**1998 Abstracts Table of Contents**

**98/001**: TRANSPORT CHARACTERISTICS OF LOW-MOLECULAR-WEIGHT SOLUTES IN CONTINUOUS RENAL REPLACEMENT THERAPY USING A FRESENIUS F80 DIALYZER  
M. Stoltz, E. Baugh, B. Aleman

**98/002**: THERMAL ENERGY BALANCE DURING CONTINUOUS VENOVENOUS HEMOFILTRATION  
M. Manns, E. Maurer, H.G. Evering

**98/003**: PROSPECTIVE ANALYSIS OF DIALYSATE AND ULTRAFLTRATE PUMP ACCURACY DURING CONTINUOUS HEMOFILTRATION (CH)  
William E. Smoyer, John J. Gardner, Timothy E. Bunchman

**98/004**: DECREASING EXTRACORPOREAL BLOOD VOLUME IN PEDIATRIC PATIENTS BY USING MODIFIED HEMODIALYSIS LINES FOR CONTINUOUS VENOVENOUS HEMOFILTRATION  
G.M. Schwab, M.J. Gregory

**98/005**: REGIONAL ANTICOAGULATION USING TRISODIUM CITRATE FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION IN CRITICALLY ILL ADULTS  
W. Griswold, V. Reznik, J. Lemire, N. Benador, D. McDonald, R.L. Mehta

**98/006**: REGIONAL CITRATE ANTICOAGULATION FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION IN CRITICALLY ILL CHILDREN WITH ACUTE RENAL FAILURE  
W. Griswold, V. Reznik, J. Lemire, N. Benador, D. McDonald, R.L. Mehta

**98/007**: BENEFITS OF A BICARBONATE BUFFERED HEMOFILTRATION (HF) SOLUTION IN CVVH-TREATED ARF PATIENTS  
Werner Riegel, Steffen Uthoff, Jutta Passlick-Deetjen

Blood Purification 1998; 16:100-118
98/008: A PROSPECTIVE, RANDOMIZED, CONTROLLED CROSSOVER STUDY OF THE EFFECT OF HEPARIN-BONDED FILTERS ON FILTER LIFE AND PERFORMANCE DURING CONTINUOUS VENOVENOUS HEMOFILTRATION (CCVH)
W. Silvester, I. Baldwin, N. Bridge

98/009: REGIONAL CITRATE ANTICOAGULATION FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION IN A 2.6-KG NEONATE
Sharon Sandell, Daniel McKenney, Cathy Price, Lou Anne Baldree

98/010: QT C INTERVALS DO NOT ACCURATELY REFLECT IONIZED CALCIUM LEVELS DURING CONTINUOUS RENAL REPLACEMENT THERAPY PERFORMED WITH CITRATE ANTICOAGULATION
M.J. Barchman, S. Daughtery, C. Price, P. Bolin

98/011: THE MANAGEMENT OF RENAL REPLACEMENT THERAPY IN VICTORIA
L. Cole¹, B. Silvester¹, R. Bellomo¹, J. Reeves²

98/012: ACUTE RENAL FAILURE IN NEPHROLOGY ICU – A PAKISTANI PERSPECTIVE
I. Yazdani

98/013: A NEW APPROACH TO REGIONAL HEPARINIZATION: DESIGN AND DEVELOPMENT OF A NOVEL IMMOBILIZED HEPARINASE DEVICE
Guillermo A. Ameer, Ram Sasisekharan, Charles Cooney, William Harmon, Robert Langer

98/014: EFFECT OF HEMOADSORPTION AND CONTINUOUS HEMODIAFILTRATION FOR SEPTIC SHOCK PATIENTS

98/015: CONTINUOUS RECIRCULATION PERITONEAL DIAFILTRATION (CRPD): BLOODLESS CRRT
R. Amerling, N.S. Caraiani, R. Drazenovic
98/016: ASCITIC FLUID REINFUSION VERSUS LARGE VOLUME PARACENTESIS IN CIRRHOTIC REFRACTORY ASCITES: A CASE REPORT
E.R. Maccariello¹, S.E. Sonbol¹, J. Jurschak¹, R.L. Mehta¹

98/017: UREA NITROGEN APPEARANCE AND CREATININE PRODUCTION DURING CONTINUOUS RENAL REPLACEMENT THERAPY: ESTIMATION OF PROTEIN CATABOLISM IN CRITICAL ILLNESS
M. Leblanc¹,², L.J. Garred¹, J. Cardinal¹, V. Pichette¹, L. Nolin¹, D. Geada², D. Ouimet¹

98/018: DEFINING THE OPTIMAL OPERATING CONDITIONS FOR HIGH-VOLUME HEMOFILTRATION IN HUMANS
L. Cole, R. Bellomo

98/019: UREA AND CREATININE KINETIC MODELING IN ACUTE RENAL FAILURE PATIENTS TREATED ON THE PRISMA CONTINUOUS RENAL REPLACEMENT THERAPY SYSTEM
L.J. Garred¹, B. Simmons¹, D.C. Mendelssohn¹, J.A. Wong², M. Leblanc³

98/020: PROSPECTIVE ANALYSIS OF AMINO ACID AND PROTEIN BALANCE WITH STANDARD PARENTERAL NUTRITION DURING PEDIATRIC CONTINUOUS HEMOFILTRATION
Norma J. Maxvold, William E. Smoyer, Joseph R. Custer, Timothy E. Bunchman

98/021: EFFECTS OF FILTER PORE SIZE ON EFFICACY OF CONTINUOUS ARTERIOVENOUS HEMOFILTRATION THERAPY IN IMPROVING MORBIDITY AND MORTALITY IN AN IMMATURE SWINE MODEL OF STAPHYLOCOCCUS AUREUS-INDUCED SEPSIS
Patrice A. Lee, Robert W. Pryor, James R. Matson

98/022: A RANDOMIZED, PROSPECTIVE, CROSSESOVER STUDY OF THE HEMODYNAMIC EFFECTS OF HIGH-VOLUME HEMOFILTRATION IN PATIENTS WITH SEPTIC SHOCK
L. Cole, R. Bellomo, I. Baldwin
98/023: EVALUATION OF PREDICTORS OF MORTALITY IN CHILDREN TREATED WITH CONTINUOUS VENOVENOUS HEMOFILTRATION
D. Gipson, N. McAfee, R. McDonald

98/024: PROGNOSTIC INDEXES OF PATIENTS WITH SIRS AND MODS ON CRRT
G. Splendiani1, D. Zazzaro1, V. Mazzarella2, S. Pennacchia1, L. Delfino1, C.U. Casciani1

98/025: CONTINUOUS VENO TO VENOUS HEMOFILTRATION: ARE YOU TREATING THE PUMP OR THE PATIENT
Maureen Craig, Dawn Vierria

98/026: A CREATIVE STRATEGY FOR CONTINUOUS RENAL REPLACEMENT THERAPY EDUCATION
Deborah Schulz, Wendy Whalley

98/027: PEDIATRIC HEMOFILTRATION NURSING EDUCATION: A COOPERATIVE EFFORT BETWEEN DIALYSIS AND INTENSIVE CARE
John J. Gardner, Theresa A. Mottes, Norma J. Maxvold, Timothy E. Bunchman

98/028: CONTINUOUS RENAL REPLACEMENT THERAPY DEALING WITH FAMILY REACTIONS: A HERMENEUTIC APPROACH
Hilda L. Carr

98/029: DEVELOPMENT OF A PROTOCOL FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION USING REGIONAL ANTICOAGULATION WITH TRISODIUM CITRATE IN CRITICALLY ILL ADULTS
B.J. Anderson, R.T.N. Gibney, T. Fox, J. Westby, P. Bradbury, D. Stollery, B. Litwinowich;

98/030: HIGH-VOLUME HEMOFILTRATION FOR SEPTIC SHOCK (6 L/HOUR U.F.): NURSING CARE AND MANAGEMENT
Ian Baldwin, Peter Gleeson, Therese Kissane, Rinaldo Bellomo
98/031: PRACTICAL ASPECTS OF USING TRISODIUM CITRATE FOR ANTICOAGULATION IN PEDIATRIC CONTINUOUS VENOVENOUS HEMODIALFILTRATION (CVVHD)
Dina McDonald1,2, Mary McCulley2

98/032: EFFECT OF HEMODIALYSIS TREATMENT FOR ACUTE RENAL FAILURE CAUSED BY OPERATION
Hui Liu, Yun-kai Bai, Hua Xiao

98/033: HEPARIN REMOVAL FROM WHOLE BLOOD FOR DIALYSIS
Peter Grandics, Peter Miko, Susan Szathmary, Edit Hegyi

98/034: ON-LINE PRODUCTION OF ENDOTOXIN-FREE, ULTRA-PURE WATER FOR DIALYSIS
Peter Grandics, Bryce Dodson, Susan Szathmary, Edit Hegyi
98/001: TRANSPORT CHARACTERISTICS OF LOW-MOLECULAR-WEIGHT SOLUTES IN CONTINUOUS RENAL REPLACEMENT THERAPY USING A FRESENIUS F80 DIALYZER

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Outcome studies evaluating in vivo CRRT filter clearance and transport data are limited. The purpose of this study was to determine small-molecular-weight clearances using a hospital dialysis unit’s standard high-performance dialyzer for sequential continuous venovenous hemofiltration (CVVH) and continuous venovenous hemodialysis (CVVHD). The study measured the clearance of low-molecular-weight solutes at various blood flow rates (BFR), ultrafiltration rates (UFR), and dialysis flow rates (DFR) using a Fresenius F80 dialyzer. A modified clamped Hansen connector on the inflow dialysis port allowed the F80 to be used for continuous venovenous hemofiltration (CVVH). Standard Hansen connectors and Travenol Hemodiafiltration fluid perfusion allowed the F80 to be used for continuous venovenous hemodialysis (CVCHD) and continuous venovenous hemodiafiltration (CVVHDF). The Hospal BSM 22sc CRRT device was calibrated manually prior to study periods. Filtration fractions (FF), clearances, and mean transport rates (MTR) were calculated from measured serum, ultrafiltrate, and dialysis fluid concentrations of urea, creatinine, phosphate, and urate at different BFRs (100, 150, 225), UFR (1,000, 2,000), DFR (1,000, 1,500, 2,000), and combined UFR and DFR (400/1,500) ml/min.
The study demonstrates that (1) calculated in vivo filtration fractions differ from I for the various low-molecular-weight solutes; (2) clearances using this device are adequate for current treatment goals, and (3) the F80 could be converted sequentially from CVVH to CVVHD without filter change to increase low-molecular-weight solute clearance.

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98/002: THERMAL ENERGY BALANCE DURING CONTINUOUS VENOVENOUS HEMOFILTRATION

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Hypothermia has been recognized with an incidence of 2–50% as a potential side effect of continuous hemofiltration, but the heat and energy loss within the extracorporeal circuit has not yet been exactly quantified. The purpose of this study was to quantify the heat and energy loss during continuous venovenous hemofiltration.

The extracorporeal circuit of the Acu-Men (Fresenius Medical Care, Bad Homburg, Germany) was used for the thermodynamic measurements. The device utilizes a pneumatic blood pump to drive the blood through the circuit. The pump works in two cycles. At the first cycle, a negative pressure is generated, which fills the pump with blood. The positive pressure of the next cycle drives the blood through the filter and back to the patient. As blood passes through the filter, filtrate is produced and runs into the volumetric balancing chamber. The balancing chamber has a volume of 5 ml and consists of two chambers, separated by a nonpermeable silicone membrane. 5 ml replacement fluid run in the negative pressure cycle into the balancing chamber and press the silicone membrane towards the opposite (left) wall. This in turn pushes 5 ml filtrate into the waste bag. 5 ml filtrate fill the balancing chamber completely in the subsequent positive pressure cycle and press the membrane against the other (right) wall. This pushes 5 ml replacement fluid to the venous line. All temperature measurements were done with temperature sensors from Linear Thermistor Networks (DELTA Regeltechnik, Munich, Germany) and with sterile water (AMPUWA, Fresenius AG, Bad Homburg, Germany), which was used as blood and as replacement fluid. The figure shows the temperature measurements at different points within the extracorporeal circuit at a blood flow of 120 ml/min, a filtrate volume of 1.4 liter/h and replacement fluid temperature of 2°C.

Temperature declined from the beginning to the end of the extracorporeal circuit from 37.0 to 32.0°C. Twenty-six percent of the heat was lost through the blood tubing, 31% through the surface of the hemofilter and 43% through the filtrate and subsequent mixing of blood with replacement fluid. Heat was transmitted within the volumetric balancing chamber from the ‘warm’ filtrate to the ‘cool’ replacement fluid. The observed temperature decline corresponds to a daily energy loss of roughly 3,300 kJ. Because of the positive heat exchange within the balancing chamber, the negative energy balance increases in devices without volumetric balancing to approximately 3,900 kJ/day. If one adjusts for the different mass and heat capacity of blood compared to AMPUWA, the daily in vivo energy loss amounts to 4,100 kJ/1,000 kcal. Heating of replacement fluid to 30, 37 or 40°C reduced the energy loss by 24, 52 and 79%.
98/003: PROSPECTIVE ANALYSIS OF DIALYSATE AND ULTRAFILTRATE PUMP ACCURACY DURING CONTINUOUS HEMOFILTRATION (CH)

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Inaccuracy of dialysate and ultrafiltrate pumps during CH is far more critical during pediatric CH than during CH in adults. Pump errors within the industry standards of 5–10% of the set rate have resulted in the induction of life-threatening volume depletion in several small children and infants within 4–6 h. In an initial effort to determine the in vivo accuracy of dialysate and ultrafiltrate pumps for CH we are prospectively analyzing commercially available drip chamber and volumetric pumps during use with both dialysate and ultrafiltrate. Thus far we have analyzed pump accuracy in 1 drip chamber (IVAC, model 560A) and 1 volumetric (Ivion; Trilogy) pump in a single pediatric patient receiving CVVHD with a blood flow rate of 4 cm³/kg/min. Two data sets were collected during 15 sequential hourly collection periods on each of 2 sequential days under the following conditions: (1) A drip chamber pump infusing countercurrent dialysate (800 cm³/h) with a volumetric pump removing ultrafiltrate to maintain patient fluid balance, and (2) a volumetric pump infusing countercurrent dialysate (800 cm³/h) with an identical volumetric pump removing ultrafiltrate to maintain patient fluid balance. Dialysate and ultrafiltrate flow rates were measured in an identical manner at each hourly time point using an infant scale accurate to within +/-0.5 ml. During the first data collection period with the drip chamber pump set to infuse dialysate at 800 cm³/h the measured infusion rate was 772 +/-24 cm³/h (-3.5% error) while the volumetric ultrafiltrate pump set rate was 869 +/-17 cm³/h (+3.3%) and the measured rate 898 +/-13 cm³/h (+3.3%).

This yielded a total error rate of 6.8%, resulting in 57 cm³/h more fluid removed from the patient than was ordered. During the second data collection period with the volumetric pump set to infuse dialysate at 800 cm³/h the measured infusion rate was 780 +/-12 -2.5% error) while an identical volumetric ultrafiltrate pump set rate was 874 +/-15 cm³/h and the measured rate 898 +/-14 cm³/h (+2.7%). This yielded a total error rate of 5.2%, resulting in 44 cm³/h more fluid removed from the patient than was ordered. These preliminary findings suggest that under the above in vivo conditions: (1) both the drip chamber and volumetric pumps tested have similar error rates and result in underinfusion of fluid when used to infuse countercurrent dialysate; (2) the volumetric pump tested consistently results in excess fluid removal when used to remove ultrafiltrate, and (3) the combination of these additive effects can result in clinically significant unanticipated fluid removal and potential hemodynamic instability in pediatric patients during CH.
98/004: DECREASING EXTRACORPOREAL BLOOD VOLUME IN PEDIATRIC PATIENTS BY USING MODIFIED HEMODIALYSIS LINES FOR CONTINUOUS VENOVENOUS HEMOFILTRATION

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Strong Memorial Hospital, University of Rochester, NY, USA

Currently available CVVH systems use standard tubings with typical priming volumes of 100 ml without the hemofilter, which, in turn, can add an additional 33–75 ml. This high priming volume means extracorporeal blood volumes exceeding 10% of total blood volume in children under 15 kg, which can create hemodynamic instability if used without blood priming or require increased heparin use if used with blood priming. We have successfully used modified pediatric hemodialysis tubing on the Hospal BSM-22 hemofiltration machine (Cobe, Lakewood, Calif., USA) to decrease tubing priming volume to 45 ml and to prevent the need for blood priming and/or increased patient anticoagulation.

Two factors prevent the use of 5.0-mm pediatric HD tubing on the BSM-22: (1) the smaller tube diameter prevents arterial pressure monitoring and (2) the smaller venous drip chamber cannot be inserted into the CVVH air detector. The addition of two new parts, both created from standard 6.5-mm adult HD tubing, can overcome these issues. A 1-inch piece cut from the blood pump segment of adult arterial HD tubing and slit lengthwise is placed over the pump segment of the pediatric HD tubing to increase the diameter of the tubing segment at the arterial pillow monitor enough to measure arterial pressure. The second piece is made by cutting a 1-inch segment from a standard adult HD venous drip chamber to make a ring. A 1-inch segment is then cut from the ring to make a semicircle. This semicircle is aligned with the venous drip chamber in the pediatric lines and both are inserted into the air detector so that the semicircle covers one side of the ultrasonic sensor. Both of these parts are reusable and do not need to be sterile. Dialysate adaptors (model F48, Haemotronic, Inc., Fairfield, N.J., USA) allow the Luer-lock connectors of the HD tubing to be connected to the hemofilter ports.
Because changing the diameter of the tubing changes the actual blood flow rate obtained at a given pump speed, the actual blood flow rate for a given pump speed was measured using normal saline instead of blood, which was collected from the venous port over a 3-min interval. The volume collected was measured in a graduated cylinder and the actual blood flow rate calculated using the formula $V/t = \text{blood flow rate}$, where $V$ is the volume of saline collected in ml and $t$ is the length of collection time in minutes. Measurements were made from a single tubing set with a minimum of six collections per given pump speed. Results are shown in the figure.

This modified set-up has been successfully used in 2 patients, both weighing under 10 kg. It allows improved delivery of CVVH and CVVH-D to children, with decreased risk of hemodynamic instability, decreased need for blood products for priming, and decreased need for anticoagulation. As this technique is used more frequently in pediatrics, attention will need to be directed towards the development of equipment specific for the variable sizes of pediatric patients.
98/005: REGIONAL ANTICOAGULATION USING TRISODIUM CITRATE FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION IN CRITICALLY ILL ADULTS

B.J. Anderson, R.T.N. Gibney, J. Westby, P. Bradbury, T. Fox, D.E. Stollery, M.A. Meier; Regional Critical Care Program, Capital Health, and Division of Critical Care Medicine, University of Alberta, Edmonton, Alta., Canada

Background and Purpose: Many critically ill patients cannot tolerate conventional anticoagulant with heparin due to ongoing hemorrhage, severe coagulopathy or heparin-induced thrombocytopenia and thrombosis (HITT). In these patients, cit-rate is an alternative regional anticoagulant that produces an effect by chelating calcium and reducing the availability of ionized calcium for use in the clotting cascade. The purpose of this study is to describe the technique for using citrate as a regional anticoagulant for CVVHDF, and identify the efficacy, side effects and complications associated with 4% trisodium citrate regional anticoagulation therapy.

Methods: Five mechanically ventilated critically ill adults who underwent CVVHDF therapy using the Hospal Gambro PRISMA System received 4% sodium citrate regional anticoagulant titrated to maintain activated clotting times (ACT) of 150–220 s with a blood flow rate of 125 ml/min. A calcium chloride infusion was titrated to maintain patient ionized calcium levels. Low sodium dialysate and calcium-free hemofiltration fluids were administered. Age, indication and duration of CVVHDF, citrate and calcium chloride infusion rates, ACT and filter life were recorded prospectively. Platelet count, coagulation times, serum sodium, ionized calcium, carbon dioxide, and hydrogen ion were monitored throughout the CVVHDF therapy. Patients were monitored for complications of trisodium citrate regional anticoagulation therapy.

Results: 375 h of citrate regional anticoagulation were completed in 5 critically ill adults with multisystem organ failure, 1 of whom had HIT. 4% trisodium citrate ad-ministered at a rate of 170–250 ml/h maintained ACT in the range of 140–250 s and PRISMA filters for up to 84 h. Calcium chloride 0.8% infusion at a rate of 40–140 ml/h was required to maintain serum ionized calcium levels in normal range. Hypernatremia developed in 2 patients and responded to a change in the replacement fluid composition in 1 case and was transient in the other. Moderate metabolic alkalosis developed in 1 patient. PTT and platelet abnormalities common in patients receiving systemic heparin anticoagulation were not seen. No bleeding, dysrhythmias, or signs and symptoms of hypocalcemia were observed.

Conclusions: 4% trisodium citrate provided effective regional anticoagulation of the extracorporeal CVVHDF circuit of the Hospal Gamburgo PRISMA system in 5 mechanically ventilated critically ill adults. Regional anticoagulation with 4% trisodium citrate is a safe alternative to systemic anticoagulation for critically ill adults requiring CVVHDF therapy.
98/006: REGIONAL CITRATE ANTICOAGULATION FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION IN CRITICALLY ILL CHILDREN WITH ACUTE RENAL FAILURE

W. Griswold, V. Reznik, J. Lemire, N. Benador, D. McDonald, R.L. Mehta
University of California at San Diego and Children’s Hospital of San Diego, CA, USA

Introduction: Continuous renal replacement therapy (CRRT) is an important advance for the treatment of critically ill patients. A major problem with CRRT is the need for systemic anticoagulation with heparin. Recently we have adapted a new form of regional citrate anticoagulation for children requiring CRRT. This procedure uses continuous venovenous hemodiafiltration (CVVHDF). Anticoagulation is achieved in the extracorporeal circuit by infusing citrate directly into the blood as it leaves the patient. Citrate acts as an anticoagulant in the extracorporeal circuit by chelating calcium. The effect of citrate is reversed in the patient’s circulation by infusing calcium chloride, so that the patient’s coagulation system is unaffected by the procedure.

Methods: Twenty children received CVVHDF using regional citrate anticoagulation. All patients had acute renal failure. The age of the patients ranged from 1 to 18 years. CVVHDF was performed with a Hospal Multiflow-60 hemofilter and a Cobe-Hospal BSM-22 machine. Four percent trisodium citrate was infused into the blood as it left the patient; the infusion rate was adjusted to keep the post filter activated clotting time between 180 and 220 s. The patient’s ionized calcium level was maintained in the normal range with a separate infusion of calcium chloride. A special dialysate was used to remove the calcium-citrate chelate and to offset the sodium given as trisodium citrate. The composition of the dialysate was sodium 117 mEq/l, magnesium 1.5 mEq/l, potassium 4 mEq/l, chloride 122.5 mEq/l and glucose 25 g/l. Blood flow was 150 ml/min/1.7 m².

Results: Mean patient partial thromboplastin time (PTT) was 31.8 s (normal 25–35) indicating that the patients were not systematically anticoagulated by the procedure. Average patient serum ionized calcium was 1.19 mmol/l (normal 1.09–1.32). Mean hemofilter life was 3.5 days, including elective changes. Mean dialyzer sieving coefficient was well maintained at 0.96. Ultrafiltration rate for the CVVHDF was 14 ml/min/1.7 m². Mean urea clearance was 36 ml/min/1.7 m². During the CRRT the mean patient pH was 7.38 and base excess 0.22.

Conclusions: Continuous venovenous hemodiafiltration can be performed in children with citrate anticoagulation. Citrate anticoagulation does not affect the patient’s clotting system.
98/007: BENEFITS OF A BICARBONATE BUFFERED HEMOFILTRATION (HF) SOLUTION IN CVVH-TREATED ARF PATIENTS

Werner Riegel, Steffen Uthoff, Jutta Passlick-Deetjen
*The Multicenter Study Group; University of Saarland, Homburg/Saar; Fresenius Medical Care, Oberursel, Germany*

To investigate the effects of a new bicarbonate-based HF solution a prospective randomized multicenter study was performed. 117 acute renal failure (ARF) patients treated with postdilutional CVVH were randomized in two groups. Group I (n = 61) received the 35-mmol/l bicarbonate-buffered solution (BIC), group II (n = 56) a conventional 34-mmol/l lactate-buffered solution (LAC). An additional 23 patients (group III) suffering from ARF and lactic acidosis (lactate >5 mmol/l, pH <7.3) were treated with BIC.

Results: CVVH treatment with the bicarbonate-buffered HF solution resulted in significant higher serum bicarbonate level 23.7 +/-0.5 (BIC, group I), vs. 21.8 +/-0.6 (LAC, group II) p <0.007 as well as significant higher base excess and lower lactate levels. In spite of these positive laboratory results, no clinical benefit was evident. In contrast, in patients with lactic acidosis (group III) the bicarbonate-based CVVH increased serum bicarbonate level from initially 18.5 +/-1.5 to 23.4 +/-0.8 mmol/l. This was accompanied by a rise of mean arterial blood pressure (MAP) from 75 +/-4 to 80 ±3 mm Hg. The same was true when patients with liver affection (GPT >50 U/l) were analyzed in both groups I and II. MAP was higher in bicarbonate- vs. lactate-treated patients: 84 +/-3 (BIC) vs.7+/-2 (LAC) mm Hg. In conclusion, the bicarbonate-buffered solution is an effective tool to correct acidosis in ARF patients. Positive hemodynamic effects are seen in patients with lactic acidosis or compromised liver function.
98/008: A PROSPECTIVE, RANDOMIZED, CONTROLLED CROSSOVER STUDY OF THE EFFECT OF HEPARIN-BONDED FILTERS ON FILTER LIFE AND PERFORMANCE DURING CONTINUOUS VENOVENOUS HEMOFILTRATION (CCVH)

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Premature hemofilter clotting continues to be a significant problem with continuous renal replacement therapy in patients at risk of bleeding from systemic anticoagulation. Preliminary results suggest that the heparin-bonded polysulfone membrane filter, Duraflo II (Baxter Healthcare, USA), has a superior lifespan when compared to the non-heparin-bonded membrane, Renaflo II (Baxter Healthcare). This study was done to confirm the benefits of the Duraflo II in a controlled study within ICU.

Patients requiring CVVH were treated using the Baxter BM 25 (11/14) blood pump. Vascular access was achieved with the use of a double lumen Bard Vascath Niagara catheter (CR Bard, Ont., Canada) in either the right internal jugular or femoral vein. Following informed consent, patients were randomized to the use of either the Duraflo II or the Renaflo II filter then crossed over to the opposite filter. Heparin was infused at 300 units/h prefilter. Filter life, filter efficiency, platelet count and markers of coagulation and platelet activation were measured. 30 paired crossover hemofiltration episodes were conducted in 15 patients with demonstration of a significantly longer lifespan with the Duraflo II filter, irrespective of underlying patient coagulation status. Heparin-bonded hemofilters are superior in lifespan and maintenance of filter efficiency when compared with non-heparin-bonded filters.
98/009: REGIONAL CITRATE ANTICOAGULATION FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION IN A 2.6-KG NEONATE

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Continuous venovenous hemodiafiltration (CVVHD) using heparin anticoagulation has been established as an effective therapeutic modality in infants with multiorgan system failure (MOSF) and hemodynamic instability. We describe successful use of sodium citrate (NaCit) anticoagulation for CVVHD in a 2.6-kg neonate. Baby R was born at 37 weeks’ gestation by vacuum extraction at an outlying institution. Birth weight was 2.635 kg. At 2 h of age the baby was lethargic with circulatory shock. An arterial blood gas at 6 h of age revealed pH 6.59, PaCO₂ 13 mm Hg, PaO₂ 98 mm Hg, CO₂ 1.2 mmol/l. Volume resuscitation and pressor support were initiated; mean arterial pressure remained below 40 mm Hg. He was transferred to our institution at 8 h of age with a diagnosis of massive subgaleal hemorrhage. By 48 h of age, despite transfusion of 320 cm³/kg of blood products and high-dose dopamine and epinephrine, Baby R had MOSF with a serum lactate of 30 mEq/l. CVVHD was initiated using an 8-Fr umbilical venous catheter and a 5-Fr femoral venous catheter.

In the face of disseminated intravascular coagulation necessitating multiple daily transfusions of packed red blood cells, platelets, cryoprecipitate and fresh frozen plasma, no circuit anticoagulation was necessary for the fist 6 of 20 total days of CVVHD. On day 7, recurrent circuit clotting was noted; prefilter fluid administration failed to eliminate circuit clotting. Systemic heparinization was contraindicated because of ongoing coagulopathy and risk of intracranial hemorrhage.

Regional anticoagulation using prefilter NaCit infusion was initiated at 1.2 g/h. Rapid increase in NaCit dose to 2.4 g/h was necessary to achieve an activated clotting time (ACT) of 180–220 s. Over the next 13 days of CVVHD using NaCit anticoagulation, NaCit dose ranged from 0.6 to 4.6 g/h. CaCl infusion rate ranged from 20 to 520 mg/h to maintain an ionized calcium of 4.0 mg/dl. No prefilter fluids were used for 8 of the 13 days of NaCit therapy; no postfilter fluids were used during this time.

From the second through the ninth days of NaCit anticoagulation, intermittent intravenous and enteral administration of ammonium chloride (NH₄Cl) was used to control metabolic alkalosis. Maximum serum ammonia was 65 mmol/l. NaCit and blood products provided as much as 48 mEq (11 mEq/kg) per hour of sodium. Serum sodium and base excess were maximal on day 6 of citrate anticoagulation. At that time, the blood flow rate was decreased by 30%, allowing a 58% decrease in the NaCit infusion rate and a 45% decrease in the CaCl infusion rate, with prompt normalization of serum sodium and base excess. Peritoneal dialysis (PD) was initiated on day 11 of CVVHD; efficacy was initially limited by leakage of dialysate at the catheter insertion site. By day 20, PD was working adequately, and CVVHD was discontinued. Baby R was transferred to the pediatric ward on PD at 47 days of age. He was alert and interactive, hemodynamically stable, and required no supplemental oxygen.

We believe this to be the smallest infant in whom regional NaCit anticoagulation for CVVHD has been reported. The doses of NaCit necessary to achieve regional anti-coagulation in this newborn were
equivalent to those recommended for 10- to 30-kg children (2.4–4.0 g/h) in a reference protocol provided by another institution. The dose of NaCit needed to maintain the desired ACT decreased as the blood flow rate was decreased. The expected metabolic alkalosis was acceptably managed with intermittent NH₄Cl administration. Despite infusion of up to 265 mEq/kg/day of sodium from NaCit and blood products, hypernatremia was not a significant management problem (maximum serum Na 161 mEq/l). Regional NaCit anticoagulation appears to be a safe and effective alternative to systemic heparin for CVVHD in neonates.
98/010: QT C INTERVALS DO NOT ACCURATELY REFLECT IONIZED CALCIUM LEVELS DURING CONTINUOUS RENAL REPLACEMENT THERAPY PERFORMED WITH CITRATE ANTI COAGULATION

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As we have reported previously, total calcium levels are inaccurate measures of physiologically available calcium. Ionized calcium levels provide a more accurate estimate of free calcium but nonspecific ionic interactions are known to occur. These interactions may further reduce free calcium such that measured ionized calcium levels overestimate physiologically available calcium. Because a direct relationship between QT C intervals and free calcium levels has been shown in normal subjects, we hypothesized that QT C intervals might provide a more physiologic assessment of available calcium. The number of blood draws and lab tests might also be significantly reduced if a reliable bedside technique for assessing calcium were available.

We also assessed the lower limit of ionized calcium levels where QT C is adequately preserved since metabolic alkalosis is a known complication of citrate anticoagulation. We postulated that less citrate might be required for adequate anticoagulation if ionized calcium levels could safely be maintained at lower levels. Thirty-six patients receiving CRRT with citrate anticoagulation were evaluated sequentially. A rhythm strip was generated every 4 h at the time of each ionized calcium determination. QT intervals were measured by a single observer and QT C calculated by the formula:

\[ QT_C = \frac{QT_{measured}}{\sqrt{RR}} \]  

with normal values being 0.3–0.46 s. Correlation was then assessed in each patient as well as in the group (420 total observations). The best predictive correlation between QT C and ionized calcium was observed in the first 24 h of therapy in the pooled data with Pearson correlation coefficients ranging from 0.0043 at 4 h (first time interval) to 0.0484 at 24 h (sixth time interval). Beyond this time, no significant correlation was seen (coefficients 0.15–0.918). When patient data was assessed individually, good correlation was observed in several patients but was poor in the vast majority. Not surprisingly, there was significant overlap between each category of ionized calcium levels in both the normal QT C interval group and the prolonged QT interval group. Therefore, we were not able to demonstrate the safety to lower than normal ionized calcium levels.

In conclusion, QT C may be a helpful indicator of adequate ionized calcium levels in individual patients, but it is not generalizable to the entire CRRT population. Based on our data, we cannot recommend maintenance of lower ionized calcium levels to minimize citrate requirements for anticoagulation.
98/011: THE MANAGEMENT OF RENAL REPLACEMENT THERAPY IN VICTORIA

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Aim: To describe the utilization of renal replacement therapy (RRT) for critical illness in Australia.

Method: A prospective survey of all patients admitted to all intensive care units (ICU) in Victoria (population 5 million) during a 3-month period, September–November 1996.

Results: 125 patients received RRT, and 117 of these received the RRT for acute renal failure. All the episodes were primarily managed by the medical and nursing ICU staff, and a nephrologist was consulted in 30% of cases. The RRT population had a median age of 66 years, 60% male gender, a mean APACHE II score of 26.9 +/- 1.4 (95% confidence intervals), and a mean SAPS II score of 57.9 +/- 2.9%. Sepsis was the primary reason for admission to the ICU in almost half the cases, and subsequently the major etiological factor for the acute renal failure. In the 24 h preceding RRT, 65% had systemic inflammatory response syndrome, 77.6% were receiving mechanical ventilation, and 79.2% were inotrope-dependent. 40.8% received continuous venovenous hemofiltration (CVVH) and 54.4% received continuous venovenous hemodiafiltration (CVVHDF) as the primary technique. Most patients were commenced on RRT within 3 days of ICU admission, predominantly for fluid management.

The overall complication rate was low, and included severe hypotension (11.2%), bleeding requiring transfusion (4.8%), need for increased inotropes (4.8%) and cardiac arrest (0.8%). ICU mortality was 43% with an in-hospital mortality of 51.2%. The SAPS II predicted mortality was 58.5% (95% CI 54.0–63.0), which gave a standardized mortality ratio of 87.5 for this sample of patients. Of the 61 patients that survived to hospital discharge, 16 required ongoing intermittent hemodialysis (12.8% of the total sample).

Conclusions: The most common cause for acute renal failure in Australian ICUs is sepsis, or septic shock, in the setting of multiorgan failure. All RRT is managed by ICU staff, with few complications. Hospital mortality is less than that predicted by SAPS II.
98/012: ACUTE RENAL FAILURE IN NEPHROLOGY ICU – A PAKISTANI PERSPECTIVE

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Development of acute renal failure (ARF) in the ICU is associated with a significantly increased risk of death which has remained unchanged for years. It is unclear whether this increased mortality is the result of a unique contribution from ARF or due to patients’ overall poor medical condition. Outcome comparison between patients with ARF who were treated conservatively and those who were dialyzed are lacking. In our 4-year follow-up series, out of 7,481 patients who were admitted, 823 had ARF. 55% were cases of medical pathology, 42% surgical and 3% were pregnancy-related. ARF due to pregnancy-related causes is still a unique phenomenon related to the developing countries. In our series we had cases of post-partum haemorrhage, septicemia/DIC and septic abortion. Morbidity and mortality of cases who were treated conservatively and those who were dialyzed will be presented. The role of CRRT in the septicemia-hypotensive patient will be analyzed.
98/013: A NEW APPROACH TO REGIONAL HEPARINIZATION: DESIGN AND DEVELOPMENT OF A NOVEL IMMOBILIZED HEPARINASE DEVICE

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Regional heparinization is a method that has been used to minimize the complications of heparin in acute kidney failure patients. This procedure exposes the patient to very low systemic heparin while allowing adequate anticoagulation in the extra-corporeal circuit to prevent clotting. However, in the United States, the common use of regional heparinization with protamine titration has been limited by the complexity of the procedure and the negative side effects associated with protamine which include: hypotension, vasodilation, pulmonary platelet accumulation and bradycardia. The objective of this research was to investigate whether regional heparinization could be achieved via an immobilized heparinase reactor without the problems associated with protamine titration.

The reactor is based on the activity of heparinase I, an enzyme that degrades heparin into smaller nontoxic fragments. The novel reactor design incorporated Taylor vortices to achieve efficient mixing of whole blood at high flow rates without significant blood damage. Heparinase I was immobilized onto agarose beads via cyanogen bromide activation. There was no detectable leaching of enzymatic activity. The reactor was evaluated for safety and efficacy in vitro with saline, human blood and ex vivo in sheep. The reactor was able to convert 40–50% of the reactor inlet heparin levels, successfully effecting regional heparinization in a sheep animal model with no significant blood damage or side effects. This novel reactor design should facilitate the safe and efficient use of therapeutic enzymes such as heparinase in extracorporeal procedures performed in hospitals.
98/014: EFFECT OF HEMOADSORPTION AND CONTINUOUS HEMODIAFILTRATION FOR SEPTIC SHOCK PATIENTS

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Hemoadsorption and continuous hemodiafiltration (CHDF) have a wide spectrum of effects in, for example, multiple organ failure, intoxication, ARDS, and are known to cause septic shock in the care of critically ill patients.

**Study Objective:** To evaluate the effects of hemoadsorption and CHDF in septic shock patients.

**Methods:** Sixteen patients with septic shock underwent hemoadsorption with a hemoperfusion column of polymixin B (PMX) to adsorb endotoxin. We performed PMX hemoadsorption and PMX hemoadsorption and CHDF jointly in septic shock patients. The effect was then evaluated for these patients. We used the APACHE II score 24 h later after performing PMX hemoadsorption and before performing PMX hemoadsorption and evaluated the scores of both. PMX hemoadsorption was performed in 16 cases diagnosed as having septic shock and performed jointly with CHDF in 7 cases.

**Results:** In 4 of 10 cases, i.e. survival group, we used CHDF jointly after performing PMX hemoadsorption. The APACHE II score in all cases before PMX hemoadsorption was 12–36 points; afterwards it was 6–36 points, and a big difference was not evident. We evaluated the APACHE II score according to survival group and death group. In the survival group the score before PMX hemoadsorption was 12–19 points; afterwards it was 6–12 points. In the death group the score before PMX hemoadsorption was 16–36 points; afterwards it was 30–36 points. A significant improvement was recognized in the survival group.

**Conclusions:** (1) Comparison of the APACHE II score is useful for consequent judgment 24 h after performing PMX hemoadsorption and also before PMX hemoadsorption. (2) The higher probability of survival was suggested by the degree of amelioration according to the APACHE II score as well as CHDF cases of <25% 24 h after performing PMX hemoadsorption and before PMX hemoadsorption.
98/015: CONTINUOUS RECIRCULATION PERITONEAL DIAFILTRATION (CRPD): BLOODLESS CRRT

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Traditional peritoneal dialysis (PD) provides limited solute clearance due to ‘down time’ during in- and outflow, and the constantly decreasing concentration gradients associated with long dwell times. This renders PD inapplicable to most acutely ill, hypercatabolic patients with acute renal failure. Shinaberger, in 1965, proposed externally dialyzing a continuously recirculating stream from an intraperitoneal reservoir.

Using recirculating rates (RR) of 100–300 ml/min he reported urea clearances of 30–80 ml/min in vivo. We attempted to mimic this technique in vitro using spent peritoneal dialysate, drained after 4–6 h dwells, as the ‘patient’. This was recirculated using a dual-lumen catheter through an AN69 hemofilter using a Gambro BSM-22 modified for CVVH. The hemofilter was bathed with standard 1.5% dextrose peritoneal dialysate at 1 or 2 l/h. Creatinine and urea clearances were measured after 20 min with RR of 100, 200 and 300 ml/min, each with the two dialysate flow rates (DFR). Results are as follows:

Except at the 200 ml/min RR, there appears to be no difference in clearance with DFRs of 1 or 2 liters/h. At 300 ml/min, the creatinine and urea clearances are respectable, and would provide 65 liters of clearance over 24 h, or 21 liters over 8 h. High dextrose dialysate maintains the hyperosmolality required for ultrafiltration, which can be precisely regulated with an outflow pump. The dialysate need not be sterile and could readily be generated online. We believe that CRPD may have a role in the acute dialysis of hypercatabolic patients, particularly if blood access or anticoagulation is problematic.
98/016: ASCITIC FLUID REINFUSION VERSUS LARGE VOLUME PARACENTESIS IN CIRRHOTIC REFRACTORY ASCITES: A CASE REPORT

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The management of tense, diuretic-resistant ascites in cirrhotic patients has been a continuous challenge. Although repeated large volume paracentesis (LVP) associated with generous amounts of albumin or plasma replacement is considered safe and effective, it raises some concern regarding (1) the considerable protein loss which could exacerbate cirrhotic cachexia and lead to renal impairment, and (2) the high cost of replacement colloids required to maintain an adequate colloid osmotic pressure to minimize the hemodynamic imbalance. We report a case of a 42-year-old man with end-stage liver disease due to HCV, admitted with refractory ascites, spontaneous bacterial peritonitis (SBP) and mild encephalopathy. During the admission, and after a successful treatment of the SBP and improvement of the encephalopathy with ceftriaxone and lactulose respectively, the patient developed mild pre-renal insufficiency (BUN 82, serum creatinine (SCr) 2.9, FeNa <=1%) which improved temporarily with LVP paracentesis (6 liters over <6 h), and colloid infusion (down to BUN 48; SCr 1.3). In the next 11 days the ascites reformed and he became oliguric, BUN and SCr increased and urinalysis showed a pre-renal pattern of ARF, suggestive of hepatorenal syndrome. He then underwent ascitic fluid reinfusion (AFR) over a period of 42 h with a total ultrafiltration volume of 11,295 ml.
Method: A double lumen catheter was implanted in the right lower quadrant of the abdomen and a CRRT circuit with a Hospal BPM22 pump and a AN69S membrane was used to ultrafiltrate the ascitic fluid, returning the fluid with higher protein concentration to the peritoneal cavity. Results are shown in the table.

The procedure was very well tolerated and no complications occurred. The hemodynamic parameters as well as BUN and SCr did not change. Although plasma albumin decreased, the first value was probably a result of vigorous albumin trans-fusion performed in the previous days. Interestingly, urinary volume improved and no extra amount of colloids was necessary to maintain a stable blood pressure. AFR can be another beneficial tool in the management of tense ascites in cirrhotic patients as a form of liver support. The patient received a cadaveric liver transplant 10 days after the procedure.

<table>
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Note: Alb = Albumin (g/L); UO = urine output (ml); MAP = mean arterial pressure (mm Hg); PAWP = pulmonary arterial wedge pressure; SVRI = systemic vascular resistance; PRBC = pack of red blood cells (units); FFP = fresh frozen plasma (units); AF = ascitic fluid albumin (g/L). Results are mean ± SD.
98/017: UREA NITROGEN APPEARANCE AND CREATININE PRODUCTION DURING CONTINUOUS RENAL REPLACEMENT THERAPY: ESTIMATION OF PROTEIN CATABOLISM IN CRITICAL ILLNESS

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Thirty-eight intensive care unit (ICU) patients (26 men and 12 women; mean age 57.0 +/-16.6 years) with acute renal failure (ARF) treated by venovenous continuous renal replacement therapy (CRRT) were evaluated while in relatively steady metabolic control. Twenty-seven were on continuous venovenous hemodialysis (CVVHD), 9 on continuous venovenous hemodiafiltration (CVVHDF) and 2 on continuous venovenous hemofiltration (CVVH). Periods of analysis varied between 24 and 408 h (mean 82.7 +/-70.6 h; median 72 h). Their mean APACHE II score within 24 h of admission to the ICU was 21.3 +/-6.3 and survival rate 31.6%. Urea nitrogen and creatinine concentrations were determined every 6–12 h in both serum and effluent (spent dialysate and/or ultrafiltrate). The mean effluent rate was 1,472 +/-580 ml/h and blood flow rate, 166 +/-32 ml/min. Urine was collected daily for urea nitrogen and creatinine. Urea nitrogen appearance rate (UnA) and creatinine production rate (Pc), calculated from urea nitrogen and creatinine mass removal (UnMR and CMR, respectively) in both the effluent and the urine, using Garred mass balance equations and Forbes-Bruining formula, allowed normalized protein catabolic rate (nPCR) and estimates of lean body mass (LBM) to be derived. Creatinine metabolic degradation rate (Dc), estimated by the Mitch formula, was taken into account in calculations. The lowest body weight recorded during the study period was considered as the dry weight (BW). Creatinine index (CI) was also obtained. Mean Median Range
When creatinine production was estimated from the Cockcroft-Gault equations (as Pc'), the mean value for Pc' was similar (1,284.9 +/-484.1 mg/day) to Pc, but there were relatively large differences for the majority of cases. A positive correlation was observed between UnA and Pc (R = 0.42). Serum albumin and LBM/BW correlated poorly (R = 0.20). Outcome was weakly related to UnA and to nPCR (R = 0.29 and R = 0.31, respectively). Urea nitrogen appearance seems widely variable in critically ill ARF patients. This simple approach can provide useful information for an easy estimation of net protein catabolism in critically ill patients with ARF on CRRT.
98/018: DEFINING THE OPTIMAL OPERATING CONDITIONS FOR HIGH-VOLUME HEMOFILTRATION IN HUMANS

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Background and Objectives: High-volume hemofiltration (HVHF) has been proposed as an adjuvant treatment for severe sepsis, because of its high convective clearances. However, the ideal operating conditions for HVHF have not been established. Accordingly, we prospectively investigated the impact of alterations in re-placement fluid strategies on small and middle molecular weight solute clearance.

Design: Prospective controlled study.

Patients: Six critically ill patients with septic shock.

Interventions: Scheduled changes in the predilution: postdilution ratio of replacement fluid.

Simultaneous sampling of arterial, prefilter and postfilter blood, and ultrafiltrate to measure urea, creatinine, and vancomycin concentrations.

Results: Progressively increasing the proportion of fluid delivered postfilter significantly increases urea clearance (mean clearance at 6 liters predilution was 65.5 vs. 102.4 ml/min at 6 liters postdilution; p <0.05). Similarly, creatinine clearance was significantly increased by increasing postdilution replacement (mean clearance at 6 liters predilution was 58 vs. 96.7 ml/min at 6 liters postdilution; p <0.05). Vancomycin (a middle molecule) was also cleared more effectively with increasing post-dilution (mean clearance at 6 liters predilution was 53.3 vs. 71.6 ml/min at 6 liters postdilution; p <0.05).

Conclusions: Increasing the proportion of replacement fluid delivered postfilter increases the clearance of small and middle molecules during HVHF in septic patients. This finding has powerful implications for the operation of this novel technique.
98/019: UREA AND CREATININE KINETIC MODELING IN ACUTE RENAL FAILURE PATIENTS TREATED ON THE PRISMA CONTINUOUS RENAL REPLACEMENT THERAPY SYSTEM

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Quantitative approaches to the prescription and adequacy assessment of dialysis, while routinely employed in chronic renal failure, have seldom been applied in the acute renal failure (ARF) setting. We recently developed a mathematical model for small solute kinetics in the ARF patient treated by continuous renal replacement therapy (CRRT). According to this model, if generation rate and delivered clearance remain constant, the concentration of small solutes such as urea and creatinine follow an exponential decline reaching a plateau value after 3–4 days of CRRT. The plateau concentration equals the ratio of generation to clearance and the ratio of clearance to distribution volume governs and can be deduced from the speed of the concentration fall towards the steady-state value. To evaluate this model we conducted a retrospective study of critically ill patients treated with the Prisma machine (Hospal-Gambro, St. Leonard, Que., Canada), a recently introduced device for the controlled delivery of a variety of CRRT modalities. Treatment prescription and mathematical modeling of adequacy is facilitated with this device since it allows precise control of filter effluent flow rate (% small solute clearance in CRRT).

Medical records of 73 consecutive patients (52 M, 21 F) treated with continuous venovenous hemodialysis (CVVHD) at the Toronto Hospital were reviewed. Blood urea and creatinine concentration data over the course of CVVHD treatment were gathered and plotted to examine whether they followed an exponential fall to a plateau level as predicted by the model. A number of patients could not be modeled due to insufficient data. Of those with adequate concentration data, several patients deviated significantly from the model, presumably due to varying generation rates or other unknown factors. Eleven patients whose urea and creatinine closely followed an exponential decline were selected for further modeling. Protein catabolic rate was not significantly elevated in these patients (nPCR = 1.0 +/-0.6). Specific cases will be presented to illustrate our findings.

These results have prompted plans for a prospective study. The envisioned study will provide more complete urea and creatinine data for kinetic modeling and will allow the clinical impact of more intense CRRT therapy to be evaluated.
98/020: PROSPECTIVE ANALYSIS OF AMINO ACID AND PROTEIN BALANCE WITH STANDARD PARENTERAL NUTRITION DURING PEDIATRIC CONTINUOUS HEMOFILTRATION

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Patients in acute renal failure are in a catabolic state with reported adult protein catabolic rates of 1.4–1.8 g/kg/day, equivalent to nitrogen appearance of 240–285 mg/kg/day. Although only one report of total nitrogen appearance in pediatric patients has been published [Zobel et al., Child Nephrol Urol, 1991], values of ≈180 mg/kg/day were noted. We thus hypothesize that standard parenteral nutrition during hemofiltration in pediatric patients provides inadequate nutrition to achieve positive nitrogen balance. To test this hypothesis we are prospectively comparing 24-hour nitrogen balance and total and individual amino acid balance in pediatric patients receiving CVVH and CVVHD. Study conditions include: (1) caloric intake 20–30% above resting energy expenditure measured by indirect calorimetry; (2) protein in-take 1.5 g/kg/day; (3) hemofilter surface of 0.3 m²; (4) blood flow rate of 4 ml/kg/min, and (5) replacement fluid or dialysate flow rates of 2 liters/h/1.73 m². Amino acid analysis was performed by HPLC and urea nitrogen measurements utilized the urease methodology.

Analysis of data from the first 6 patients revealed that individual amino acid losses correlated directly with their initial plasma level. The individual amino acid losses varied between patients and ranged from 0.2% (glutamic acid) of parenterally administered amino acid to >100% (asparagine and proline). In addition in the Aminosyn-II formulation two amino acids are not supplied (glutamine and cysteine), therefore these amino acids losses represent a continuous deficit. In 5/6 of the children prestudy glutamine was depressed below the normal plasma range. In addition, glutamine losses represented the greatest loss of all of the amino acids, comprising 15–20% of total amino acid loss. This ongoing glutamine deficient may limit optimal protein synthesis since it is a major intracellular nonessential nitrogen source. Mean nitrogen balance (nitrogen intake minus ultrafiltrate urea nitrogen and change in urea nitrogen pool) was negative for both CVVH -1.87 +/-34 g/day/1.73 m² and CVVHD -0.76 +/-1.16 g/day/1.73 m². Total nitrogen appearance/excretion, a marker of the degree of catabolism, was high on both therapies, markedly above Zobel’s findings in children, with a mean of 287 mg/kg/day on CVVH and a mean of 250 mg/kg/day on CVVHD. These preliminary data suggest that current protein supplementation appears to be inadequate to maintain nitrogen balance in pediatric patients receiving CH. In addition, what role the composition of amino acid solutions without glutamine contributes to this imbalance may also be a concern.
98/021: EFFECTS OF FILTER PORE SIZE ON EFFICACY OF CONTINUOUS ARTERIOVENOUS HEMOFILTRATION THERAPY IN IMPROVING MORBIDITY AND MORTALITY IN AN IMMATURE SWINE MODEL OF STAPHYLOCOCCUS AUREUS-INDUCED SEPSIS

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**Purpose:** To compare a conventional hemofilter with a 50-kD cutoff to a prototype hemofilter with a 100-kD cutoff, with respect to their effects on survival time in a swine model of lethal Staphylococcus aureus sepsis. Hemofilter membranes have pore sizes which limit the sieving of molecules to a molecular size below their designed cutoff. This cutoff is usually expressed in terms of molecular weight, that is, the largest molecular weight molecule which will pass through the membrane pores. A great many putative mediators of sepsis/MOSF have molecular weights of 100 kD or less. Previously, we showed that continuous arteriovenous hemofiltration (CAVH) with a conventional (50 kD pore size) filter produced a 300% increase in survival time (compared to sham filtered control animals) in a lethal swine model of S. aureus sepsis.

**Methods:** In the present study, spontaneously breathing, ketamine-sedated swine were given a lethal dose of live S. aureus (IV). Animals were then filtered (blood pump driven) with either a 50-kD cutoff filter (RenalFlo HF 400, Minntech, Inc.; control group) or a 100-kD cutoff filter (prototype, Minntech, Inc.; experimental group). Physiologic measurements were made hourly and hematologic and biochemical parameters were obtained every 3 h. No animals received antibiotics. Animals were monitored continuously until death, and survival time in hours recorded (Permanent survival = 168 h/7 days).

**Results:** Animals filtered with the 100-kD filter survived significantly longer than control animals.
The 100-kD-filtered group had one permanent survivor (168 h). Protein concentration of the ultrafiltrate obtained from the 100-kD-filtered animals was 10-fold higher than control ultrafiltrate. This protein did not contain a high percentage of albumin. No significant differences were seen in any of the other measured parameters.

**Conclusion:** These data indicate that compared to the conventional hemofilter, filtration with the prototype filter having a wider molecular weight spectrum - up to 100 kD - significantly reduces mortality in this model of sepsis. This may result from removal by filtration of greater quantities and a wider spectrum of inflammatory mediators. Speculation: use of this 100-kD filter in human sepsis may improve survival.
98/022: A RANDOMIZED, PROSPECTIVE, CROSSOVER STUDY OF THE HEMODYNAMIC EFFECTS OF HIGH-VOLUME HEMOFILTRATION IN PATIENTS WITH SEPTIC SHOCK

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**Background and Objectives:** High-volume hemofiltration (HVHF) has been used as adjuvant treatment for septic shock despite the lack of controlled trials. Accordingly, we performed a controlled pilot study of its hemodynamic impact.

**Design:** Randomized, prospective, crossover, study comparing the hemodynamic effects of 8 h HVHF (6 liters/h UF rate) to 8 h conventional CVVH (1 liter/h UF rate).

**Patients:** Nine critically ill patients with hyperdynamic, vasopressor-dependent septic shock and multiorgan failure.

**Setting:** Tertiary ICU.

**Measurements:** Complete invasive hemodynamic assessment every 15 min for the first 2 h, every 30 min from 2 to 6 h and at 7 and 8 h. Recording of vasopressor requirements. Calculation of area under the curve (AUC) for all variables (in mm Hg or liters/m²/min).

**Results:** Hemodynamic stability was maintained under both conditions (AUC for MAP: HVHF 37,921 +/- 697 SEM vs. CVVH 38,494 +/- 838; cardiac index AUC: HVHF 2,084 +/- 220 vs. CVVH 2,001 +/- 179; right atrial pressure AUC HVHF 5,084 +/- 255 vs. CVVH 4,890 +/- 312; pulmonary artery occlusion pressure AUC: HVHF 6,401 +/- 318 vs. CVVH 6,596 +/- 395; all NS). Both therapies were associated with decreased norepinephrine requirements: median reduction with HVHF: 9.5 mg/m² (r 1 to 20) corresponding to a percentage reduction of 68% (r 6 to 100%) vs. median reduction with CVVH of 1 mg/m² (r +4 to -8) corresponding to a proportional reduction in dose of 7% (r +33 to -100%). The median reduction in dose was significantly greater during HVHF (p = 0.017).

**Conclusions:** HVHF can be performed with excellent hemodynamic stability in vasopressor-dependent patients with septic shock. The application of HVHF is associated with a decreased in vasopressor requirements. Such a decrease is significantly greater than that achieved by conventional CVVH.
98/023: EVALUATION OF PREDICTORS OF MORTALITY IN CHILDREN TREATED WITH CONTINUOUS VENOVENOUS HEMOFILTRATION

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This is a cohort study of 25 children treated with continuous venovenous hemofiltration (CVVH) between 1990 and 1997 at a single children’s hospital. This study was designed to evaluate predictors of mortality in children treated with CVVH. We hypothesized that the survival of acutely ill children treated with CVVH is determined by the primary disease entity and severity of illness. The potential predictors evaluated included duration of therapy, sepsis, history of heart disease, postoperative cardiac repair, use of pressors and the Pediatric Risk of Mortality (PRISM) III score. This score was used to quantitate the severity of illness and is determined during the first 24 h of intensive care unit hospitalization. The PRISM III ranges between 0 and 72. Increasing scores are correlated with a increasing probability of death in pediatric patients. The cohort was composed of patients ranging in age from 1 day to 17.15 years and weight between 1.1 and 80 kg. The sample included 17 males and 8 females with a mortality rate of 44%. The logistic regression technique was used for this analysis. While it likely reflects the small number in our database, no associations were identified between primary disease and survival. Results revealed the PRISM score was the best predictor of a fetal outcome within 7 days following CVVH therapy. Gender was identified as a confounding variable and was included in the final model. There were no interactions identified. The PRISM score is a significant predictor of outcome with a 17% increased risk (95% CI 2–35%) of death for every 1 unit increase in score, independent of gender.

This study was limited by the small numbers and retrospective design. In single pediatric institutions, the patient pool is traditionally small but can serve as a foundation for future studies. Despite these limitations, this study suggests that the PRISM score is useful in predicting mortality in children treated with CVVH.
98/024: PROGNOSTIC INDEXES OF PATIENTS WITH SIRS AND MODS ON CRRT

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The aim was to determine if prognostic indexes would be significantly correlated with the mortality in patients with or without SIRS (systemic inflammatory response syndrome) and MODS (multiple organ dysfunction syndrome). SIRS was defined by the Consensus Conference of 1991. Diagnosis requires that two or more of the following criteria be met: temperature >38 or <36°C; heart rate >90 bpm; respiratory rate >20 breaths/min or PaCO₂ <32 mm Hg, and WBC >12,000/mm³ or 4,000 mm³. There is as yet no consensus on the criteria that define MODS; this clinical process is established by degrees of organ dysfunction that need artificial methods of support. We studied 40 intensive care unit patients during 20 months (1/96-8/97): 27 (67%) had a diagnosis of SIRS and 13 (33%) of NSIRS (non-SIRS). We registered the APACHE (acute physiology age chronic health evaluation) II, APACHE III and SAPS (simplified acute physiology score) II score for 24 h after admission to the intensive care unit. APACHE II score is the predictive index of the physiopathologic answer with a maximum score of 71 (total mortality is observed with <55); in the review of this method in 1991, APACHE III registered 17 different points from the 12 before and the SAPS II with a score from 0 to 194. In the NSIRS group mortality was 28%; in SIRS mortality was of 79%. Correlated with final outcome the results (died/alive) with the three prediction indexes (APACHE II, APACHE III, SAPS II) were: pts NSIRS 38/29.5-84.4/68.7-81.1/76.8; pts SIRS 32/29.8-84.3/69-68.8/49.

In conclusion, the prognosis was significantly better in the NSIRS group than SIRS. The prognostic indexes are predictive of outcomes.
98/025: CONTINUOUS VENO TO VENOUS HEMOFILTRATION: ARE YOU TREATING THE PUMP OR THE PATIENT

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**Purpose:** (1) To simplify the documentation process for CVVH. (2) To establish an accurate meaningful documentation process that focuses on the patient as a whole.

**Methods:** (1) Established ongoing inter-departmental meetings to assess documentation variances from our original standard. (2) Developed a method of documentation for CVVH, congruent with our current ICU flowsheet. (3) Planned and trialed alternative documentation methods.

**Summary:** (1) Less in-service time was required to understand the flowsheet. (2) Less time was needed to document on the flowsheet. (3) Accurate, meaningful fluid balance information was extractable by all members of the health care team.

**Conclusions:** Our final product is the integration of the CVVH flowsheet into the ICU flowsheet. This newly combined flowsheet simplifies documentation and provides accurate, meaningful malformation that focuses on the patient as a whole.
98/026: A CREATIVE STRATEGY FOR CONTINUOUS RENAL REPLACEMENT THERAPY EDUCATION

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Providing learning activities and educational experiences for caregivers in a variety of clinical areas is a challenge for any education department. At a time of diminishing financial resources, cost-effective and creative strategies for education are in demand. The Renal Education Department at the Health Sciences Centre in Winnipeg, Manitoba, Canada, has developed a comprehensive Continuous Renal Replacement Therapy Educational Program. The content of this program includes: (a) certification; (b) annual review, and (c) video presentation on continuous renal replacement therapy modalities and the PRISMA CFM demonstration of initiation and termination of therapy.

The focus of the poster presentation is on the development of the Health Sciences Centre Continuous Renal Replacement Therapy Education Program. Each component of the CRRT Education Program was developed to meet the learning needs of the caregivers in a variety of clinical areas. Implementation was achieved through workshops with over 250 staff members responsible for the delivery of this therapy. Evaluations were utilized to measure the skill level and knowledge of the caregivers, as well as the satisfaction of the stakeholders with the program. Based on an evaluation of the program, additional components were added and recommendations were implemented to enhance the quality and efficiency of the content.

To date, there have been approximately 85 patients treated with continuous renal replacement therapy at HSC. These treatments have occurred in a variety of clinical settings, involving a variety of caregivers. The feedback received indicates that there is a strong correlation between increased preparation and reported level of confidence.
98/027: PEDIATRIC HEMOFILTRATION NURSING EDUCATION: A COOPERATIVE EFFORT BETWEEN DIALYSIS AND INTENSIVE CARE

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Many pediatric hemofiltration programs utilize ‘adapted’ hemofiltration machinery or are faced with utilizing machinery that is not pediatric-specific. Experience utilizing adapted machinery has demonstrated a patient survival of 48%. An educational program between the dialysis unit and intensive care staff has proven to provide bedside nursing direction in machine trouble-shooting, anticoagulation protocols, ultrafiltration protocols as well as the basis of research projects.

Initially, PICU staff undergo an intensive 8-hour hands-on training with a primed machine that is given in cooperation by both hemodialysis as well as critical care nurses. Education on the physiology of ultrafiltration and solute clearance is provided. This session then allows for machine trouble-shooting in response to alarms, adjustment of anticoagulation based upon acceptable ranges of monitoring and for identification of excess or ineffective ultrafiltration. At the end of the session an exam is taken to measure the level of understanding. This is followed up by every other month refresher sessions unless the use for pediatric hemofiltration is sufficient to maintain proficiency.

This cooperative effort has resulted in: (1) preprinted standing hemofiltration orders; (2) preprinted standard ultrafiltration worksheets; (3) protocols for anticoagulation, and (4) a locally published hemofiltration book with trouble-shooting guides. These efforts have resulted in a well-established program that is capable of performing hemofiltration in children of all ages and sizes and allows for nursing involvement in clinical research.
98/028: CONTINUOUS RENAL REPLACEMENT THERAPY
DEALING WITH FAMILY REACTIONS: A HERMENEUTIC APPROACH

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The purpose of this study is to decipher, by interpretation, fears and anxieties of families who may have a close relative receiving continuous renal replacement therapy (CRRT), thus alleviating and reducing anxiety fears and concerns. The hermeneutic method was chosen, the science or art of interpretation. Different family reactions to CRRT were collected. To summarize the results: Patterns of reactions could be noted from silence to fainting. Most family members had high anxiety levels at the initial site of the CRRT. Reactions such as previously mentioned were manifested by the family members’ voice and body language while visiting the patient. Sample verbal reactions: ‘Is this an experiment?’ ‘Are you experimenting on him?’ Hermeneutic interpretation: Lack of trust.

In conclusion, families need information about CRRT to foster hope and establish trust in those who care for the critically ill patient. Health professionals can be more sensitive to different kinds of reactions which can be based on a person, his or her race, creed or traditions, thus being able to read between the lines of all reactions. The success of CRRT in the 21st century will be strengthened by health professionals who collaborate and intervene, assisting families as they cope with the concepts of the critically ill patient on CRRT.
98/029: DEVELOPMENT OF A PROTOCOL FOR CONTINUOUS VENOVENOUS HEMODIAFILTRATION USING REGIONAL ANTICOAGULATION WITH TRISODIUM CITRATE IN CRITICALLY ILL ADULTS

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Program Summary: Continuous venovenous hemodiafiltration (CVVHDF) is increasingly being used as a renal replacement therapy for critically ill patients with acute renal failure. Conventional systemic anticoagulation therapy using heparin to prevent clotting in the extracorporeal system cannot safely be used in patients with heparin-induced thrombocytopenia and thrombosis (HITT) or for those either at risk of hemorrhage or actively bleeding. In these patients, citrate is an alternative regional anticoagulant that produces an effect by chelating calcium and reducing the availability of ionized calcium to the clotting cascade. Nurses were unfamiliar with regional anticoagulation using citrate and felt uncomfortable administering and monitoring the therapy. To ensure safe and effective administration and monitoring of the therapy, a multidisciplinary team of health care providers developed a protocol for regional anticoagulation using trisodium citrate.

Protocol Development: A multidisciplinary continuous renal replacement therapy (CRRT) committee was convened for the purpose of developing evidence-based procedures for management of patients requiring CVVHDF. The committee member-ship includes physicians, nurses and pharmacists from all areas involved in providing CVVHDF. The committee reviewed the literature on regional anticoagulation using citrate for intermittent hemodialysis and CRRT. A request for information and protocols on the use of regional sodium citrate anticoagulation in CVVHDF was posted on the Internet. A small work group met to review the information and developed a protocol for regional anticoagulation using trisodium citrate for CVVHDF. The protocol was disseminated widely for review and revisions were made based on the feedback obtained.

Implementation: The protocol for regional anticoagulation using trisodium citrate requires reconstitution and monitoring of nonstandard drugs for continuous infusion. Standard patient care physician orders were developed. These orders outline the appropriate dialysate and hemofiltration fluids, display the formula for reconstitution of sodium citrate and calcium chloride, include a sliding scale for titration of the sodium citrate to activated clotting times and identify the appropriate patient monitoring throughout the therapy. A nursing procedure for regional anticoagulation using trisodium citrate in CVVHDF was also developed and implemented. The protocol for regional anticoagulation with trisodium citrate is being subjected to ongoing evaluation and revision as experienced is gained with this anticoagulation regimen in critically ill adults.

Conclusion: Use of regional anticoagulation in CVVHDF using trisodium citrate is facilitated through the use of a protocol including standard patient care orders and a step-by-step nursing procedure. These tools increased the comfort level of health care providers participating in the delivery of an unfamiliar
anticoagulation therapy. CVVHDF using trisodium citrate regional anticoagulation can be safely used and monitored in critically ill adults when these tools are in place.
98/030: HIGH-VOLUME HEMOFILTRATION FOR SEPTIC SHOCK (6 L/HOUR U.F.): NURSING CARE AND MANAGEMENT

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*Introduction:* High-volume hemofiltration (HV-CVVH) has the potential to become a form of adjunct treatment for patients with severe sepsis.

*Study Objective:* To assess the feasibility of HV-CVVH in the ICU and its requirements from a nursing perspective.


*Results:* During the total of 1,440 min of operation, 144 liters of plasma water were exchanged. Hemodynamic stability was maintained and hypothermia was avoided. Fluid balance achieved as prescribed, no filter clotting or electrolyte abnormalities. The nurses involved in patient care considered the treatment was safe. All 3 patients experienced a decrease in vasopressor requirements.

*Conclusion:* A suitable system to achieve HV-CVVH was safely implemented as part of the management of 3 critically ill, vasopressor-dependent patients. Specific nursing care and management techniques are essential for this treatment to be successful.
98/031: PRACTICAL ASPECTS OF USING TRISODIUM CITRATE FOR ANTICOAGULATION IN PEDIATRIC CONTINUOUS VENOUS-VENOUS HEMODIAFILTRATION (CVVHD)

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One challenge in treating pediatric patients with CVVHD has been determining which anticoagulation regime is the safest and most effective. Due to the increased risk of bleeding complications from heparinization, we have used citrate anticoagulation exclusively. Twenty pediatric patients have been treated with CVVHD at Children’s Hospital and UCSD Medical Center over the past 3 years. These patients ranged in age from 10 months to 18 years of age. Four percent trisodium citrate is infused into the extracorporeal circuit via a stopcock at the arterial limb of the dual lumen access. Calcium chloride is infused via a central venous line to replace calcium lost by chelation and dialysis. Specially prepared dialysate is utilized that is lower in sodium and free of calcium and bicarbonate. Activated clotting times and ionized calcium levels are utilized to titrate citrate and calcium infusion rates according to prewritten algorithms. The use of citrate for anticoagulation in pediatric patients is easily incorporated into the CVVHD treatment plan and is a safe and effective treatment for pediatric patients.
98/032: EFFECT OF HEMODIALYSIS TREATMENT FOR ACUTE RENAL FAILURE CAUSED BY OPERATION

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Purpose of the Study: To evaluate the effect of hemodialysis treatment in severe patients with post-operation complicated by acute renal failure (ARF).

Method: This is a retrospective analysis (from 1987 to 1996) of 1,021 severe postoperative patients (572 men and 449 women; mean age 53.6 +/-10.5 years) in the intensive care unit in our hospital.

Results: Among the 1,021 patients, there were 36 with postoperation complicated by ARF (a rate of 3.6%). Of the 36 patients, 16 were treated by intermittent hemodialysis (IHD). Of the 16 patients, 9 died and 7 survived. The survival rate was 43.8%. The other 20 patients were not treated by IHD. Of the 20 patients, 19 died and only 1 survived. The survival rate was 5%. The survival rates of the two groups were significantly high (p <0.01). The causes of the 20 patients without IHD included: (1) hypovolemia and anoxia; (2) severe inflammation of the lungs; (3) difficult to move due to mechanical ventilation with tracheotomy.

Conclusions: Early IHD therapy can improve survival of postoperative patients complicated by ARF. Because continuous renal replacement therapy is thought to achieve therapeutic equivalence with IHD and be beneficial concerning the hemodynamic and ventilatory status of ARF, we presume that perhaps it is an effective therapy in postoperative patients complicated by ARF who are not suitable for IHD.
98/033: HEPARIN REMOVAL FROM WHOLE BLOOD FOR DIALYSIS

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We have developed an extracorporeal method for treating blood or plasma for heparin removal. Purified antithrombin III (ATIII) is immobilized to a large bead chromatography support (2 mg ATIII/1 ml of bead) packed into the column device. This constellation allows the free passage of blood (including cellular components) through the column bed as well as a sufficient contact of the particles with the heparinized blood. Passing the blood thru the column results in the removal of heparin from the blood to undetectable levels. Purified human ATIII was a generous gift from Alpha Therapeutic Corp., Los Angeles, Calif. The use of this method would allow regional heparinization during dialysis eliminating most of the side effects of heparin. Heparin would be administered only to the blood residing in the extracorporeal compartment. The deheparinization device should be placed at the end of the extra-corporeal circuit. The blood, free of heparin, can be returned to the patient.

In model experiments we have tested various heparin loads ranging from 0.5 to 5 IU/ml blood at different loading velocities. Heparin removal was successful. Kabi Pharmacia's heparin test was used to detect residual heparin in the treated blood. The amount of heparin was reduced below detectable levels. Potential medical applications of this technology include all devices requiring extracorporeal circulation of blood, including hemodialysis.
98/034: ON-LINE PRODUCTION OF ENDOTOXIN-FREE, ULTRA-PURE WATER FOR DIALYSIS

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Endotoxin (ET), a product of Gram-negative bacteria, is a ligand for CD14 loci on monocytes. In the presence of ET, monocyte activation occurs, which leads to cytokine production. Some cytokines have a deep influence on cell cycle regulation. Via distinct signaling pathways, endothelial cells are driven into programmed cell death, which leads to endothelial damage. Cell cycle arrest in G 0/1 may prevent vascular repair, causing severe cardiovascular diseases in dialysis patients. Repeated exposure to low amounts of ET therefore needs to be taken seriously as well. ET is difficult to remove, partly because of its extreme temperature resistance and pH stability. The aim of our project was to develop an on-line system capable of producing large volumes of ultrapure water, and ET-free dialysate. In general, RO water used as water source contains an average of 1–5 EU/ml of ET. We created a high-flow on-line system, the ClarEtox System™, to produce ultrapure water from RO water. ClarEtox™consists of specifically modified particles that bind to ET with high affinity. The current version of the device in its useful lifetime is capable of producing 13,000,000 liters of ultrapure water. It removes ET below 0.005 EU/ml, and reduces conductivity to <1.25 mS/cm. The intended use of treated water at dialysis stations are reuse, and preparation of dialysate. We have also developed the ClarEtox Dial-Guard™to capture residual ET from ready-to-use dialysate. Based on our safety studies, ClarEtox Dial-Guard™does not alter the ion and glucose composition of the dialysate. The system is versatile. This new technology can provide dialysis treatment with low-cost ultrapure dialysate and water for replacement fluid as well.