ACT, ANTICOAGULATION, HEPARIN, FIBRINOLYSIS

A CLINICAL EVALUATION OF THE CORRELATION AND REPRODUCIBILITY OF THREE AUTOMATED DEVICES FOR MEASUREMENT OF ACTIVATED CLOTTING TIMES

Mark Dumond*, David Dumond, Cheryl Cook, Brett Duffner
Julia Laribee

The Activated Clotting Time (ACT) assumes an important role in documentation of adequacy of perfusion. Therefore, it is important to document the correlation and reproducibility of automated systems currently available to measure the ACT value. Throughout surgical procedures of 37 patients requiring cardiopulmonary bypass, blood samples were drawn in a single syringe and ACT values obtained using four Hemotec ACTs (T-ACT), four Hemochron ACTs (M-ACT), and two Sonoclot ACTs (S-ACT). Sample points with the mean of two of the three sets of ACT's exceeding 600 sec. were excluded and the values were divided into heparinized (ACTH) (n=44) and non-heparinized (ACTN) (n=58) groups.

GROUP	MEAN VALUE	AVG. STD.DEV.	R W/ T-ACTN	R W/ H-ACTN	R W/ T-ACTH	R W/ H-ACTH
T-ACTN	104	3	...	.638	...	...
H-ACTN	128	5	.638	...	...	...
S-ACTN	138	11	.663	.580	...	...
T-ACTH	551	48	...	...	...	.224
M-ACTH	514	69	...	...	.224	...
S-ACTH	768	98	...	...	.041	.224

The very poor correlation of the three systems raises doubts as to interchangability of ACT values from each system. The reproducibility (based on the size of the STD.DEV.) of the Hemotec system is signficantly better than the Sonoclot.

*410 W. Tenth Ave., Columbus, OH 43210

CLINICAL EVALUATION OF THE HEMOTEC HEPARIN DOSE RESPONSE CARTRIDGE

Mark Dumond*, David Dumond, Cheryl Cook, Brett Duffner

The intent of this study is to evaluate the ability of the Hemotec System Four to provide an accurate predictor of heparin requirements for patients undergoing cardiopulmonary bypass (CPB). The study group consisted of 27 consecutive patients undergoing CPB. Patient charts were reviewed for preoperative use of heparin or IV Nitroglycerin therapy. Blood samples were drawn prior to induction of anesthesia and an Activated Clotting Time (ACT) obtained from a Hemochron 400, along with the heparin maintenance level (HML) in units/kg and slope in sec/mg/kg obtained from the Hemotec System Four. Following heparinization of the patient at 300 units/kg, an ACT was performed prior to initiation of CPB and additional heparin given if the value failed to reach at least 480 seconds. The amount of heparin (AHL) needed to reach an ACT of 480 seconds was calculated from a dose response curve utillizing the final heparin dose, the initial ACT, and the final ACT. The correlation of the HML and the AHL was .547. The correlation of the slope value to AHL was -.596. The level of false negative responses obtained from the HML or the slope value were not significantly different from the levels achieved from use of preoperative heparin or IV nitroglycerin therapy as an indicator of heparin resistance. The heparin dose response did not improve our ability to predict the individual patients heparin requirements.

*410 W. Tenth Ave., Columbus, OH 43210

THE COURSE OF D-DIMERS AND THE NORMAL ROLE OF FIBRINOLYSIS DURING CARDIOPULMONARY BYPASS

T.L. Moretz, J. B. Riley*, E.A. Jeter, R. G. Sutton, D.G. Bishop, J.M. Kratz, and F.A. Crawford, Jr.

D-Dimers (DD) are the expressed degradation products of the lysis of fibrin. Fibrin monomers may normally occur during routine CPB; therefore, fibrinolysis could play a protective role. Serum DD levels were observed at six events associated with routine CPB. An expected patient DD level while heparinized would be <0.5 mcg/ml, showing that fibrin is not being formed.

The majority of elevated DD levels came at the termination of CPB when only one of 20 patients investigated showed a minimal DD level of <0.5. The other patients ranged from >0.5 to >10.0 mcg/ml at termination of CPB.

EVENT	ACT	DD LEVEL
Baseline	123±15	1.0±1.1
Post Sternotomy		1.6±1.9
5 min on CPB	497±95	1.6±2.3
Terminate CPB	432±84	5.1±2.8
Post Protamine	116±11	5.1±2.8
1 Hr Post Op		4.9±3.0

ACT = mean activated clotting time ± 1SD

The last three event DD levels were significantly greater than the DD from the first three events ($p<0.01$) demonstrating that fibrinolysis may be a normal occurrence during CPB. The weak

correlation in the rise in DD during CPB versus the minimal CPB ACT data (n=20, r=.114) although not statistically significant, suggests that ACTs should be maintained above 480 seconds throughout CPB to minimize fibrin formation and therefore minimize fibrinolysis.

Medical University of South Carolina, Extracorporeal Circulation Technology, 171 Ashley Ave., Charleston, SC 29425-2701.

THE ROLE OF ANTITHROMBIN 3 IN HEPARIN RESISTANCE

Dennis C. Rivard*, Steven J. Thompson, Duke Cameron

Resistance to the anticoagulation action of sodium heparin during cardiopulmonary bypass is a serious concern and a poorly understood phenomenon. In the majority of cases, the desired prolongation of the activated clotting time (ACT) is achieved by administration of additional heparin. A patient's previous exposure to heparin has been suggested as the cause of this clinical dilemma. The administration of fresh frozen plasma to patients who demonstrated a heparin resistance have been shown to produce a normalization of their heparin/ACT dose response curve and a decrease in total heparin requirements during cardipulmonary bypass. These results could be an indication of a deficiency of a component in patient's plasma.

This study was designed to compare antithrombin 3 in two patient populations. Group A consisted of 15 patients receiving intravenous heparin therapy prior to cardiopulmonary bypass for greater than 24 hours. Group B included 15 patients who had not been exposed to heparin therapy preoperatively. All patients were candidates for coronary artery bypass grafting. The quantitative assay utilized the Loyal Rocket Immunoelectrophoresis Technique and the qualitative assay was determined by the AT3 Anti-10A Activity Assay.

Two sample t-test analyses of variance revealed no statistical significance ($p>0.05$) between the two populations in either the quantitative assay ($p=0.054$) or the qualitative assay ($p=0.06$). A comparison of the ratio (qualitative/quantitative) showed a statistical difference ($p=0.016$).

It can be suggested from these results that the resistance to heparin demonstrated in heparin therapy patients is the result of a combination of factors associated with AT3. Administration of heparin decreases the available AT3 and decreases its function. The combination of these two factors contribute to this resistance phenomenon.

* *Dept. of Cardiac Surgery, 618 Blalock, JHH, 600 N. Wolfe St., Baltimore, MD 21205*

HEPARIN COATED CARDIOPULMONARY BYPASS SETS DURING SURGERY-A CLINICAL STUDY

S. Thelin*, A. Bylock, L. Bagge, J. Borowiec, L. Nilsson, J. van der Linden, P. Venge, E. Thorno, P-A Hillstrom, L. Larsson, H-E. Hansson

Cardiopulmonary bypass (CPB) causes trauma to blood cells. In our previous animal studies, the use of surface heparinized CPB sets reduced postoperative bleeding and enhanced preservation of blood cells. In this clinical trial the membrane oxygenator (Maxima, Medtronic) tubings and cannulas were surface-coated by end-point attachment of heparin (CBAS, Carmeda Bioactive Surface). Twelve male patients in NYHA class III scheduled for coronary bypass surgery were randomized. Six were operated with a non-coated system (group NC) and given full dose heparin (300 IU/kg). Six patients were operated on with a heparin-coated system (group C) and we reduced heparin (225 IU/kg) Additional heparin was given when ACT (Activated Clotting Time) was $\leq$400 sec in group NC and $\leq$300 sec in group C. Filters were inserted in the arterial line.

Results: The total heparin and protamine doses were 228$\pm$6 IU/kg, 1.8$\pm$0.1 mg/kg in group C and 353$\pm$17 IU/kg, 3.2$\pm$0.2 mg/kg in group NC. During CPB group C had shorter ACT, 393$\pm$17 vs. 471$\pm$18 sec. Platelet count and adhesion, fibrinolysis, leukocyte count and postoperative blood loss were not significantly different. A trend to better blood cell preservation in group C was supported by significantly lower plasma myeloperoxidase (MPO) at the end of CPB (207$\pm$23 vs. 606$\pm$153 ug/l). Scanning electron microscopy of the arterial filters and deposit estimation of fibrin, platelets, erythrocytes and activated leukocytes revealed significant reduction of those elements in filters from group C. The filters from group NC served as good substrates after bacterial incubation while almost no bacterial growth was seen in filters from group C.

Conclusion: Utilizing heparin coated CPB-sets permitted safe reductions of heparin to 75% dose and the concomitant protamine dose to 50%. The reduced adhesion of blood elements to the arterial filters and the lower secretion of MPO, derived from activated leukocytes, indicate that heparin coated surfaces are more biocompatible compared to non-coated surfaces in group C.

* *Dept. of Thoracic Vascular Surgery, University Hospital, Uppsala, S-751 85, Sweden*

QUALITATIVE ASSESSMENT OF SHED MEDIASTINAL BLOOD

U. Volken*, B. Walpoth, U. Nydegger, U. Althaus

In a randomized prospective study of patients undergoing coronary bypass surgery, autologous blood from chest drainage was collected and retransfused into 10 patients (RTX) whereas 10 patients without retransfusion served as controls. There was no significant difference referring to age, weight, height, perfusion time and number of distal anastomosis. Our main regard was directed to a qualitative analysis of the retransfused autologous blood.

Results (Mean values/patient)
1. There was no bacterial contamination in the reservoir just prior to retransfusion.
2. Elevated levels of free plasma hemoglobin (o-tolidin-method) were encountered after one hour on cardiopulmonary bypass (CPB) and a 6-fold increase in the shed blood from the cardiotomy reservoir (211 mg/dl ± 44).
3. The potassium value in the cardiotomy reservoir was slightly increased (5.8 mmol/l ± 2.9).
4. In no case hemoglobinuria or coagulation disfunction was noted. The activated clotting time (ACT) after retrasnfusion did not change (117 sec ± 15) as compared to preopertive values (112 sec ± 16).
5. No evidence for complement activation (determined by measurements of C3a and C5b-9), induced by CPB was seen.
6. Red cell adenosintriphosphate in the shed mediastinal blood was lowered to 2.56 umol/gHb ± 0.78 whereas red cell 2,3 diphosphoglycerage remained normal.

On the basis of these results, we consider the retransfusion of shed mediastinal blood following cardiac surgery a simple, cost effective and safe method of blood salvage.

* *Dept. of Thoracic & Cardiovascular Surgery, Inselspital Berne, Switzerland*

A COMPARISON OF THREE BLOOD PROCESSING TREATMENTS DURING AND AFTER CARDIOPULMONARY BYPASS

R.G. Sutton, B.S. Yates, S.P. Borg, C.E. King, J.E. McClendon-Few, J.B. Riley*, J.M. Kratz, F.A. Crawford Jr.

Sixty cardiopulmonary bypass patients undergoing routine coronary artery bypass grafting were randomly prospectively assigned to one of three possible treatment groups: Ultrafiltration (UF), Cell Saving (CS) or Dilution (DL). Samples were taken pre-bypass, post-bypass, eight hour and 24 hour post-operative and the results were as follows:

	EndCOP	20COP	20FIB	20PLT	20TT	8HPLT
UF/CS	12.1/10.8	12.2/10.8	243/191	190/131	27/42	190/131
p<	0.05	0.05	0.1	0.05	0.1	0.1
UF/DL	12.1/11.0	12.2/11.7	243/196	190/148	27/25	192/154
p<	0.1	NS	NS	NS	NS	0.1
DL/CS	11.0/10.9	11.7/10.8	196/191	148/131	25/42	154/154
p<	NS	NS	NS	NS	0.05	NS

End=End bypass, 20=20 minute after treatment blood given, 8H=8 hours post-operative, COP=Colloid osmotic pressure, FIB=Fibrinogen, PLT=Platelet count, TT=Thrombin Time, NS=Nonsignificant

Age, body surface area, number of grafts, preoperative values, blood product usage, plasma free hemoglobins, time on the respirator, static lung compliance, dynamic lung compliance, eight hour labs (excluding platelets), and 24 hour labs were nonsignificant. In conclusion, UF is superior to DL and CS at the end of CPB and 20 minutes after processed blood was administered. UF was found to be superior to CS eight hours post-operative, and not significantly different from the other methods 24 hours post-operatively.

* *Medical University of South Carolina, Extracorporeal Circulation Technology, 171 Ashley Ave., Charleston, SC 29425-2701.*

CARDIOPULMONARY BYPASS OF BLOODLESS PRIME USED IN OPEN HEART SURGERY OF CHILDREN AND INFANTS (48 CASE ANALYSIS)

Han Youqi*, Su Zhaokang, Ding Wenxiang

This paper reviewed the perioperative courses of 48 children and infants who underwent operations for complete repair of congenital heart disease. All cases ranged in age from seven months to eight years (4.9 ± 1.8 years), 29 cases' age (60.4%) were less than five years and weighed six to 24.5 kg (14.9 ± 3.5 kg), 27 cases' (56.3%) weight were less than 15 kg. All operations were performed using bloodless hypothermia cardiopulmonary bypass with Ringer's solution prime. The hematocrit of patients remained higher than 15%. None died in hospital. During hospitalization, 27 cases received blood and blood products because of postoperative bleeding and volume loss. The other 21 cases didn't need blood or blood product transfusion in ICU. The hematocrit of these cases was higher than 28% with no manifestations of bleeding. The results demonstrate that open heart surgery can be safely performed in children and infants with hypothermia cardiopulmonary bypass and asanguinous prime.

1665 Kon Jiang Road, Xin Hua Hospital, Department of Pediatric, Cardiac and Thoracic Surgery, Shanghai 200092 China.

A CONVERTIBLE CARDIOPULMONARY BYPASS SYSTEM FOR OPTIMIZED HEMOFILTRATION

Ludwig von Segesser*, Eligio Garcia, Marko Turina

Hemofiltration during or after cardipulmonary bypass has proven to be an efficient tool for hemoconcentraion. Classically, the hemofilters are supplied by the arterial line and the filtration rate is mainly a function of the perfusion pressure. We have developed a convertible cardiopulmonary bypass system including a double head roller pump for blood cardioplegia application that allows optimized hemofiltration independent from systemic perfusion.

Serial bench studies were performed at normothermia with a mean hematocrit of 20% and identical hemofilters:

	Classic	Optimized	p≤
Systemic pump flow l/min	3.5±0.9	3.5±0.9	NS
Arterial line pressure mmHg	148±3	135±8	0.05
Filter line pressure mmHg	144±8	378±30	0.05
Filter flow ml/min	152±3	346±6	0.05
Filter output ml/15 min	999±228	1599±174	0.05

* *Herzgefasschirugie Universitatsspital, CH-8091, Zurich, Switzerland.*

EFFECT OF SERUM PRECOAT ON COMPLEMENT ACTIVATION IN MEMBRANE OXYGENATORS: AN IN VITRO STUDY

James R. Collett*, Patrick F. Plunkett

Previous studies have shown that extracorporeal circulation devices can activate the alternative pathway of the complement cascade. Anaphylatoxins (C3a and C5a) generated by complement activation may lead to pulmonary leukocyte sequestration, pulmonary edema, granulocytopenia and microvascular lung damage. This is of particular concern in patients on ECMO. The purpose of this study was to examine the impact of precoating membrane oxygenators with serum on complement activation. A pool of recalcified human serum was prepared from fresh frozen plasma stored in CPD. SciMed membrane oxygenators (N=4) were primed with 200 ml aliquots of pooled serum which was recirculated through the oxygenators for 180 minutes at 37°C. The prime serum C3a levels (mean ± SD) measured by radioimmunoassay techniques at 0, 60, 120, and 180 minutes were 122.25 ± 26.22, 430.25 ± 164.39, 456.0 ±154.16 and 577.5 ± 163.07 ng/ml respectively. Each oxygenator was then flushed with saline and reprimed with a fresh 200 ml aliquot of pooled serum which was recirculated for 180 minutes at 37°C. The test C3a levels (mean ± SD) measured at 0, 60, 120, and 180 minutes were 130.75 ± 15.67, 213.25 ± 58.24, 283.75 ± 27.24 and 301.75 ± 19.18 ng/ml respectively. There were significant differences in serum C3a levels between the prime and test samples ($p<0.05$). These results suggest that preconditioning the oxygenator may be a way to moderate complement activation during cardiopulmonary bypass.

* *206 Mugar Hall, Northeastern University, Boston, MA 02115.*

CLINICAL TRIALS OF A NEW INFANT MEMBRANE OXYGENATOR

J. Merrill, T. Akers, R.G. Sutton, J.B. Riley*, R.M. Sade, F.A. Crawford Jr.

Clinical trials of a new infant/pediatric hollow fiber membrane oxygenator were undertaken at the Medical University of South Carolina with parental consent. The oxygenator has a static priming volume of 170 ml with a rated blood flow of 2.5 l/min. The oxygenator was used on 15 infant/pediatric patients undergoing corrective surgery for congenital defects. The patients ranged from one month to 10.4 years and from BSAs of 0.2 to 1.01 m^2. Circuit priming volumes ranged from 800 to 1000 ml.

Results show no significant differences in plasma-free hemoglobin or platelets between pre-op and four day post-op. Statistical analysis of the data produced theoretical (TH) and practical (PR) multiple linear regression equations which enable the perfusionist to determine FiO_2 and gas flow (GF) for desired PaO_2 and alpha stat $PaCO_2$.

	TH-FiO_2	TH-GF	PR-FiO_2	PR-GF
r=	.91	.80	.89	.79

p< 0.0001 for all values

This oxygenator can be safely used with a relatively large range (3 to 25 kg) of infant and pediatric patients with statistically predictable results.

* *Medical University of South Carolina, Extracorporeal Circulation Technology, 171 Ashley Ave., Charleston, SC 29425-2701.*

REPORT ON THE CLINICAL TRIALS OF THE PLEXUS MEMBRANE BLOOD OXYGENATOR

A. Hodgson-Smith, R.G. Sutton, J.B. Riley*, C.A. Stotland, M.E. Pienta, V.W. Dillon, J.M. Toomasian, J.M. Kratz, F.A. Crawford Jr.

Twenty adult patients gave informed consent to clinical cardiopulmonary bypass (CPB) trials with a new adult hollow fiber membrane oxygenator. Clinical CPB trials averaged 88 ± 25 min (mean ± 1 SD) for these patients that weighed 78 ± 13 kg and had BSAs = 1.9 ± .2 m^2. Blood Flow averaged 4.0 ± .8 l/min and hypothermia was employed at 26.5 ± 2.4°C. FiO_2's = .59 ± .15 and gas to blood flow ratios = .64 ± .18 were required to maintain the PaO_2 > 100 mm Hg and to accomplish alpha-stat. The oxygenator exhibited a pressure drop of 50-60 mm Hg at 5.0

l/min and a heat exchanger performance factor over .55 during most of CPB.

Multiple regression analysis of the clinical database demonstrated that the FiO_2 required to achieve a desired PaO_2 was dependent on the blood flow, gas to blood flow ratio, and SvO_2 (r = 0.89, standard error = 0.07). The gas flow required to accomplish alpha-stat was dependent on patient age, weight, blood flow, hematocrit and the blood temperature (r = 0.785, standard error = 0.6).

The Plexus blood oxygenator is safe for adult cardiopulmonary bypass and its clinical performance is statistically predictable.

* *Medical University of South Carolina, Extracorporeal Circulation Technology, 171 Ashley Ave., Charleston, SC 29425-2701.*

DEVICE COMPARISONS

CLINICAL ACCURACY OF CONTINUOUS HEMOGLOBIN OXYGEN SATURATION MONITORING DEVICES

Gregory Z. Bolen, Gary E. Anderson, James R. Huddelson, Jeffrey B. Riley*, Robin G. Sutton, David G. Bishop

Four devices used to measure hemoglobin oxygen saturation in the extracorporeal circuit were studied. The American Bentley OxySat, Oximetrix AccuSat, and the Radiometer ABL4 blood gas monitor were compared to the IL 282 cooximeter as the control. Fifty-one sample points were obtained during all phases of cardiopulmonary bypass with results as follows:

	r		DIFF	SD	P	
ACCUSAT	0.94	p<.0001	-0.6	3.2	0.1834	NS
ABL4	0.93	p<.0001	-1.7	3.3	0.0008	S
OXYSAT	0.87	p<.0001	-6.8	4.4	0.0001	S

r=correlation coefficient with corresponding p value, DIFF=difference from control, SD=Standard deviation of difference, P=p value for testing the hypothesis of no difference between test device and control, NS=No significant difference, S=Significant difference

The AccuSat was found to be a statistically more accurate means of monitoring hemoglobin oxygen saturations during cardiopulmonary bypass than the ABL4 and the OxySat using the IL 282 as the control. All devices had significant correlation with the control and with each other.

* *Medical University of South Carolina, Extracorporeal Circulation Technology, 171 Ashley Ave., Charleston, SC 29425-2701.*

IN VITRO COMPARISON OF ECC BLOOD FLOW MEASUREMENT TECHNIQUES

K. Gallimore-Kirven, G. Anderson, G. Bolen, A. Hodgson-Smith, J. Coward, J. Huddelson, T. Akers, J. Merrill, T. Moretz, R.G. Sutton, J.B. Riley*, D. Kirven

Four extracorporeal blood flow measurement devices were compared for accuracy: the digital display (Stockert-Shiley roller pump), the Sarns doppler flow probe, the Transonic transit-time flow probe, and the Bio-Medicus electromagnetic flow probe. The effects of temperature and hematocrit at various flows were compared.

Eighty-four blood flow measurements were recorded for hematocrits from 17.5 to 35%, temperatures ranging from 25 to 37°C and flows from 3.0 to 5.5 l/min. A summary of the results follows:

	ACTQ	HCT	TEMP	INTER	MEAN	SD
		r^2			%DIFF	%DIFF
BIO-MEDICUS	.98	.0001	.0069	.0053	1.0	2.3
SARNS	.96	. 01	NS	NS	1.6	3.2
SHILEY RPM	.99	NS	NS	NS	-2.3	1.5
TRANSONIC	.99	.0001	.02	NS	4.3	1.4

ACTQ r^2= correlation with actual flow, HCT= p value for effect of hematocrit on error, TEMP= p value for effect of temperature on error, INTER=p value for interaction of hematocrit and temperature on error, MEAN %DIFF=average % error, SD %DIFF= standard deviation of % error, NS=Non significant

All flow measurement systems significantly correlate with actual flow (p<.0001). The Bio-Medicus and Sarns exhibited significantly less percent error in reporting the true flow (p<.001). The Bio-Medicus, Sarns, and Transonic errors were affected by hematocrit; the Bio-Medicus and Transonic errors were affected by temperature. A 5% error in reporting actual flow is suggested not to be of clinical significance.

* *Medical University of South Carolina, Extracorporeal Circulation Technology, 171 Ashley Ave., Charleston, SC 29425-2701.*

DATA ACQUISITION BY A COMPUTERIZED CENTRAL UNIT IN CARDIAC SURGERY

D. Gaillard*, C. Barraud, O. Bical, L. Detoni, A. Vanetti

We present a computerized system which acquires, stores and processes all the parameters currently measured during heart surgery.

The aim of this computerized system is based on:
-continuous acquisition and processing of patient and ECC data
-adaptability of user's system to this system
-user-friendliness
-adaptability to all operating theatre equipment

The hardware includes an IBM PS/2, 8570, with a color screen and HP Laser printer.

This computer is compatible with seven different monitors. The incoming values are displayed either instantaneously or as averages. The results can be displayed either in color graphics form and updated automatically, or in the forms of tables.

All parameters commonly measured in the operating room at present can be recorded by the software. For example: all arterial and venous pressures, venous and arterial saturation, five different temperatures, cardiac output, ST segment level, pump flow rate, arterial and venous blood gases in continuity with CDI 300.

With any parameters, computed data, such as vascular resistances, and O_2 consumption is also obtained on a continuous basis.

The computer is a powerful instrument because of its multiple personalization and interfacing capabilities, not only for the whole surgical team but also for research situations.

* *Hospital St. Joseph, 7 rue Pierre Larousse, 75014 Paris, France.*

OPTIMAL DESIGN OF HOLLOW FIBER MEMBRANE DEVICES FOR GAS TRANSFER

Edward L. Cussler*, Robert W. Callahan

The purpose of this study is to develop models for gas transfer in microporous hollow fiber membrane devices. The gases examined include oxygen and carbon dioxide. For oxygen transfer (water), rates are controlled by aqueous phase resistance independent of membrane resistance. For carbon dioxide transfer (aqueous caustic), membrane resistance becomes important at high aqueous flow rates. Membrane devices with perpendicular flow of gas and liquid were found to be significantly more efficient than devices with parallel flow. The design equations are successfully used to predict oxygenation transfer rates for a series of commercial hollow fiber devices. Using the design equations as a basis, the impact of changes in membrane diameter, wall thickness, pore size and tortuosity on device performance are presented, as well as an examination of the impact of a thin film coating on the membrane.

* *Department of Chemical Engineering, University of Minnesota, Minneapolis, MN 55455.*

THE HEART LUNG PUMP/HUMAN INTERFACE: A REAL TIME MICROCOMPUTER-BASED SIMULATION

Richard B. Davis*

A microcomputer-based simulation of the important processes which occur during cardiopulmonary bypass has been developed for preclinical practice for perfusion technologist trainees. The interface to the computer is through a custom designed electronic console with controls for five pump heads, heat exchanger water temperature, gas flow and content, oxygenator and cardiotomy reservoir heights, clamp detection for flow control and variable venous clamping. A keypad is provided for menu-driven entry of patient characteristics, timer control, data requests, drug and fluid administration, and perfusion system data.

The system operates in real time with waveform and digital data displays of information typically available to the perfusion technologist clinically. The timing and accuracy of the presented information is controlled by the program and patient responses calculated with randomly selected deviations.

Major components of the simulation have been compared to clinical data. Mean error for pO_2 was 0.67%, for CO_2 transfer -0.014ml/l/min and for heat exchanger performance -0.018°C. The simulation has been used for preclinical student training and found to be effective for both practice and student evaluation.

* *Ohio State University, 1583 Perry St., Columbus, OH 43210.*

LEFT VENTRICULAR ASSIST IN THE INFANT

Susan C. Ratty, Mary Winkler*, John Lamberti, Todd Grehl, and Ricardo Moreno-Cabral

Two cases are described in which the Bio-Medicus centrifugal pump is used to support left ventricular failure post CPB in the infant patient. The first patient (5 kg) was diagnosed with anomalous left coronary artery and pre-operative myocardial infarction. This patient required left ventricular assist support for 13 hours following surgical repair and failure to wean from CPB. The second patient (5 kg) presented 12 days s/p mustard procedure with post operative ECMO support, for resuscitative

CPB following an acute cardiac arrest incident. The patient could not be weaned from CPB with adequate cardiac output and required left ventricular support for 24 hours. Both patients were cannulated from left atrium to ascending aorta. The circuit consisted of 1/4" tubing an electromagnetic flow probe, and a pediatric bio-pump head connected to the Bio-Medicus centrifugal pump. High flows and minimal anticoagulation were maintained and both patients were successfully weaned from the left ventricular assist device. The text will describe the details of perfusion management and patient outcomes. We conclude LVAD is a viable adjunct to the care of infants unable to be weaned from CPB.

* *Cardiovascular Perfusion, Inc., 7910 Frost St., Suite 204, San Diego, CA 92123-2758.*

THE EFFECT OF SUBSTRATE ENHANCED CARDIOPLEGIA ON POSTBYPASS ELECTRICAL AND HEMODYNAMIC RECOVERY

Alfred H. Stammers*, G. Michael Deeb, Russell R. Butler, Julie Palbykin, Cecilia M. Claprood, and Julie Anderson

Substrate enhanced terminal cardioplegia increases metabolic activity which may enhance recovery in the post cardiotomy patient. Twenty-eight consecutive low risk patients requiring coronary artery bypass grafting were randomly assigned to receive either aspartate glutamate enriched cardioplegia or unmodified pump blood reperfusate. There were no significant differences between patient groups in prebypass parameters. Bypass indices including bypass time, cross clamp time and grafts performed did not vary between groups other than total cardioplegia volume administered (2364 $\pm$ 578 cc mean $\pm$ SD in the non-aspartate glutamate group, vs 2828 $\pm$ 579 cc in the aspartate glutamate group, $p<.05$). Treated hearts received less defibrillatory shocks with lower total joules and were paced less than the non-aspartate glutamate hearts. There were no significant differences in the use of inotropes or antiarrhythmics, nor did cardiac index or systemic vascular resistance differ between groups over the first several postoperative days. Our results show that the routine use of substrate enriched terminal cardioplegia did not improve immediate postoperative hemodynamic recovery in patients undergoing low risk coronary artery bypass grafting.

* *Dept. of Thoracic Surgery, University of Michigan, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-0344.*

PERFUSION TECHNIQUES OF PROFOUND HYPOTHERMIA AND CIRCULATORY ARREST FOR PULMONARY THROMBO-ENDARTERECTOMY

Mary Winkler*, Charlene Rohrer, Glenn Frey, Pat Daily, Walter Dembitsky, Stuart Jamieson, and Kenneth Moser

One hundred ninety-three patients with the diagnosis of chronic pulmonary thromboemboli have been operated on at the UCSD Medical Center utilizing profound hypothermia and circulatory arrest. A subset of nine of these patients have been treated during hospitalization with Iloprost for heparin induced thrombocytopenia.

The surgical procedure of pulmonary thrombo-endarterectomy requires multiple periods of circulatory arrest under profound hypothermia. Perfusion management of this procedure involves cerebral and myocardial protection, cooling, reperfusion at hypothermia, and rewarming treatment with Iloprost when appropriate, and methods of hemodilution.

The methods of perfusion management emphasizing techniques utilized for profound hypothermia and circulatory arrest will be addressed.

* *Cardiovascular Perfusion, Inc., 7910 Frost St., Suite 204, San Diego, CA 92123-2758.*

EXTRACORPOREAL CIRCULATION DURING TREATMENT OF ANEURYSMS OF THE ASCENDING AORTA

Alfred H. Stammers*, Russell Butler and Marvin M. Kirsh

Extracorporeal circulation in the treatment of aneurysms of the ascending aorta and transverse arch present both the surgeon and perfusionist with a formidable challenge. At the University of Michigan, 27 patients with either of these anomalies have been treated in a two-year period from August 1987 to August 1989. Of these, eight had lesions which involved one or more head vessels and necessitated either a period of circulatory arrest or cerebral perfusion (four patients in each group). Mean circulatory arrest periods were 44.8 $\pm$ 9 minutes (Mean $\pm$ SD), while the cerebral perfusion patients had one or more head vessels cannulated for periods of 64.3 $\pm$ 19.7 minutes. Postoperative complications in the circulatory arrest group included encephalopathies (4/4 patients) and high perioperative mortality (2/4 patients). In the cerebral perfusion group only one patient experienced postoperative neurological complications and there were no immediate postoperative deaths. Although these population groups are small we believe that this technique of cerebral perfusion offers distinct advantages to that of circulatory arrest.

* *Dept. of Thoracic Surgery, University of Michigan, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-0344.*

METABOLIC APPROACH OF MYOCARDIAL INJURY DURING COLD CARDIAC ARREST

Y. Glock*, J.Pereira De Souza, C. Dubocher, J. Montastruc, C. Serradeil, M. Galinier

Goal: Are deep modifications present in pharmacological structures of myocardium after cold cardiac arrest with

cardioplegia (St. Thomas II)?

Method: Study of patients operated on coronary artery bypass graft (CABG) and valve replacement (VR). Arterial, venous and coronary sinus blood samples are analyzed (pH, lactate, bicarbonate), electron microscopy radio immunological assay of AMP-c and beta adreno-receptors and catecholamines (Falk-Hillarp) are studied in right atrial myocardial tissue before and after aortic cross clampage.

Results: Cold cardiac arrest induced metabolic acidosis, significant decrease of coronary sinus pH, extraction of lactate and cardiac extraction of bicarbonate, with swelling of the mitochondria in spite of the cardioplegia. The kinetic of the catecholamine is comparable to a response to sympathetic stimulation, but there is neither significant variation in AMP-c nor beta adreno-receptors at the atrial level.

Conclusion: Cold cardiac arrest with cardioplegia induce significant lactic injury but preserve the main pharmacological pathways.

* *Dept. of Cardiovascular Surgery, Rangueil University Hospital, Toulouse, 31054, France.*

POSTER SESSIONS

POSTPARTUM DISSECTION OF CORONARY ARTERY (LAD) - CASE REPORT

Darrell A. Woodman*

A 35-year-old female, one month postpartum, was admitted to the hospital with chest pain. Emergency coronary angiography showed acute dissection of the left coronary artery. The patient was immediately taken to the operating room, where emergency coronary bypass surgery to the LAD was performed. We will discuss this case as well as review the literature on the rare but extremely interesting disorder.

**1764 Summernight Terrace, Colorado Springs, CO 80909*

PROPOSALS FOR IMPROVING PERFUSION PRACTICE IN DEVELOPING COUNTRIES

John George*, Ljafri A. Majid, Samani A. Ghani, Lim Jee-Shailim

In advanced countries such as the United States, perfusion practice has kept pace with the rapid development of cardiac surgical practice. This is evident by the rigorous formal education programs and the numerous continuing education programs existent in these countries.

In developing countries, however, a wide gap exists between cardiac surgical expertise and perfusion practice. While authorities educate and train cardiothoracic surgeons abroad, perfusionists, per se, are recruited from the ranks of paramedics and learn the art and science of practice "in-service."

Aimed at narrowing the gap between surgical and perfusion practice in developing countries, this presentation proposes a two-tiered formal education program and the formation of committed national perfusion organizations -- both with clearly defined objectives.

The benefits of affiliating with developed perfusion communities through an International Council of Perfusion Societies are highlighted and a deliberate attempt is made to implore AmSECT to undertake the noble task of reorganizing the ICPS.

**c/o Dept. of Surgery, Faculty of Medicine, Universiti Malaya, 59100 Kuala Lumpur, Malaysia*

CARDIOPULMONARY BYPASS FOR AMNIOTIC EMBOLISM - CASE REPORT

Darrell A. Woodman*

A 27-year-old female developed complete cardiac arrest, two hours post-op for caesarian section. After one hour of CPR, the patient was taken to the operating room and placed on total bypass. Because of DIC and brisk hemmorrhage from the uterus, a TAH was also performed. Large amounts of friable tissue and thrombus were retrieved from the left pulmonary artery. The patient was weaned from bypass, and discharged from the hospital 13 days later. This presentation will discuss this very interesting case, and will review the literature on amniotic fluid embolism.

**1764 Summernight Terrace, Colorado Springs, CO 80909*

EVALUATION OF HEAT EXCHANGERS

R. Barthelemy*, N. Chauveau, J.P. Morucci

An acute and simple way to use a bench test has been achieved in order to evaluate and to compare heat exchangers used in extra-corporeal circulation for cardiac surgery.

With this technique, we have tested about 30 different heat exchangers. The results show that in the normal range of work (which is from 4-6 liters/mn in adults), the performances of all these exchangers are very different and are more efficient than those of the previous generation.

We have now an easy to use bench test with a quick procedure and good reproductibility. This permits us to choose the best heat exchanger on the market.

CHR Rangueil, Experimental Surgery, Avenue Jean Poulhes, 31054 Toulouse, France

IN-VITRO COMPARISON TESTS OF FIVE LEFT-VENTRICLE SUCTION CONTROL VALVES

George C. Siposs*

Many surgical teams employ a suction pump to decompress the left ventricle. The problems associated with this venting technique relate to safety and convenience. If the pump is accidentally reversed in the vent line, massive air embolism may occur. If the cannula is occluded, pump speed has to be juggled to prevent the line from collapsing and sucking air into the heart around the purse-string suture. We have in-vitro tested five vent valves from various manufacturers (RLV-2100 "B", LV-100, H-130, GLV and VRV-200 "B") which were designed to: (a) regulate suction in the vent line, (b) prevent flow towards the heart and (c) vent downstream pressure to the atmosphere. The valves were tested at various flow rates for suction and pressure pop-off settings, using a roller pump and U-tube mercury manometers. The results of the pressure and suction tests are tabulated and graphed. We found that the H-130 has an unnecessarily high suction relief setting. The LV-100, GLV and VRV-200 "B" valves leaked even under minimal pressure heads. The RLV-200 "B" was the only valve that combined optimal suction relief setting with no leakage under normal venting conditions.

2930-G Grace Lane, Costa Mesa, CA 92626