.5894
PLATELET USAGE (% NOT NEEDED)	77.8	75	0.8041
PUL COMP(% NONE)	51.1	62.5	0.5835
STROKE (% NONE)	91.7	88.9	0.4323
PSYCH PROB (% NONE)	77.8	83.3	0.1642
RENAL COMP (% NONE)	77.5	81.6	0.8536
STERNAL COMP (% NONE)	73.8	86.1	0.1879
TOTAL HOSP STAY	12.7	7.556	0.3918
PT STATUS (% ALIVE)	94.4	91.7	0.3387
% PTS ON VENT <24 HRS	89	92	0.8341

TABLE 3: PRE OPERATIVE AND DESCRIPTIVE STATISTICS

CATAGORY	PRE COMPUTER	POST COMPUTER LATE DATA	P VALUE
AGE	64.47	62.2	0.3274
SEX (% MALE)	77.8	79.6	0.7567
HX OF MI (% NEG)	50	50	0.6521
NU OF VESSLES DISEASED	4.222	3.48	0.1892
BSA	1.921	1.94	0.6637
BYPASS TIME	121.8	107.5	0.5635
XCLAMP TIME	51.63	48.6	0.162
NU OF GRAFTS	3.47	3.3	0.4454
CHAR OF OPER (% ELECT)	38.9	42.6	0.5398
TOTAL OPER TIME	256.6	237.8	0.4193
SURGEON			0.2327
PREV CARDIAC SURG (% NONE)	88.9	92.6	0.6488

TABLE 4: POST OPERATIVE MORBIDITY AND MORTALITY STATISTICS

CATAGORY	PRE COMPUTER	POST COMPUTER LATE DATA	P VALUE
INTRAOP COMP (% NEG)	77.5	87	0.3747
IABP USAGE (% NOT USED)	86.1	96.3	0.2572
ECG CHANGES (% NEG)	69.4	75.9	0.7454
CPK MB (% INDIC NO MI)	55.6	46.3	0.1828
BLOOD USAGE	2.64	2.61	0.6213
PLATELET USAGE (% NOT NEEDED)	77.8	68.5	0.5638
PUL COMP(% NONE)	51.1	90.7	0.0096
STROKE (% NONE)	91.7	94.4	0.6278
PSYCH PROB (% NONE)	77.8	96.3	0.0143
RENAL COMP (% NONE)	77.5	92.6	0.1644
STERNAL COMP (% NONE)	73.8	98.1	0.0267
TOTAL HOSP STAY	12.7	8.13	0.2033
PT STATUS (% ALIVE)	94.4	98.1	0.3681
% PTS ON VENT <24 HRS	89	92.6	0.4127

TABLE 5: INTRA OPERATIVE CARDIOPULMONARY BYPASS STATISTICS

CATAGORY	EARLY COMPUTER CASE AVG	LATE COMPUTER CASE AVG	P VALUE
NUMBER OF TWO SECOND PERIODS DURING BYPASS			
CO < 2L/M PER M^2	84	63	0.402
MAP<50	180	154	0.509
MAP>100	12	12	0.99
SVR<800	145	113	0.298
SVR>1400	238	188	0.354
MINIMUMS AND MAXIMUMS			
MIN HGB	6.38	6.83	0.138
MIN pO2	121	112	0.292
MAX pO2	377	307	0.001
MIN pCO2	32.1	33.47	0.05
MAX pCO2	43.08	41.96	0.26
MIN pH	7.31	7.32	0.423
MAX pH	7.43	7.41	0.202
MIN V pO2	34.44	35.15	0.682
MAX V pO2	62.7	57.42	0.493
MIN V SAT	61.35	62.64	0.685
MAX V SAT	85.17	84.75	0.86
MIN MAP	34.3	29.3	0.151
MAX MAP	135.5	116.66	0.05
MIN SHUNT	13.61	10.62	0.376
MAX SHUNT	31.75	28.79	0.109
MIN GRADIENT	4.73	1.58	0.207
MAX GRADIENT	34.73	23.55	0.138
AVERAGES			
AVG MAP	66.19	67.79	0.346
AVG SVR	1072	1085	0.691
AVG HGB	7.51	7.75	0.332
AVG pO2	229.3	199.59	0.003
AVG pCO2	36.7	37.71	0.118
AVG pH	7.37	7.364	0.534
AVG V pO2	45.8	46.98	0.273
AVG SHUNT	21.93	19.66	0.244
AVG GRADIENT	10.19	8.3	0.16

TABLE 6

PROGRAM LISTING FOR FIO2 AND SWEEP GAS SETTINGS FOR A SHILEY M2ØØØ OXYGENATOR AT CURRENT TEMPERATURE AND PREDICTIONS FOR COOLING OR WARMING

```
FOR LL%=-3 TO 3 STEP 3
L=INFO(QQQ-1,Ø)-37+LL%
IF L<=Ø AND BG(B-1,1Ø)<=4Ø THEN
    LLL=(BSA*13ØØ)-((ABS(L)^.6)*18Ø)-(((4Ø-BG(B-1,1Ø))^1.2)*8Ø)
    PRINT USING
      "AT ###.# DEGREES GAS FLOW SHOULD BE #### CC'S PER MIN   ";L+37;LLL;
IF L<=Ø AND BG(B-1,1Ø)>4Ø THEN
    LLL=(BSA*13ØØ)-((ABS(L)^.6)*18Ø)+(((BG(B-1,1Ø)-4Ø)^1.2)*1ØØ)
    PRINT  USING
      "AT ###.# DEGREES GAS FLOW SHOULD BE #### CC'S PER MIN   ";L+37;LLL;
IF L>Ø AND BG(B-1,1Ø)<=4Ø THEN
    LLL=(BSA*13ØØ)+((L^.6)*2ØØ)-(((4Ø-BG(B-1,1Ø))^1.2)*8Ø)
    PRINT USING
      "AT ###.# DEGREES GAS FLOW SHOULD BE #### CC'S PER MIN   ";L+37;LLL;
IF L>Ø AND BG(B-1,1Ø)>4Ø THEN
    LLL=(BSA*13ØØ)+((L^.6)*2ØØ)+(((BG(B-1,1Ø)-4Ø)^1.2)*1ØØ)
    PRINT USING
      "AT ###.# DEGREES GAS FLOW SHOULD BE #### CC'S PER MIN   ";L+37;LLL;

IF L<=Ø AND BG(B-1,11)<=17Ø THEN PRINT USING"and FIO2 SHOULD BE ####";
((48.4*BSA)-12.5)+((3ØØØ/LLL)^1.3)-((ABS(L)^.6)*1Ø)+(((17Ø-BG(B-1,11))^1.2)*.1)

IF L<=Ø AND BG(B-1,11)>17Ø THEN PRINT USING"and FIO2 SHOULD BE ####";
((48.4*BSA)-12.5)+((3ØØØ/LLL)^1.3)-((ABS(L)^.6)*1Ø)-(((BG(B-1,11)-17Ø)^.87)*.1)

IF L>Ø AND BG(B-1,11)<=17Ø THEN PRINT USING"and FIO2 SHOULD BE ####";
 ((48.4*BSA)-12.5)+((3ØØØ/LLL)^1.3)+((L^.6)*1Ø)+(((17Ø-BG(B-1,11))^1.2)*.1)

IF L>Ø AND BG(B-1,11)>17Ø THEN PRINT USING"and FIO2 SHOULD BE ####";
 ((48.4*BSA)-12.5)+((3ØØØ/LLL)^1.3)+((L^.6)*1Ø)-(((BG(B-1,11)-17Ø)^.87)*.1)

NEXT LL%
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VARIABLES:

```
INFO(?,Ø) = VENOUS TEMPERATURE IN DEGREES C
BG(?,1Ø)  = ARTERIAL pCO2
BG(?,11)  = ARTERIAL pO2
BSA       = PATIENT'S BSA
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defined by the Providence Medical Center Perfusion Protocol.

DISCUSSION

The pre-operative descriptive data (**Tables 1 and 3**) clearly shows that there was no difference in the patient populations between the three groups in any of the areas evaluated. The confidence level was lowest regarding sex and surgeon in the Group 1 versus 2 comparison. The morbidity and mortality statistics also show that Group 1 and 2 exhibited no statistical difference in case outcomes. It can, therefore, be stated that there was no benefit to the patients in the immediate time period following the institution of computerized bypass. There are, however, several flaws in the pathway to this conclusion. The first flaw was that the intra-operative parameters were not monitored or recorded in the first group of patients. The second flaw is that given time, the better alarm functions and predictive capacity of the computer assisted cases would give rise to better perfusion by a closer range of tolerances, if these tolerances and alarm warnings were promptly acted upon. It could be argued that the second group of patients did not receive the same level of care during the bypass period as Group 1 due to the still evolving computer algorithms for alarm and warning functions and that this would cause any benefit derived from computer usage to be masked. To address this potential problem a third group of patients was selected. The patients in Group 3 had no difference in descriptive statistics from the control Group 1 (**Table 3**).

Since data was now available to compare the bypass parameters, it was analyzed to determine if any causes could be found to account for the differences in the two computer usage groups. **Table 5** shows that there was an improvement in patient care in the areas of maximum PO_2 observed, average PO_2 recorded, minimum PCO_2 allowed and maximum mean arterial pressure during cardiopulmonary bypass. The maximum PO_2, the average of highest allowed arterial PO_2 reading on an in room Radiometer ABL3[d] blood gas machine dropped from a value of 377 for Group 1 to 307 for the late computer usage group. The possible explanation for this improvement was the use of the highly specific algorithm (**Table 6**) gives the program listing and explanation of variables) derived from the work of Dearing[5] to predict oxygenator FIO_2 requirements during the changing patient conditions. This explanation also applies to the drop in the average PO_2 recorded from a Group 1 level of 229 to 199 for the late computer usage group, as well as the average minimum recorded PCO_2 increase from 32.1 to 33.4. The difference reported in the average maximum recorded mean arterial pressure from 135.5 to 116.6 could be explained by the improved sensitivity of the alarm features used in the late computer group over the other two groups. This improved alarm routine also included a progressive warning system that was utilized sooner.

CONCLUSION

For research, documentation of records, maintenance of a patient database and for evaluation of new equipment or changes in perfusion technique, the computer is a valuable tool. However, if a perfusionist regularly attends meetings, believes other published data, does not work in an environment committed to research, and has an accurate and complete record system, this study has shown that a computer does not improve patient care or help reduce patient operative complications and its use is somewhat superfluous. The improved monitoring and diagnostic functions provided by a computer system could be just as easily achieved by using current monitors and alarms along with running a few more blood gases or getting one of the several in- line monitors available and using the values they report as a indication of change rather than an absolute value.

One possible alternative to purchasing a prepackaged computer system is to assemble a homemade system[1] and customize it to your needs, both in and out of the surgical suite. This option trades the initial capital expense for a rather substantial time commitment but provides new learning opportunities for the perfusionist interested in improving his or her professional stature and should future studies prove the worth of real time computers, the perfusionist will at least have become familiar with the new technology.

d. Radiometer, Copenhagen, Denmark

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