The abstracts are only available online, free of charge, under
www.karger.com/doi/10.1159/000083654

The 10th International Conference on Continuous Renal Replacement Therapies (CRRT)

March 10–12, 2005, San Diego, Calif.

Abstracts

Editor
R.L. Mehta, San Diego, Calif.

Contents

KARGER

Basel · Freiburg · Paris · London · New York ·
Bangalore · Bangkok · Singapore · Tokyo · Sydney

Abstracts

Patient Characteristics

ß RIFLE: (Risk of renal failure, Injury to the kidney, Failure of kidney function, Loss of kidney function and End stage renal failure), APACHE II: Acute Physiology, Age and Chronic Health status, SAPS II: Simplified Acute Physiology Score II, MAP: Mean Arterial Pressure, UOP: Urine Output, GCS: Glasgow Coma Scale, ROC: Receiver Operator Curve.

1

The Outcome of Acute Renal Failure in a General Intensive Care Unit According to a New Classification System; Model Application, Sensitivity and Predictivity

N.Y. Abosaif[1], Y.Y. Tolba[2], M. Heap[3], A. Meguid El Nahas[4]

[1]Sheffield Kidney Institute, Northern General Hospital, Sheffield University, [2]Intensive and Anathethic Department, Manchester Royal Infirmary, [3]Intensive and Anathethic Department, Northern General Hospital, [4]Sheffield Kidney Institute, Northern General Hospital, Sheffield University, Manchester, UK

Acute Renal Failure (ARF) is a severe complication in intensive care patients that is associated with a high mortality and enormous treatment expenditure. For the nephrologists, ARF is an extremely unsolved puzzle due to the contribution of several parameters in the definition, classification, diagnosis of associated morbidity and finally choice of management. In order to have a better approach to ARF patients in the intensive care unit (ICU), we tried to follow the new classification of ARF recently published by the Acute Dialysis Quality Initiative (ADQI) group called the (RIFLE)ß and apply it retrospectively on already managed patients to examine their outcome as regards renal and patient survival. Also to prove if this classification system can lead to better understanding and improvement of the quality of care provided to this particular category of patients. Also to assess the general scoring systems (APACHE IIß and SAPS IIß) used in the usual ICU setting and see if they can fit this new classification and help in prediction of future renal and patient outcomes. 183 patients were divided into 4 groups according to percent drop in Glomerular filtration rate (GFR) from baseline. Group I (Risk group: 67 patients, GFR loss >25% & <50%), Group II (Injury group: 59 patients GFR loss >50% & <75%), Group III (Failure group: 33 patients GFR loss >75%) and group IV (Control group: 24 patients GFR loss). The sensitivity of the general scores was more predictive of mortality when applied to separate groups of patients and not to the whole patients in the study. This was tested by the ROCß curve analysis and we found that SAPS II score was more sensitive for prediction of patient survival in the risk and injury group vs. failure and control group. In conclusion, we found that the application of this new classification system led to proper adjustment of different clinical parameters, time of initiation of RRT, and to good prediction of renal and patient outcomes in the setting of Intensive Care Unit.

2

The Challenges of CRRT Delivery Following a Hospital Merger

L.L. Beck, H.J. O'Keefe

Thunder Bay Regional Health Sciences Centre, Thunder Bay, Ontario, Canada

Introduction: CRRT is a complex therapy that requires effectively trained, experienced staff, open communication, collaborative medical care and a well structured program. CRRT delivery in a shared care nursing model presents many challenges in our ever-changing health care environment. **Discussion:** The Thunder Bay Health Sciences Centre (TBRHSC) is a 375-bed acute care facility in Northwestern Ontario, Canada. As part of a restructuring strategy McKellar and Port Arthur General Hospitals merged to one new building in February 2004. During the restructure the 22 bed ICU adopted a 'closed unit' managed by Intensivists. Historically McKellar was home to the Renal Program. CRRT was medically managed by Nephrologists with an ICU/Renal shared nursing care model. Renal staff was responsible for set-up, initiation and discontinuation; the ICU staff monitored the patient and treatment. The Port Arthur nurses and physicians had little exposure to renal patients and CRRT. Prior to the merger only 40% of the ICU nurses were experienced in CRRT. Coincidentally the hemodialysis unit increased their nursing staff by 50%. With shared nursing care and the high influx of new staff we have experienced challenges in interpersonal relationships, CRRT competence, interruptions in treatment and financial burden. These factors have the potential to negatively impact the effectiveness of treatment and clinical outcomes. Nephrologists continue to consult in the ICU but Intensivists challenge current practice by expanding the use of CRRT beyond renal failure. There is now an unclear delineation of medical management. The differences in CRRT uses, prescribing techniques, fluid balance calculations and variations in approaches to care have lead to errors and frustration. **Conclusion:** As our environment continues to change, innovative strategies will be required to maintain an effective and collaborative CRRT program. Providing a standardized orientation program for renal and ICU staff, sharing resources and developing interdepartmental working groups are approaches that are being implemented to ensure quality of care for our CRRT patients.

3

Outcome of Continuous Renal Replacement Therapy in Children

Y.J. Lim[1], H.-S. Jin[1], H. Hahn[1], S.H. Oh[2], S.J. Park[1], Y.S. Park[1]

[1]University of Ulsan College of medicine, Asan Medical Center, Seoul, Korea, [2]Handong University, Sunlin Hospital, Pohang, Korea

Purpose: There is growing use of continuous renal replacement therapy (CRRT) for pediatric patients, but reports about the use and outcome of CRRT in children is rare in Korea. We report our experiences of CRRT in critically ill pediatric patients. **Methods:** We reviewed medical records of 23 pediatric patients who underwent CRRT at Asan Medical Center between May 2001 and May 2004. We evaluated underlying diseases, clinical features, treatment courses, CRRT modalities and outcome. **Results:** Age ranged from three days to 16 years with a median of five years. Patients weighed 2.4 to 63.9 kg (median 23.0 kg; 10 patients $\leq$20 kg). The underlying diseases were malignancy (nine cases), multiple organ dysfunction syndrome (five cases), hyperammonemia (four cases), acute renal failure associated with liver failure (three cases), dilated cardiomyopathy (one case) and congenital nephrotic syndrome (one case). Pediatric Risk of Mortality (PRISM) III score was 17.6 ± 7.6 and the mean number of failing organ was 3.0 ± 1.7. Duration of CRRT was one to 27 days (median nine days). Eleven patients (47.8%) survived. Chronic renal failure developed in two cases, intracranial hemorrhage in one case, and chylothorax in one case among the survivors. PRISM III score and the number of vasopressor before the start of CRRT was significantly lower in the survivors (12.7 ± 4.2 and 0.9 ± 1.1) compared with non-survivors (22.1 ± 7.8 and 2.4 ± 1.4)($P < 0.05$). **Conclusion:** CRRT driven in venovenous mode is an effective and safe method of renal support for critically-ill infants and children to control fluid balance and metabolic derangement. Survival is affected by PRISM III score and the number of vasopressors at the initiation of CRRT.

4

Survival, Renal Recovery and Disposition of Patients Requiring Prolonged Inpatient Dialysis for Acute Renal Failure

D.W. Louvar, E.N. Haugen

Mayo Graduate School of Medical Education, Rochester, MN, USA

A cohort of critically ill patients requiring prolonged (minimum 4 weeks and 12 dialytic treatments) has previously been described. Patients experiencing acute renal failure are getting older and have more comorbidities at initiation of dialysis. This is likely to have an impact upon survival, recovery of kidney function and long term quality of life. We describe a cohort of 172 patients who experienced ARF and required a minimum of 12 inpatient dialytic treatments. 168 out of 172 patients required ICU admission at some point in their hospitalization. 123/172 were on CRRT for at least one day. 114/172 (66%) of patients survived to discharge. 70/114 (61%) required dialysis at discharge.

Age was a significant determinant of whether or not patients recovered GFR. Long term survival was also dependent upon whether or not the patient recovered GFR and was off dialysis at the time of dismissal (median survival 690 vs. 138 days). 30% of patients who survived were dismissed to home. The remainder went to skilled nursing facilities. Of the original 172 patients, only 7% went home off of dialysis. As the demographics of our patients change and short term survival for ARF is improving, we feel it is important to study the long term prognosis and impact upon QOL our therapies may have on this group of patients.

Summary of outcome estimates for patients requiring prolonged dialysis for ARF		Frequency	%
Total		172	100
Survived to discharge		114/172	66.3
Dialysis status			
	No RRT at discharge	44/114	38.4
	Dialysis dependent	70/114	61.4
	Discontinued dialysis after discharge	9/70	12.8
	Remained on dialysis	54/70	77
	Unknown	7/70	10
Survival at 2.5 years based on dialysis status at discharge	Total with adequate follow up info	101/114	95.6
	No RRT at discharge	22/39	56.4
	Dialysis dependent at discharge	17/62	27.4

5

The Cost of Acute Renal Failure in the Intensive Care Unit

A. Rauf[1], O. Gajic[2], K.H. Long[3], S.S. Anderson[3], L. Swaminathan[4], R.C. Albright[4]

[1]Division of Critical Care, [2]Division of Pulmonary Critical Care, [3]Division of Health Care Policy and Research, [4]Division of Nephrology and Hypertension, Mayo Clinic College of Medicine, Rochester, MN, USA

Objective: Many patients admitted to Intensive Care Units (ICU) receive dialysis for treatment of Acute Renal Failure (ARF). Several studies failed to show a survival benefit between intermittent hemodialysis (IHD) and continuous renal replacement therapy (CRRT). Cost analyses are limited and have failed to properly control for differences in patient disease severity and comorbidities by method of RRT. Our objective was to formally estimate the length of stay (LOS) and direct medical costs (hospital and physician) associated with CRRT and IHD in the ICU among critically ill patients experiencing ARF. **Methods:** All adult ICU patients receiving a nephrology consultation for ARF between January 2000 and December 2001 were considered. Patients who had peritoneal or any prior dialysis and initial serum creatinine >5 mg/dL were excluded. Patient demographics, comorbidities, ARF etiology, APACHE II scores, renal recovery, survival and mode of RRT were abstracted. Administrative data tracked LOS and direct medical costs from the

time RRT was initiated to ICU and hospital discharge. We used generalized linear modeling to predict economic outcomes by RRT method adjusting for observed differences in patient characteristics. **Results:** A total of 163 patients met inclusion criteria: 85 (52%) received CRRT and 78 (48%) received IHD. Patients who received CRRT were significantly younger (58 vs. 66), more likely female (42% vs. 23%), had higher APACHE II scores (32.3 vs. 27.7), and were less likely to have chronic renal insufficiency (Cr >2 mg/dL or GFR <65 cc/min). Mean adjusted ICU LOS was 8.5 days shorter for IHD than CRRT treated patients (p = 0.00). The adjusted difference in hospital and total costs from start of RRT to ICU discharge was $52,961 and $57,492, in favor of IHD (p = 0.00). Mean adjusted total costs through hospital discharge were $92,134 and $142,340 among IHD and CRRT treated patients, respectively (p = 0.00). **Conclusion:** This observational study suggests total costs of care significantly differ by method of RRT. Patients receiving IHD had lower adjusted LOS and estimated total costs as much as $57,000 lower per patient compared with CRRT. Without evidence for improved patient outcomes with CRRT, IHD could be the economically preferred alternative.
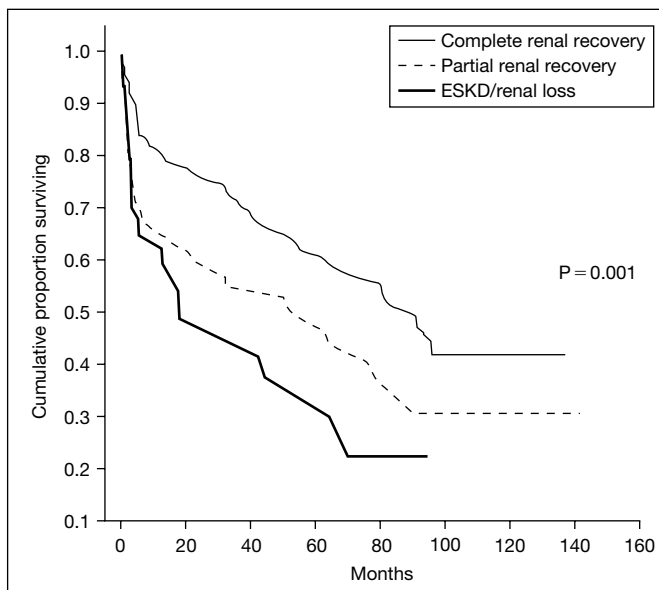
Figure 1.

6

Analysis of Long-Term Survival of Surgical Intensive Care Patients Who Develop Acute Renal Failure

A. Bihorac[1], A. Gabrielli[2], J.A. Layon[2], M.S. Segal[3]

[1]Department of Medicine, [2]Department of Anesthesiology, [3]Division of Nephrology, University of Florida, Gainesville, FL, USA

Although acute renal failure (ARF) is common in the surgical intensive care unit (SICU) setting, it is unclear whether long-term mortality is adversely affected by the ARF and renal replacement therapy (RRT), even after their recovery. We performed a retrospective analysis of existing SICU patients' database by the ICD9 codes for ARF and/or RRT. 896 adult SICU patients during the period 1990–2000 were identified and their medical records were individually reviewed. ARF was defined using the recently published RIFLE criteria on the basis of the change in the serum creatinine as compared to baseline creatinine values at the time of admission to hospital. 469 patients (52%) survived to discharge from the hospital. Survival for 87 patients with chronic kidney disease (CKD) and 107 with ESRD were analyzed separately. 251 patients with normal renal function at the time of admission were categorized into three groups with regard to recovery of renal function at the time of discharge, according to Rifle criteria: Group 1 (57%) had complete renal recovery (CR); Group 2 (28%) had partial renal recovery (PR) and Group 3 (15%) had ESKD/renal loss at the time of discharge and was hemodialysis (HD) dependent. Long-term survival was significantly worse among patients who were HD dependent at the time of discharge compared to both patients with partial and complete renal recovery. The 5-year survival for groups 1, 2 and 3 was 60%, 46% and 37%, respectively Figure 1. This increased mortality was not just dependent on need for RRT, since the 5-year survival of those who required RRT at any time during admission was 46%, not significantly different from the survival of those who did not require RRT, 56%. Thus the development of ARF among surgical ICU patient is the critical risk factor for long-term survival. Renal recovery at the time of discharge appears to be major determinant of the long-term survival, disrespectful of the need for RRT during hospitalization.

	Complete renal recovery N = 143 (57%)	Partial renal recovery N = 71 (28%)	Loss/ESKD N = 37 (15%)	P
Age	58 ± 171	66 ± 12	64 ± 12	0.001
Female sex %	43	32	43	NS
Caucasian and others %	89	93	84	NS
Creatinine on admission (mg/dl)	1.58 ± 1.78	1.50 ± 1.00	1.98 ± 2.04	NS
Peak creatinine (mg/dl)	3.95 ± 2.45	5.09 ± 2.39	7.10 ± 2.16	<0.001
Creatinine at discharge (mg/dl)	1.04 ± 0.95	3.28 ± 4.95	4.97 ± 1.96	<0.001

7

Referral Patterns to Nephrology for Acute Renal Failure in the Intensive Care Unit

D. Rosenbaum[1], M. Kiaii[1], O. Djurdjev[2], D. Dorscheid[3], G. Grant[3], A. Levin[1]

[1]Division of Nephrology, St. Paul's Hospital, [2]CHEOS Department of Health Care and Epidemiology, [3]Division of Critical Care, St Paul's Hospital, University of British Columbia, Vancouver, British Columbia, Canada

Acute renal failure (ARF), as a cause of increased morbidity and mortality, is an ongoing concern in the ICU. This study describes

referral patterns to nephrology of ARF patients (pts) in a tertiary care teaching hospital ICU in Vancouver, Canada. **Methods:** All pts admitted to the ICU for >24 hours were prospectively followed until discharge from hospital or death over a 4 week period. **Results:** 45 pts were admitted to ICU during the 4 weeks. Five pts were excluded (3 known renal replacement therapy (RRT), 2 pts in the ICU <24 hrs). Of the 40 pts, 20 pts had ARF identified by predetermined criteria. Seventeen of these 20 pts were identified by the ICU as having ARF. Of the 20 pts with ARF, 10 were referred to nephrology: 9/10 within 24–48 hrs of ARF diagnosis, 1/10, 4 days later. Table 1 describes characteristics of ARF pts referred to nephrology. Nephrology's and ICU's impression of the cause of ARF was concordant in 7/10 pts (impression: prerenal or ATN). In 3/10 pts where impression differed, nephrology's impression was vasculitis, TTP and tumor lysis syndrome. Of the 10 pts referred to nephrology 6 pts died, versus 3/10 pts not referred. See table for RRT and survival outcomes. **Conclusion:** Of those pts meeting criteria of ARF, 50% were referred to nephrology. Those referred had higher creatinines, were less likely to recover renal function, more likely to need RRT and more likely to die. Implications will be discussed.

Table 1.

	Nephrology consult N = 10	No nephrology consult N = 10	p value
Age-median (range)	62 (32–82)	47 (27–80)	0.272
Female gender	2 (20%)	4 (40%)	0.628
Cr-umol/L on admission	375 (102–832)	152 (123–598)	0.089
Peak Cr-umol/L	497 (250–1000)	172 (123–621)	0.004
APACHE	24 (18–30)	22 (15–27)	0.225
Renal recovery (full or any)	5 (50%)	9 (90%)	n/a
No renal recovery	5 (50%)	1 (10%)	n/a
RRT	8	2	n/a
CVVHD	2/8 pts (25%)	2/2 pts (100%)	n/a
IHD	4/8 pts (50%)	0	n/a
Both CVVHD & IHD	2/8 pts (25%)	0	n/a
Death	6	3	n/a
Death with recovery or improved renal function	2/6 pts (33%)	2/3 (67%)	n/a
Death on RRT or no renal recovery	4/6 pts (67%)	1/3 (33%)	n/a

8

Vascular Access in Pediatric CRRT

R.M. Hackbarth[1], D.J. Sanfilippo[1], N.J. Maxvold[1], G.-M. Barletta[2], T.E. Bunchman[2]

[1]DeVos Children's Hospital-Pediatric Critical Care, [2]DeVos Children's Hospital-Pediatric Nephrology, MI, USA

Vascular access is critical to successful CRRT and especially important in the pediatric population due to the wide range of age and size. We report our CRRT experience over the past 24 months in eighteen children ranging in age from 2 days to 18 yrs (mean 7.3 yrs); weight range 2.5 to 78 Kg (avg. 30 Kg). Indications for CRRT range from sepsis, multi-organ dysfunction syndrome and tumor lysis syndrome. During this period of time 8 children were treated with the BM-25 (Baxter, Deerfield, IL), 9 with the Prisma (Gambro, Lakewood, CO) and one on both. Access was based upon size of the patient but included the 7 Fr dual lumen 10 cm Softline (Medcomp, Harleysville, PA), 8 Fr 12 cm (Kendall, Mansfield, MA), and 12 Fr 16 and 20 cm triple lumen catheters (Arrow, Reading, PA). Access placement was femoral in 10 children, internal jugular (IJ) in 7, and subclavian in 1. All patients were treated with citrate anticoagulation. Blood flow rates (BFR) were on average 76 mls/min on the BM-25 and 86 mls/min on the Prisma. Average circuit life was 3.1 days with the range from 0.3–11 days. In these 18 children, 5 had vascular access clots that required changing the catheter. Four of these occurred with 7 Fr catheters and one with an 8 Fr catheter; 3 of these were femoral and 2 were IJ. No access clots occurred in the 12 Fr catheters. All access clots occurred in children <6 kg and <18 months of age with circuit blood flow averaging only 30 mls/min. In conclusion, large triple lumen access can be successfully used in larger (>35 kg) children. IJ approach is preferred due to patient movement, yet the data to date do not support the superiority of one location over another. In smaller children (2–15 kg), despite the presence of citrate anticoagulation, there is a greater occurrence of access clotting that appears to be flow dependent. Research in smaller access is needed to support CRRT for smaller children.

9

Analysis of 4-Years-experience in the Treatment of Acute Renal Failure (ARF) in Non-Renal Solid Organs and Bone Marrow Transplant Recipients: The Role of Sepsis in the Pathogenetic Mechanisms and in T

V. Cantaluppi, A. Pacitti, G. Podda, C.M. Fenocchio, F. Bermond, G.P. Segoloni

Nephrology, Dialysis and Renal Transplantation Unit, Torino, Italy

The characteristics of ARF patients has been changing, with an increase in Intensive Care Units (ICUs) in the presence of sepsis and concomitant failure of other organs (MOF). In 2000–2004, we treated 598 patients with ARF by Slow Hemofiltration (SHF). Performing more than 5000 SHF, we noted a rise of ARF cases in sepsis (33.6%) and in solid organs or bone marrow transplantation (11.8%). We treated 39 patients bearing a liver graft, 10 heart graft, 6 lung graft, 5 bone marrow transplantation, 1 combined liver/kidney and 1 combined pancreas/kidney transplantation. Moreover, a small percentage of patients with an artificial organ substitution such as ventricular devices (Berlin Heart) or MARS came to our observation for ARF. The cases of Delayed Graft Function (DGF) in kidney transplant recipients were treated by intermittent techniques in a Semi-Intensive Unit. Only 9 patients bearing a renal graft were admitted to ICU for hemodynamic instability or to undergo surgical procedures. According to Goris, most of cases showed the failure of more than 3 organs, with concomitant urinary signs of acute tubular necrosis (ATN) due to the presence of severe hypotension (failing heart grafts), of other unresolved 'pre-renal' situations including hepato-renal syndrome (failing liver grafts), and in particular of sepsis-related release of cytokines, a condition that complicates the management of immunosuppressive regimen and leads to an high mortality (81.6%). In a few cases (9.85%), acute rejection was responsible for organ dysfunction predisposing to ARF.

In conclusion, here we report the increased percentage of ARF in non-renal solid organs and bone marrow transplant recipients, with an high mortality that seems to be related to the presence of sepsis/MOF. By contrast, only a few patients bearing a renal graft with DGF were admitted to ICU, with a low risk of mortality in the absence of sepsis/MOF. These observations suggest that the altered response of immune system in sepsis-related ARF/MOF and not ARF itself may be the major responsible for the high mortality of the group. This finding is strengthened by the recovery of renal function in transplant recipients in the absence of sepsis/MOF.

10

Factors Affecting Survival and Renal Recovery in Patients with Acute Renal Failure in the Intensive Care Unit on ContinuousS Renal Replacemant Therapy

P. Suri, A.J. Tolwani

Department of Medicine, University of Alabama at Birmingham, Albama, USA

Acute renal failure (ARF) in the intensive care unit (ICU) continues to have a high mortality and morbidity, despite advances in supportive care and renal replacement therapies. Besides dialysis-related variables, other factors have been shown to impact outcomes in this setting. We herein describe the results of prospectively collected data in 51 patients with ARF admitted to the ICU at our institution between 7/2003 and 2/2004 with regards to factors affecting survival or renal recovery at ICU discharge. All patients received continuous venovenous hemodiafiltration (CVVHDF) using the Prisma machines with M100 filters and were randomized to receive an ultrafiltration rate of 20 ml/kg/hr (standard dose) and 35 ml/kg/hr (high dose). The mean age of the patients was 61 ± 15 years, mean Acute Physiology, Age, and Chronic Health Evaluation (APACHE) II score 25 ± 5, mean BUN and creatinine at the initiation of renal replacement was 82 ± 35 mg/dL and 4.5 ± 2 mg/dL respectively, and mean number of days from ICU admission to initiation of CVVHDF was 5 ± 6.1. Of the total 51 patients, 55% were male, 57% were oliguric, and 6% had cirrhosis. As for the cause of renal failure, 59% had sepsis as the main cause, 22% had post-operative renal failure, and 18% had ARF secondary to cardiogenic shock. The overall ICU survival was 63%, and of these 45% of the patients had recovery of renal function at discharge from the ICU. The variables analyzed using multiple logistic-regression analysis included age, gender, oliguria, sepsis, APACHE II score, cirrhosis, and days from ICU admit to start of CVVHDF. None of the tested variables had a significant effect on ICU survival; however, there was a trend towards higher mortality in patients with sepsis (p = 0.0892). With renal recovery as the outcome variable, gender had a significant effect (p = 0.0169), and sepsis (p = 0.0732) displayed a trend towards significance. We conclude that in our study, the only significant variables affecting survival and renal recovery in ARF in the ICU were sepsis and male gender. Other patient characteristics and process factors did not have a significant effect on these outcomes. Moreover, the overall ICU survival was better than previously described.

11

CRRT in a Tertiary Centre in India

R. Chakravarthi Madarasu, S. Hussaini, Sai Ram Reddy, Keithi Reddy

Care hospitals, Hyderabad, India

Introduction: Acute renal failure in the ICCU settings in developing countries is similar to that seen in Western world. CRRT as a modality of dialytic support is fast becoming an acceptable option to manage this ARF. We report a retrospective analysis of 267 consecutive CRRT sessions performed on 259 patients between March 2002 to August 2004. Eighty seven of these patients were female and one hundred and seventy two of these patients were male. The maximum age encountered was 81years and the minimum age encountered was 17 years. The cause of Acute renal failure was predominantly sepsis with multi organ failure in ICCU or Post cardiothoracic surgery acute tubular necrosis in CTICU. Heparin was the main mode of anticoagulation used and those who had altered coagulation parameters were managed with half hourly normal saline flushes. The dialysate solution used was the commercially available peritoneal fluid. The mode of CRRT predominantly used was CVVHD. The technique survival was hundered percent. The mean life of circuit on heparin anticoagulation was 68 hrs and mean life of circuit on saline flushes was 52 hrs. In view of the cost constraints, in 49 CRRT sessions after the initial catridge clotted a polysulphone membrane was used to continue the therapy. The mortality was significantly different depending on the underlying cause of ARF. **Conclusions:** CRRT is an accepted mode of dialysis for ARF in ICCU settings even in developing countries. Heparin anticoagulation is economical and suffices for performing CRRT. Normal saline flushes are an alternative to heparin in select patients. Polysulphone membranes can be used for CRRT in non hypercatabolic patients after the initial forty eight to seventy two hours of therapy. This brings down the cost of the therapy. Mortality is significantly affected by the underlying cause of ARF.

Emerging Concepts in ARF and CRRT

12

Enhanced Valproic Acid Dialytic Clearance with an Albumin-based Dialysate in Continuous Venovenous Hemodialysis

M.D. Churchwell[1], D.A. Pasko[2], W. Smoyer[2]

[1]College of Pharmacy, University of Michigan,
[2]C.S. Mott's Childrens Hospital, Ann Arbor, MI, USA

Background: Over 10,000 valproic acid toxic ingestions occur annually in the United States, many of which result in hospitalization and death. Therapies like hemodialysis are relatively ineffective at removing valproic acid because valproic acid is extensively (80–90%) protein bound. The purpose of this project was to determine the feasibility of utilizing an albumin-based dialysate to accelerate valproic

acid dialytic clearance. **Methods:** A bovine blood based in vitro continuous venovenous hemodialysis (CVVHD) model using a B.Braun DiapactÆ CRRT machine and a Multiflow 60 (Gambro) dialyzers. Valproic acid was added to the bovine blood. NormocarbÆ dialysate was used as a control and compared to NormocarbÆ dialysate with 5% albumin added to it. Valproic acid transmembrane CVVHD clearance was assessed at blood flow rates of 180 and 250 ml/min and dialysate flow rates of 1, 2, and 4 l/hr. Three dialyzers were assessed at all flow rate combinations. Blood samples obtained pre and post-filter and spent dialysate samples were assessed for valproic acid content. Transmembrane valproic acid clearance at each flow setting were compared by paired t-test. **Results:** See table. **Discussion:** Valproic acid clearance can be significantly enhanced with the addition of albumin to the NormocarbÆ dialysate as compared to NormocarbÆ dialysate alone. **Conclusion:** Albumin-based CVVHD should be investigated further to determine the feasibility of use in highly protein bound drug overdose.

Mean valproic acid transmembrane clearances (ml/min)
(n = 3 M-60 dialyzer at each setting)

Qb setting	Qd setting	5% Albumin dialysate	Standard dialysate	P value (standard vs. albumin dialysate)
180 ml/min	1 l/hr	17.1	5.6	0.004
180 ml/min	2 l/hr	21.4	11.8	0.133
180 ml/min	4 l/hr	24.2	19.9	0.518
270 ml/min	1 l/hr	17.8	4.7	0.031
270 ml/min	2 l/hr	23.9	7.7	0.018
270 ml/min	4 l/hr	30.3	11.5	0.011

13

Application of CRRT in the Treatment of Severe Gomerular Diseases

Q. Jin

Renal Division, Department of Medicine, Peking University First Hospital Beijing, P.R. China

Objective: To investigate the effect of continuous renal replacement therapy (CRRT) in the treatment of severe glomerular diseases. **Method:** 11 patients with severe glomerular diseases were enrolled in the study, including 3 cases of primary rapidly progressive glomerulonephritis (RPGN), 3 systemic lupus erythematosus (SLE), 2 ANCA associated small vasculitis, and 3 hemolytic uremia syndrome. They all had acute renal failure, accompanied with severe edema, anemia, massive proteinuria, hypoalbuminemia and hypercoagulation. These patients could not endure conventional intermittent hemodialysis due to hypotension, thus were given daytime slow low-efficient daily hemofiltration (SLEDHF). There were total 56 treatments, average 11.67 ± 3.53 hours per treatment. Machines used were either Freseninus ADM08 or Baxter ACCURA, and AV600 or HF 1200 hemofilters were employed. Volume of replacement fluid (or dialysate) were 3000–4000 mL/hr, UF rate was 100–400 mL/hr. Low molecular weight heparin (LMWH) was administered for anticoagulation. **Results:** Patients' blood pressure were stable during

treatment and no any indisposition. Mean value of various parameters of the patients before treatment were serum creatinine $630.10 \pm 220.64\,\mu$mol/L, hemoglobin 78.50 ± 8.67 g/L, serum albumin 27.64 ± 8.09 g/L, fibrin 6.27 ± 1.54 g/L, after treatment were serum creatinine $420.90 \pm 242.59\,\mu$mol/L (P < 0.05), hemoglobin 80.60 ± 16.82 g/L (P > 0.05), serum albumin 29.53 ± 6.93 g/L (P > 0.05), fibrin 5.04 ± 2.75 g/L (P > 0.05). Out of 11 patients, 1 patient restored his normal renal functions, 10 patients' renal function improved. No patients died or went into maintenance dialysis. **Conclusions:** Severe glomerular diseases often manifested as acute renal failure, and require renal replacement therapy in its acute phase. However, these patients often have hypoalbuminemia and were dehydrated, and hypercoagulated in most cases. Conventional intermittent hemodailysis may induce hypotension or thrombosis in that it require relative large volume of UF in a shorter period of time. CRRT may be a very good alternative choice in acute phase of the treatment of severe glomerular diseases.

14

The Role of Adqi-rifle Criteria in the Diagnosis of Early Renal Dysfunction in Critically Ill Patients and Their Relationship with Other Standardized Urinary Markers of Tubular Injury

A. Pacitti, V. Cantaluppi, F. Bermond, C.M. Fenocchio, G. Podda, G.P. Segoloni

Nephrology, Dialysis and Renal Transplantation Unit, Torino, Italy

The importance of early diagnosis of renal dysfunction has been rising as one of the most important concepts in order to establish the appropriate strategies to prevent the need of renal replacement therapies (RRTs) and the high mortality of critically ill patients. Nowadays, serum creatinine and urinary output still are the basic points to assess the presence of renal impairment. Trying to classify Acute Renal Failure (ARF) in different categories, ADQI proposed the RIFLE criteria. Moreover, the modern research has focused on the finding of urinary markers of tubular injury (KIM-1). In 2000–2004 we treated 624 ARF cases by Slow Hemofiltration (SHF), with the esecution of more than 5000 sessions. During 2004, basing upon the report of serum creatinine and urinary output, we applied the RIFLE criteria to all the patients observed in ICU. We noted that the majority of cases were included in the categories 'Injury' (35.18%) 'Failure' (44.14%), or 'Loss of Function' (12.96), and only a few cases were found in the category 'Risk' (7.4%). Moreover, an high percentage of cases underwent a progression in the stages of renal dysfunction, reaching the 'Loss of function' and requiring SHF treatment. However, even advanced stages of the alteration of kidney functions, still showed a typical behavior of a 'pre-renal' syndrome, characterized by low levels of Fractionale Excretion of sodium (FENa) and of urea (FEU), the standardized markers of tubular damage. In some cases, it was also found the presence of fragmented proteins in the urine, a condition that, in our experience, identifies a particular moment immediately before the onset of acute tubular necrosis (ATN). In conclusion, the ADQI-RIFLE criteria have a pivotal role in the early definition of clinical conditions at risk of development of ATN. The co-operation

between the Nephrologists and the Intensivists at earlier stages (such as 'Risk' condition) of renal impairment may lead to the onset of therapeutic strategies able to maintain the 'pre-renal' condition allowing the recovery of renal function and avoiding the progression of renal dysfunction due to the persistent ischemic or toxic injury and the need of renal replacement therapies.

15

The Treatment of Patients with Hyperbilirubinemia by Hemodialysis Using Plasma-based Dialysate

D. Gong, D. Ji, B. Xu, B. Ren, Y. Liu, L. Li

Research Institute of Nephrology, Jinling Hospital, Nanjing University School of Medicine, Nanjing, P.R. China

Objective: We proposed a new blood purification modality – hemodialysis with plasma-based dialysate (PHD), to treat the patients with hyperbilirubinemia, and evaluated the effect on removing of serum bilirubin. **Methods:** Eleven patients diagnosed as hyperbilirubinemia were involved in this study. Four of them were treated by high volume hemofiltration (HVHF) for 12 hr, 3 patients were treated by hemoperfusion (HP) using macroporous resin sorbents, the other four were treated by PHD with plasma-based dialysate for 6 hr. During PHD, 4000 ml frozen plasma was used circularly as dialysate at flow rate of 6000 ml/hr, and BLS816G filters were used as dialyzers. Serum total bilirubin (TB), direct bilirubin (DB) and indirect bilirubin (IB) was monitored before and after treatment in all patients, During HVHF, ultrafiltration was examined for TB, DB and IB concentrations, and during PHD, plasma dialysate was also examined for these indices. **Results:** After 12-hour treatment of HVHF, the mean reduction of serum TB, DB, IB is $10.4 \pm 4.2\%$, $10.0 \pm 6.3\%$ and $10.1 \pm 7.5\%$, respectively, and the concentration of TB, DB and IB in ultrafiltration is 3.33 ± 0.96, 1.98 ± 0.81 and $1.35 \pm 0.26\,\mu\text{mol/L}$, respectively. After HP treatment, the mean reduction of serum TB, DB and IB is $14.4 \pm 3.2\%$, $14.4 \pm 4.0\%$ and $14.8 \pm 3.2\%$, respectively. After 6-hour PHD, the mean reduction of serum TB, DB and IB is $21.5 \pm 5.3\%$, $20.5 \pm 2.9\%$ and $24.1 \pm 14.0\%$ respectively. **Conclusion:** Hemodialysis using plasma-based dialysate is more effective in removing of serum bilirubin than the existing blood purification modalities such as HVHF and HP.

16

Utility of Cystatin C Serum Levels in Intensive Care Unit

M. Ferrannini[1], E. Venti[2], S. Casciani[3], S. De Angelis[1], M.R. Dess[3], P. Ortis[2], A. Tartaglione[2], F. Leonardis[2], G. Splendiani[1]

[1]Nephrology and Dialysis Unit, [2]Intensive Care Unit, [3]Department of Laboratory Medicine,'Tor Vergata' Univerisity, Rome

Background: The occurrence of Acute Renal Failure (ARF) in critical ill patients is between 1,1–31%, according to the definition of ARF, and is associated with excess mortality. It is know that an early diagnosis and therapy of ARF improves the prognosis. The Serum Creatinine (SCr) is the most common marker of renal function, but it has some limits. The serum Cys C concentration may correlate more closely with the GFR than the SCr, especially to indicate mild renal insufficiency. **Aim:** To determine the role of serum Cys C levels in diagnosis of ARF in ICU patients. **Material and Methods:** 23 consecutive ICU patients (13 males, 10 females; mean age 65 ± 20, 79 years), with normal renal function at the admission in ICU, were daily monitored for serum Cys C levels. To determine ARF events, serum creatinine levels and urine output were detected; moreover the Cockcroft-Gault equation was calculated daily for all patients. In accord with RIFLE criteria, the AFR was defined as 'I' level. **Results:** 10 out of 23 patients had 'I' level of ARF, 5 of them starting RRT. At the day of AFR, the serum Cys C levels were always higher than normal values, and the Cys C and creatinine levels had a good correlation (R_2 0,6559; $p < 0,05$). Moreover, comparing the *timing* of increase of serum Cys C levels to the diagnosis of ARF, we observed in all patients levels of serum Cys C higher than the normal $5,5 \pm 4$ days before the ARF. In all case of high Cys C levels we observed AFR. **Conclusion:** the serum Cys C is a useful marker of renal function in ICU, as well as serum creatinine; in our small population, the Cys C predicted the ARF 5,5 days before the 'I' level of RIFLE criteria, without false positive cases. Larger population needs to confirm this results.

17

CRRT in Pediatric Bone Marrow Transplant Patients: A Report from the Prospective Pediatric CRRT (PPCRRT) Registry Group

F.X. Flores, P.D. Brophy, J.M. Symons, J.D. Fortenberry, A.N. Chua, S.R. Alexander, J.D. Mahan, T.E. Bunchman, D.L. Blowey, M.J.G. Somers, M.A. Baum, R.M. Hackbarth, D.H. Chand, K.D. McBryde, S.L. Goldstein

The ppCRRT Registry Group, Houston, Texas, USA

CRRT has become more prevalent in the management of pediatric bone marrow transplant (BMT) pts with acute renal failure. Since 1/1/01, 44/295 pts from the13 center ppCRRT Registry were BMT pts. Median age was 7.71 years (range 0.53–23.52 years). 27 (61%) were males and 32 (73%) required ventilatory support. The CRRT modalities were CVVH (44%), CVVHD (40%) and CVVHDF (16%). The most common diagnoses leading to CRRT were sepsis (20%), respiratory problems (14%), MODS (11%), hepatorenal syndrome (9%), VOD (6%), drug toxicity (4%). 16% had no single identifiable diagnosis. CRRT indications were fluid and electrolyte abnormalities combined (48%), or FO (38%) or electrolyte abnormalities (12%) alone.18 pts survived (40%). 2003 vs. 2004 survival rates were 36% vs. 42%, (p = 0.75). Ventilated pts had lower survival rates (31% vs. 67%, $p < 0.05$). These ppCRRT Registry BMT pt data show (1) negligible recent improvement in pt survival (2) no difference between S and NS in % FO or Paw at CRRT initiation, but (3) significant improvement in pulmonary status by the end of CRRT. We suggest while early CRRT initiation to keep FO <20% may be important for BMT pt survival, further survival improvement may not be achieved with stricter fluid management alone but rather requires more effective prevention and treatment of pulmonary dysfunction.

	Survivors	Non-survivors	P value
Age (yrs)	11.3 ±1.73	9.78 ±1.44	0.55
Weight (kg)	43.10 ± 6.67	38.26 ± 5.69	0.58
Initial PRISM 2	10.46 ± 1.78	13.91 ± 1.31	0.12
Initial paw	15.5 ± 2.52	17.76 ± 1.74	0.46
FO at CRRT (%)	11.38 ± 7.0	14.61 ± 5.88	0.72
GFR	49.14 ± 8.52	63.24 ± 7.27	0.21
CVP (cm H_2O)	13.87 ± 2.15	15.18 ± 1.52	0.62
Number of pressors	0.6 ± 0.3	1.13 ± 0.24	0.20
Time ICU to CRRT (days)	1.17 ± 0.28	1.94 ± 0.33	0.08
CRRT duration (days)	7.37 ± 2.92	15.04 ± 2.43	0.05
UF volume (ml)	75208 ± 19217	61405 ± 16028	0.58
Paw at end CRRT	8.44 ± 2.69	26.06 ± 2.02	<0.05

All values are mean ± SE.

clinicians' efforts in achieving dosing targets proposed in recent literature.

18

Impact of CRRT Circuit Design on Achievable Blood Flows in ARF Patients

G. Friederichs[1], P. Murray[2], D. Treu[1]

[1]NxStage Medical Inc., Lawrence MA, [2]University of Chicago, Chicago IL, USA

Purpose: Recent studies highlight the clinical benefits of high volume convective CRRT (>35 ml/kg/hr, or nearly 65 liters daily in a 75 kg patient). Other publications have advocated even higher doses of convective therapy for patients with sepsis. Higher blood flows aid in achieving these targets. Although blood flows between 200 and 300 ml/min are routinely achieved in ARF patients using conventional intermittent equipment, prevalent blood flows in CRRT are generally lower (180 ml/min or below). Achievable blood flows are limited by venous access performance, but they are also influenced by extracorporeal circuit design. In particular, resistance in the arterial (or draw) line limits flow potential. Lower resistance leads to lower negative pressures at a given flow rate, and thus higher achievable blood flows from a given access. The System One employs a unique circuit designed to minimize resistance and facilitate higher blood flows. This study compares NxStage flow performance versus prevalent CRRT equipment. **Methods:** A 49% wt glycerin in water solution warmed to 37 dC was recirculated by the System One (NxStage Medical) and the Prisma System (Gambro). 16 gauge fistula needles connected to the arterial and venous blood lines were used to simulate patient access. Flow rates were increased and the corresponding arterial pressure was measured for arterial pressures of up to −200 mmHg. Actual blood flow rates were measured using a transonic flow meter (Transonic Systems Inc.). **Results:** At the same nominal blood flow rates, the System One arterial pressures were significantly lower than those of the Prisma System (>60% lower, p < 0.005) from identical vascular access. This translates into 60–74% higher actual blood flows for the System One at any given arterial pressure (see figure). In the low resistant flow design of the System One Cartridge, the arterial pressure as measured by the system closely reflects the actual access pressure. **Conclusion:** The NxStage circuit design allows a higher blood flow from a given patient access. This capability may aid
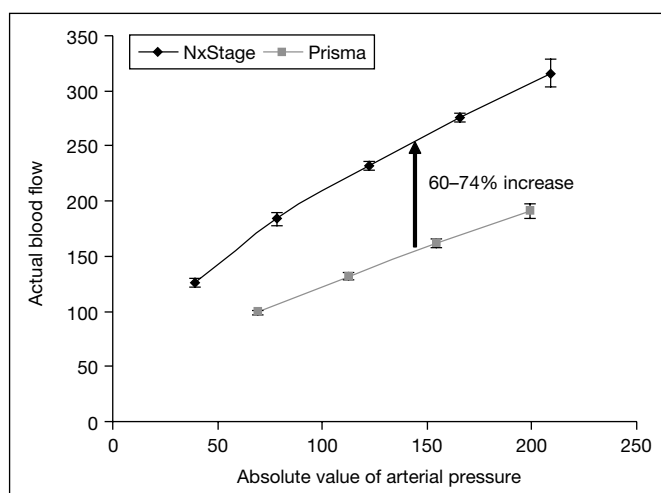
19

Accurate Fluid Balancing With a Novel Volumetric Control System

G. Friederichs[1], P. Murray[2], M. Kraus[3], K. Ellsworth[1]

[1]NxStage Medical Inc., Lawrence MA, [2]University of Chicago, Chicago IL, [3]Indiana University, Indianapolis IN, USA

Purpose: Recent publications describe benefits of high volume CRRT therapy (>35 mL/kg/hr, or nearly 65 L daily for a 75 kg patient). As volume increases, so does the importance of accurate fluid balancing. In addition, ease of fluid handling is essential to minimize nursing interventions. Scale-based systems, prevalent today, are accurate but have shortcomings exacerbated in high volume applications. Effluent must be collected to monitor balance. Scale capacity limitations make frequent solution and effluent bag changes necessary. In addition, scales are sensitive to user error, movement, and other operating environment disturbances. The System One from NxStage Medical incorporates a novel continuous volumetric balancing approach and the ability to deliver high volumes of therapy (Q_b: up to 600 mL/min, Q_{uf}: up to 14.4 L/hour). Volumetric balancing eliminates the need to collect effluent and thus reduces the frequency of fluid-related interventions. Incorporating the volumetric balancing circuit into a disposable cartridge simplifies setup and maintenance. This study characterizes the accuracy of this system under intensive care therapy conditions. **Methods:** In-vitro conditions were defined to represent high-volume CRRT (64 liters over 24 hours), 'conventional' volume CRRT (44 liters over 24 hours) and extended daily therapy (44 liters over 12 hours). The 'patient' was simulated using a measured volume of fluid. Each condition was repeated 6 times (twice each on three NxStage systems). Blood flows were 250 mL/min, and 4 kg of net fluid removal was targeted. **Results:** Accuracy is expressed as the difference between actual and targeted patient weight at the end of the

simulation, both in absolute volume and as a percentage of therapy volume. In all tests, daily fluid balance was accurate within 0.5 kilogram. Average hourly fluid balancing accuracy was 9.2 ± 14.8 mL/hr. This performance compares favorably with specifications of common scale-based systems, despite the higher therapy volumes and flow rates evaluated. **Conclusion:** Volumetric control as practiced by the NxStage System One provides accurate fluid balancing in a simplified format that minimizes fluid-related interventions.

Condition	N	Difference = Actual vs. Target Average ± Stdev (kg)	Percentage of total therapy volume Average ± Stdev (%)
Conventional volume CRRT (44 L)	6	0.01 ± 0.21	0.03 ± 0.34
High volume CRRT (64 L)	6	0.10 ± 0.23	0.15 ± 0.36
Extended daily therapy (44 L)	6	0.28 ± 0.18	0.63 ± 0.48
Overall	18	0.13 ± 0.23	0.27 ± 0.48

20

Pediatric CRRT for Multiorgan Dysfunction Syndrome (MODS): A Prospective Pediatric (PPCRRT) CRRT Registry Group Report

S.L. Goldstein, J.M. Symons, M.J.G. Somers, M.A. Baum, P.D. Brophy, D.L. Blowey, F.X. Flores, T.E. Bunchman, R.M. Hackbarth, J.D. Mahan, D.H. Chand, S.R. Alexander, A.N. Chua, K.D. McBryde, J.D. Fortenberry

The ppCRRT Registry Group, Houston, Texas, USA

Purpose: Most previous pediatric (ped) CRRT studies report a retrospective single-center experience without severity of illness (SOI) assessment. **Methods:** From 1/1/01 to 11/30/2004, the ppCRRT Registry has collected data from 294 critically ill ped patients (pt) who received 45,983 hours of CRRT at 13 US centers and used Pediatric Risk of Mortality (PRISM 2) score to control for SOI. Each center followed local practice for CRRT initiation (CRRTinit), modification and termination of CRRT. Survival was defined as discharge from intensive care unit (ICU). This abstract reports data for the 181 ppCRRT Registry pt with MODS. **Results:** Sepsis (28.7%) and cardiovascular shock (16.0%) were the most common primary diseases associated with acute renal failure leading to CRRT. Complete outcome data were available for 177 MODS pt. 90/177 (50.8%) pt survived to ICU discharge. Pt age, weight, GFR, pressor number, and PRISM 2 score did not differ between survivors (S) and non-survivors (NS) at ICU admission (ICUadm). Mean percent fluid overload (% FO) and PRISM 2 at time of CRRTinit were lower for S vs. NS (Table). % FO was lower (p < 0.01) for S vs. NS when controlled for SOI by PRISM 2 at CRRTinit. Survival rates were no different for pts on 0–1 (50%), 2 (53%) or 3+ (45%) pressors at CRRTinit. Survival rates were better (p < 0.001) for pts <20% FO (61%) vs. >20% FO (32%) at CRRTinit. **Conclusion:** Our ppCRRT data show: (1) similar clinical variables for S vs. NS at time of ICU admit and (2) PRISM 2 score and % FO at CRRTinit were worse for NS vs. S. We suggest that (1) greater degrees of % FO might lead to worse SOI and (2) 'early' initiation of CRRT at 10–20% FO coupled with preferential use of pressors over volume might lead to improved survival in critically ill children with MODS.

	S	NS	p
PRISM at ICU admit	14.4 ± 8.8	16.3 ± 9.9	NS
PRISM at CRRTinit	15.5 ± 8.3	19.5 ± 8.2	0.003
Age (years)	8.9 ± 6.8	7.9 ± 7.3	NS
Weight	34.6 ± 25.2	30.1 ± 29.8	NS
Paw at CRRTinit (mmHg)	16.5 ± 7.8	18.7 ± 9.0	NS
CVP at CRRTinit	16.3 ± 6.3	17.9 ± 8.5	NS
Pressor number at CRRTinit	1.4 ± 1.0	1.6 ± 1.1	NS
GFR at CRRTinit	37.7 ± 34.4	38.4 ± 29.8	NS
% FO at CRRTinit	13.9 ± 15.2	32.1 ± 30.1	<0.005

21

Effect of Continuous Veno-venous High Volume Hemofiltration in Treatment of Severe Acute Pancreatitis With Multiple Organs Disfunction Syndrome

J. Daxi, G. Dehua, L. Leishi

Research Institute of Nephrology, Jinling Hospital, Nanjing University School of Medicine, Nanjing, P.R. China

Objective: To investigate the effect of continuous veno-venous high volume hemofiltration (CVVHVHF) in treatment of severe acute pancreatitis (SAP) with multiple organ dysfunction syndrome (MODS). **Methods:** Forty-three SAP patients with MODS involved, including 28 males and 15 females, with average age of 49.6 (27–73) years. The APACHE II score of the patients was 14.14 ± 3.62, the CT severity score was 8.5 ± 1.4. CVVHVHF was started 5.9 ± 6.3 days after onset of disease and sustained for at least 72 hours, AN69 hemofilter ($1.2 \, m^2$) was changed every 24 hours. During CVVHVHF the ultrafiltration rate was 4 L/h, blood flow rate was $250 \sim 300$ ml/min, and the substitute fluid was infused with pre-dilution. Low molecular weight heparin was used for anticoagulation. **Results:** CVVHVHF was well tolerated in all the patients. 34 of the patients were cured, 6 patients died and 3 of the patients quitted for financial reason. The ICU mortality was 14.0%. Body temperature, heart rate and breath rate decreased significantly after CVVHVHF. APACHE II score was 14.1 ± 3.6 before CVVHVHF, and was 9.5 ± 4.0 after CVVHVHF, which decreased significantly (P < 0.01). Partial pressure of oxygen in arterial blood before CVVHVHF was 68.0 ± 13.6 mmHg, and increased significantly after CVVHVHF, which was 91.3 ± 22.2 mmHg (P < 0.05). During CVVHVHF the hemodynamics were stable, and serum potassium, sodium, chlorine, glucose and pH were at normal level. **Conclusion:** In SAP patients with MODS, CVVHVHF can improve the temperature, the heart rate, the respiratory rate, the APACHE II score, and the PaO_2 markedly. CVVHVHF may become one of the assistant therapies to improve the outcome.

22

The Clinical Application of a New CRRT Machine: HF400

T. Jing, J. Daxi, G. Dehua, X. Bin, R. Bin, L. Yun, Z. Yidan, J. Zhonghua, L. Leishi

Research Institute of Nephrology, Jinling Hospital, Nanjing University School of Medicine, Nanjing, P.R. China

Objective: To perform a clinical trial for a new continuous renal replacement therapy (CRRT) machine, with emphasis on the accuracy of volume control in clinical running. **Method:** Twenty-four inpatients in the Research Institute of Nephrology, Jinling Hospital were enrolled in this study. The causes for needing CRRT included acute renal failure (ARF) and chronic renal failure (CRF) complicated with heart failure or edema. Continuous veno-venous hemofiltration (CVVH) was performed in these patients using HF400 CRRT-machine and AV600s filters, with substitute fluid rate 3–4 L/h, duration for 6–8 hours. Serum level of urea, creatinine, uric acid, and electrolytes such as potassium, sodium and chloride before and after CVVH were evaluated in these patients. During CVVH, prescribed treatment dose, net ultrafiltration volume, and delivered treatment dose, delivered net ultrafiltration volume were recorded. **Results:** All the patients tolerated CVVH therapy well. Reduction rate of serum urea, creatinine, uric acid after CVVH were $42 \pm 11\%$, $41 \pm 12\%$ and $56 \pm 8\%$, respectively. Serum electrolytes levels were maintained in stable range. The difference percentage between prescribed dose (28.6 ± 3.7 L) and delivered dose (27.8 ± 3.4 L) was $2.9 \pm 2.1\%$. The difference percentage between prescribed net ultrafiltration volume (2748 ± 969 ml) and delivered net ultrafiltration volume (2554 ± 819 ml) was $7.1 \pm 4.8\%$. The deviation rate of total volume control was $0.56 \pm 0.45\%$. **Conclusions:** HF400CRRT machine is safe and effective, with excellent accuracy of volume control in clinical applications.

23

Non-renal Indications for Continuous Renal Replacement Therapy (CRRT): A Report from the Prospective Pediatric CRRT (ppCRRT) Registry Group

K.D. McBryde, J.M. Symons, M.J.G. Somers, M.A. Baum, P.D. Brophy, D.L. Blowey, F.X. Flores, T.E. Bunchman, R.M. Hackbarth, J.D. Mahan, D.H. Chand, S.R. Alexander, J.D. Fortenberry, A.N. Chua, S.L. Goldstein

The ppCRRT Registry Group, Houston, TX, United States

Purpose: From 1/1/01 to 11/24/04, the ppCRRT Registry has collected data from 292 pediatric patients (pts) at 12 U.S. centers. The current abstract reports data for 25 ppCRRT Registry pts who received CRRT for non-acute renal failure indications. **Methods:** The ppCRRT is a prospective observational registry of 12 pediatric centers. Each center follows local practice for CRRT initiation, modification and termination. **Results:** There were 5 treatments for intoxications, 8 for tumor lysis syndrome, 11 for hyperammonemia,

and 1 for hyponatremia. There were 8 females and 17 males. Survival to ICU discharge was 74%. Pt age, weight, PRISM 2 score at ICU admit, calculated GFR, presence of multiorgan dysfunction syndrome (MODS), % fluid overload (FO), or mean airway pressure (MAP) at initiation or end of CRRT did not differ between survivors (S) and non-survivors (NS). Only PRISM 2 at the time of CRRT initiation and the use of vasopressors were significantly lower for S vs. NS. **Conclusions:** Our ppCRRT data demonstrate a significant association between the PRISM2 score at the initiation of CRRT and the use of vasopressors with pt non-survival from CRRT treatment for non-renal indications. There is a clinical trend towards pts non-survival and the PRISM2 at ICU admission. Overall pt mortality was low, with 74% of patients surviving to ICU discharge. We conclude that CRRT is a useful adjunct in the treatment of metabolic disorders in the absence of renal failure.

Clinical measures of survivors vs. non-survivors

	S (N = 19)	NS (N = 6)	p-value
Age (months; median ± SD; range)	38.0 ± 87.9 (0.13–215)	23.2 ± 107.5 (0.1–275)	0.75
Weight (kg; median ± SD; range)	29.0 ± 25.2 (1.3–78.7)	8.3 ± 47.7 (1.3–118)	0.34
PRISM 2 at ICU admit	14.9 ± 12.2	24.2 ± 11.0	0.09
PRISM 2 at CRRT start	16.8 ± 12.1	28.8 ± 9.8	0.03*
Calc GFR	52.1 ± 38.3	62.6 ± 48.0	0.64
MODS (Y/N)	2/14	2/4	0.24
% FO at CRRT start	2.9 ± 6.1	8.1 ± 6.1	0.11
Vasopressor (Y/N)	3/16	5/1	0.01*
MAP at CRRT start	8.6 ± 2.4	8.2 ± 6.3	0.88
MAP at CRRT end	6.3 ± 4.8	12.9 ± 7.5	0.09

* = 2-sided p-value <0.05.

24

Continuous Renal Replacement Therapy (CRRT) in Children $<$10 Kilograms: A Prospective Pediatric Continuous Renal Replacement Therapy (ppCRRT) Registry Group Report

M.J.G. Somers, S.L. Goldstein, J.M. Symons, P.D. Brophy, D.L. Blowey, F.X. Flores, K.D. McBryde, T.E. Bunchman, R.M. Hackbarth, J.D. Mahan, D.H. Chand, S.R. Alexander, J.D. Fortenberry, A.N. Chua, M.A. Baum

The ppCRRT Registry Group, Houston, Texas, USA

Although CRRT is used increasingly in small children, limited data examines its efficacy and outcome in this population. Using the

ppCRRT Registry, we analyzed data from all 69 children <10 kg (60% boys; median age 69 days; median weight 4.2 kg) who underwent CRRT. 80% underwent CRRT for fluid overload and electrolyte imbalance with a median % fluid overload (% FO) at CRRT start of 9%. 19% had an underlying inborn error with a dialyzable metabolite. 96% were dialyzed via dual or triple lumen 7–12.5 F catheters with 58% of catheters femoral in placement, 28% internal jugular, and 12% subclavian. 12 children received CVVH, 45 CVVHD, and 11 CVVHDF. Median blood flow was 7.5 ml/kg/min with median dialysate or replacement fluid rates of 2300 ml/hr/1.73M2. CRRT duration ranged from 0–83 days (median 4 days). Compared to all children >10 kg in the CRRT Registry (n = 207), survival in children <10 kg was lower (43% vs. 63%; p < 0.01). In comparing non-survivors <10 kg (NS) to survivors <10 kg (S), there was no difference in gender, age, weight, residual GFR, time in ICU prior to CRRT, length of ICU stay, duration of CRRT, modality of CRRT, or degree of filtration. Compared to S, NS were more likely to have underlying GI/hepatic disease than underlying cardiac, metabolic, oncologic, or intrinsic renal disease (p < 0.02); were more likely to have MODS (89% vs. 68%); were more likely to be pressor dependent throughout CRRT (80% vs. 50%; p = 0.03); and had higher median PRISM scores at ICU admit (21 vs. 16) and CRRT start (24 vs. 20). NS also had less urine output for the day pre-CRRT start (0.4 vs. 1.2 ml/kg/hr; p=0.05); were more likely to have >10% FO at CRRT start (71% vs. 43%; p = 0.03); and at CRRT end were more likely to have higher Mean Airway Pressures (18 vs. 10, p < 0.001). We conclude that in children <10 kg undergoing CRRT: (1) Technically adequate vascular access and filtration circuits are achieved; (2) Overall survival rates are lower than larger children; (3) Presence of GI disease and pressor dependency are poor prognostic features; (4) Volume overload as represented by decreased urine output, greater % FO, and higher MAP portends significantly worse outcomes.

25

Affect of Continuous Veno-venous Hemofiltration on Plasma Cytokines in Patients With Severe Acute Pancreatitis

Y. Chen, L. Zhihong, C. Zhaohong, G. Dehua, J. Daxi, L. Leishi

Research Institute of Nephrology, Jinling Hospital, Nanjing University School of Medicine, Nanjing, P.R. China

Objective: To determine whether continuous veno-venous hemofiltration leads to extraction of pro-inflammatory cytokines including tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6) and anti-inflammatory cytokine IL-10 from the circulation of critical patients with severe acute pancreatitis, and its effect on plasma cytokine concentrations. **Methodology:** Twelve patients with severe acute pancreatitis including 6 cases of SIRS and 6 of sepsis were observed in this study. All of them underwent continuous high volume veno-venous hemofiltration (CVVHVHF) for 72 hours using a polyacrylonotrile filter (1.6 m^2, AN69). The ultrafiltrate rate was set at 4000 ml/h and blood flow at 250 ~ 300 ml/min; and the substitute fluid were infused with pre-dilution. Hemofilter was changed every 24 hours. Blood were taken from the patients at 0, 2, 6, 12, 24, 48 and

72 h during CVVHVHF. The ultrafiltrate were taken simultaneously. Peripheral monocytes were isolated and stimulated with LPS to detect the ability of production of cytokines. The levels of TNF-α, IL-6 and IL-10 were tested by ELISA in the supernatant, ultrafiltrate and plasma. **Results:** (1) All of those cytokines were be adsorbed. After 12 hours using a new filter, the adsorption was significantly decreased. (2) The major cytokine in the ultrafiltration was IL-6, the SC of IL-6 was 0.0881 ± 0.0711. The amount of IL-6 in the ultrafiltration had a positive correlation with the concentration in the plasma ($r = 0.4637$, $P < 0.001$). (3) After CVVHVHF treatment, the plasma cytokines' levels in the most of the patients with SIRS were decreased, as same as the cytokines' production of these patients. The plasma cytokines' levels in the most of the patients with sepsis were no markedly changed, not as the status of cytokines' production. **Conclusion:** (1) Adsorption is the major method of cytokines' clearance. The ability of adsorption was gradually decreased when 12 hours used. All three cytokines can be adsorbed. (2) IL-6 was the major cytokine detected in the ultrafiltration. The amount of IL-6 in the ultrafiltration had a positive correlation with the concentration of plasma. (3) The levels of plasma cytokine were influenced by the balance of production and clearance of cytokines. CVVHVHF has an affect on both production and clearance of cytokines.

26

Clinical Application and Effects of The Protein A-Based Immunoadsorption

J. Daxi, G. Dehua, R. Bing, X. Bing, L. Yun, Z. Yidan, X. Honglang, T. Jing, H. Weixing, L. Zhihong, L. Leishi

Research Institute of Nephrology, Jinling Hospital, Nanjing University School of Medicine, Nanjing, P.R. China

Objective: To observe the clinical application and effect of immunoadsorption in severe patients treated by a native protein A-based apparatus. **Methodology:** Thirty-six patients with various diseases including 7 cases of systemic lupus erythematosus (SLE), 5 anti-glomerular basement membrane (GBM) disease, 10 acute rejection after renal transplantation, 7 liponephropathy, one case due to high panel reactive antibodies (PRA) level (before receiving a second renal transplantation), one membranoproliferative glomerulonephristis, one Henoch-Schönlein nephritis, one cryoglobulinemic glomerulonephristis, one Sjögren's syndrome, one Guillain-Barre's syndrome and one case of drug intoxication were enrolled this study. All of them received immunoadsorption using a native genetic recombination protein A-based apparatus (WCXJQ blood purification apparatus). In total 204 courses of immunoadsorption were performed in 36 cases, and average courses per case were 5.67 times. Treated plasma volume summed to (6142.3 ± 112.09)L. **Results:** The combination rate of immunoglobulin and completement by blood single passing through the immunoadsorption column was (95.1 ± 4.0)% for IgG, (38.8 ± 10.3)% for IgM, (25.2 ± 13.7)% for IgA, (14.1 ± 9.4)% for C_3, and (12.1 ± 0.71)% for C_4. The mean reduction rate of serum level after each treatment was (63.1 ± 16.5)% for IgG, (25.2 ± 13.7)% for IgA, (30.8 ± 10.3)% for IgM, (14.1 ± 9.4)% for C_3, and (12.1 ± 10.7)% for C_4. Remissions were found in 7 SLE patients after treatments, with ANA and anti-ds-DNA

antibody changing to negative in 50% patients. Among 5 patients with anti-GBM disease, 3 presented with anti-GBM antibody negative after treatments till to 4 months, one presented with antibody reducing by 62.8% after the first period of treatments, and reducing to negative after the second period of treatments, one of four patients requiring hemodialysis before immunoadsorption treatments recovered renal function and indepanded on hemodialysis after treatments. 6 of 10 patients with acute rejection post-transplantation obtained normal renal function after treatments, and 4 lost grafts. Immunoadsorption therapy decreased high level of PRA in one patient who received a second transplantation, and whose graft function remained stable in two-years follow-up period. Serum apoE level decreased, and proteinuria decreased significantly in 7 patients with liponephropathy after treatments. The improvements of clinical conditions and renal function by immunoadsorption were observed in all the other patients except one with drug intoxication. **Conclusion:** Native protein A-based immunoadsorption appraratus is effective in removal of IgG and other immunoglobulin, completement, and is contributed to alleviation of some damages resulted from active autoimmune diseases. Less cost and few complications will make it more widely applied in clinical practice.

27

Comparison of Heparin or Citrate Anticoagulation in Normal Swine Supported With the Renal Assist Device (RAD)

R. DaSilva[1], N. Jones[1], K. Howk[2]

[1]Nephros Therapeutics, Lincoln, RI, [2]Charles River Laboratories, Southbridge, MA, USA

Citrate anticoagulation is used as an alternative to heparin anticoagulation in patients treated with continuous veno-venous hemofiltration (CVVH). Citrate inhibits clotting by reducing calcium concentrations. The RAD is a device containing hollow fibers lined with cultured human renal epithelial cells (HREC), and it is under evaluation in clinical trials in patients with acute tubular necrosis. Preclinical and ongoing clinical evaluations of the RAD have used heparin-based anticoagulation. The purpose of this preclinical study in swine was to assess the integrity and physical functionality of the RAD when maintained in calcium concentrations similar to those present in CVVH patients anticoagulated with citrate. Secondary purposes were to assess the safety of citrate anticoagulation, and the effects of citrate on biochemical parameters. Renal Bio-Therapy is performed with CVVH and the RAD. The patient's blood first enters a conventional hemofilter. As in normal continuous renal replacement therapy (CRRT), the filter separates the blood into components capable of passing through the filter (hemofiltrate) and the non-filterable components (large molecular weight and cellular components). The hemofiltrate is then passed through the fibers of the RAD. The cellular and large molecular weight components circulate on the outside of these fibers. The renal cells grown on the inside of the fibers are intended to communicate with cellular components through the membrane. The circuit is designed to perform like an artificial nephron responding to hemofiltrate and blood components across the hollow fiber membrane. Four normal, swine (approx 70 kg body weight)

were anesthetized, intubated, and maintained on a CVVH and RAD circuit. Two pigs were anticoagulated with heparin, and two with citrate. The duration of RAD treatment was six hours. Physiologic and biochemical measurements were collected over the course of experimental treatment. The animals tolerated the study procedures well. Preliminary results show citrate and heparin anticoagulation are similar in terms of biochemical measurements and the maintenance of a functional RAD circuit and RAD cellular integrity. Detailed study results will be presented.

28

Demographic Characteristics of Pediatric CRRT: A Report of the Prospective Pediatric Continuous Renal Replacement Therapy (ppCRRT) Registry Group

J.M. Symons, M.J.G. Somers, M.A. Baum, T.E. Bunchman, P.D. Brophy, D.L. Blowey, J.D. Fortenberry, D.H. Chand, F. X. Flores, R.M. Hackbarth, S.R. Alexander, A.N. Chua, J.D. Mahan, K.D. McBryde, S.L. Goldstein

The ppCRRT Registry Group, Houston, Texas, United States

Since 1/1/01, 293 patients from 13 US centers have been enrolled in the ppCRRT registry. We now report demographic characteristics and outcomes for 273 patients with complete data. Ages were newborn to 25 years, 59% males, weights 1.3–160 kg (mean 32.7 kg, median 23.9 kg). Subjects averaged 6.5 days in ICU prior to CRRT (range 0–202, median 2). At CRRT initiation, 45% were on diuretics and 65% were on vasoactive drugs. The table lists indications for CRRT and principal diagnoses. 30% received CVVH alone; 52% received CVVHD alone; others received multiple modalities. Mean blood flow (Q_B) was 98.8 ml/min (range 10–350 ml/min, median 100 ml/min); mean Q_B per body weight was 5.1 ml/min/kg (range 0.4–53.6 ml/min/kg, median 4.2 ml/min/kg). Days on CRRT were <1–83 (mean 8.3; median 6). Overall survival was 57%. Survival was lowest when CRRT was started for combined fluid overload and electrolyte imbalance. There was better survival in subjects with principal diagnoses of drug toxicity, tumor lysis syndrome, hypovolemic shock and renal failure; survival was lowest in liver disease and bone marrow transplant. There were no survivors past 40 days of CRRT; only two subjects receiving CRRT past 28 days survived. Survivors and non-survivors were not significantly different for other reported demographic data. We conclude that CRRT can be used successfully for a wide range of critically ill pediatric patients and that patient survival is best for those with acute, specific abnormalities who lack multiple organ involvement. Earlier use of CRRT may lead to better outcomes; sicker patients with selected diagnoses may have lower survival.

	N	Survivors	Non-survivors	% Survival
Indications for CRRT				
Fluid overload and electrolyte imbalance	121	60	61	50
Fluid overload only	78	50	28	64
Electrolyte imbalance only	37	23	14	62
Prevent fluid overload to allow intake	9	6	3	67
Other	28	18	10	64
Diagnoses				
Sepsis	59	34	25	58
Bone marrow transplant	43	19	24	44
Cardiac disease/transplant	31	17	14	55
Malignancy (no tumor lysis syndrome)	24	13	11	54
Renal failure	20	14	6	70
Liver disease/transplant	19	7	12	37
Hypovolemic shock	17	12	5	71
Inborn error of metabolism	16	9	7	56
Pulmonary disease/failure	12	7	5	58
Tumor lysis syndrome	11	9	2	82
Drug toxicity	9	9	0	100
Other	12	7	5	58

Technique Characteristics

29

A New Technique and Percutaneously for the Placement of CAPD Catheters Early Complications

A. Borazan, M. Comert, M. Sert

Zonguldak Karaelmas, Niversitesi, Zonguldak, Turkey

Purpose: Starting continuous ambulatory peritoneal dialysis (CAPD) immediately after insertion of peritoneal dialysis catheter is essential in end-stage renal disease (ESRD). In this reason, some mechanics and infectious complications can be come in existance because of used method. In this study, we aimed to compare early complications of percutan method and laparoscopic preperitoneal tunnelling method which was improved for to reduce complication by us. **Subjects and Method:** Preperitoneal tunnelling method: After induction of general anesthesia and gastric decompression, the patient was placed in a supine position. The pneumoperitoneum was achieved using a Veress needle placed at the mid-claviculer costal margin (Palmer's point). The abdomen was insufflated to 15 mmHg pressure, and a 5 mm nondisposable metal port was introduced into the peritoneal cavity at the initial Veress location. The peritoneum was then evaluated using the 3.3 mm, 0o minilaparoscope (Karl Storz, Model 26007AA, Tuttlingen, Germany). A 5 mm left-lower-quadrant incision was made at the preferred exit site for the peritoneal dialysis catheter. Next, another 5 mm nondisposable metal trocar was introduced into the peritoneal cavity for intra-peritoneal manipulations. After that, a 4 mm vertical skin incision was made at a point approximately 2 cm left and inferolateral to the umbilicus. A Veress needle was moved ahead slowly until the tip of needle reached the preperitoneal space without puncturing the peritoneum under direct vision. Then, 10 ml of isotonic saline solution infused into this space to obtain a secure initial dissection. After removal of the Veress needle, the subcutaneous tissue, rectus abdominis sheat and the muscle dissected blindly with a Kelly clamp until the tip of clamp was inserted into the preperitoneal space. From this incision, a double-cuff Tenckhoff peritoneal dialysis catheter (Quinton Instrument Company, Seattle, WA, USA) was inserted with the metal guidewire until the tip of catheter was introduced into the preperitoneal space. And then, it was directed to the pubic symphysis through the preperitoneal space parallel to the peritoneum. Because preperitoneal space is filled with avascular fat tissue and loose areolar tissue, we performed this procedure very easy and it took only a few seconds to create a preperitoneal tunnel without any complication. At the level of pubic symphysis, a 3–4 mm of incision was made on the peritoneum overlying the superior border of bladder with the help of an endoscopic scissors, and the CAPD catheter was passed through this opening. After the placement of the catheter tip into the retrovesical pouch, the guidewire was removed. We did not place any suture to the fascia at the insertion site of the catheter to avoid leakage. After the camera was removed, the pneumoperitoneum was terminated. Neither the fascia at the camera port nor the fascia at the second port was sutured. Thus, after the body of catheter was passed through the preperitoneal tunnel which was 25–30 cm in length, only the catheter tip portion with multiple holes was left into the pelvis. A total of 42 patients had diagnosed as end stage renal disease (ESRD), 12 of them who had placed peritoneal catheter with laparoscopic preperitoneal tunnelling method and 30 of them who placed peritoneal catheter percutaneously from April 2003 to July 2003. All patients complete six months in CAPD. Mechanic and infectious complications in these cases at first six months were compaired. **Results:** In all cases, CAPD was immediately started after operation. No operative morbidity was seen. Early leakage 10%, pericatheter bleeding 3.3% and hernia 3.3% occurred in percutaneously method while any mechanic complication was seen in laparoscopic preperitoneal tunnelling method. Infectious complications were seen peritonitis one episode/36 patients-months in laparoscopic preperitoneal tunnelling method and peritoniris one episode/22.5 patients-months. Catheter exit site infection was not seen laparoscopic preperitoneal tunnelling method while in percutanously method was seen one episode/180 patient-months. Tunnel infection was not seen any patient. **Conclusion:** We believe that laparoscopic preperitoneal tunnelling method is a new technique which was improved and used rutinly by us are quite safe for early complications.

30

Tunnelled Femoral Catheters Improve Renal Replacement Therapy Efficiency in ICU-Acute Renal Failure

L. Amigues[1], K. Klouche[1], P. Massanet[1], S. Deleuze[2], B. Canaud[2], J.J. Beraud[2]

[1]Intensive Care Unit, Lapeyronie University Hospital, Montpellier, France, [2]Nephrology Care Unit, Lapeyronie University Hospital, Montpellier, France

Introduction: In ICU-acute renal failure, the relationship between survival and delivered dose lead to optimize dialysis modalities and

efficiency. The discrepancy observed between prescribed and delivered dose may be due for a part to vascular acces through recirculation and catheter dysfunction. This randomised study was undertaken to compare tunnelled (TKT) and non tunnelled (NTKT) femoral catheters in term of dialysis dose : Kt/V and effluent rate. **Methods:** 30 patients with acute renal failure (APACHE II: 30.2 ± 6.2) treated by intermitent hemodialysis (IHD) and/or continuous hemodiafiltration (HDF) were randomised for vascular access: TKT (2 soft silicone polymere catheters: Twincath, MedComp, Harleysville, USA) or NTKT (2 polyurethane catheters: MedComp). IHD modalities: Nephral 400 ST (Hospal) $1.65 m2$ AN69 membrane; dialysat flow rate: $500 ml/mn$ and blood flow rate: 200 or $300 ml/mn$. HDF modalities: Prisma (Hospal), pre-set 100 (AN69 $0.9 m2$ membrane), blood flow rate: $180 ml/mn$, effluent flow rate (infusat + dialysat): $66.7–75 ml/mn$. Dialysis dose was assessed in IHD by prescribed Kt/V (pKt/V calculated from in-vitro clairance), delivered Kt/V (dKt/V; Daugirdas IIsp), % Kt/V = (dKt/V/pKt/V)*100 and in HDF by daily prescribed and delivered effluent rate (pQef and dQef) and % Qef = (dQef/pQef)*100. KT performance was assessed during IHD by recirculation, hourly return venous pressure (RVP), hourly effective blood flow (eQB) and its ratio % QB from prescribed blood flow and by RVP/eQB ratio. Time of insertion was assessed for each catheter. A potential thrombosis or/and catheter's infection were investigated every week. In cases of infection, thrombosis or dysfunction, the catheter was removed. The number of catheters used for each patient (Np) was collected. All data were compared between TKT and NTKT. **Results:** Insertion of TKT was impossible in 4 patients. Time of insertion was 45.6 ± 27.5 mn vs. 22.8 ± 14 mn ($p < 0.05$) and recirculation $10.6 \pm 9.5\%$ vs. $9.4 \pm 5.1\%$ for TKT and NTKT (NS) respectively. 142 IHD (dKt/V = 1.14 ± 0.3) and 90 HDFz (eQef = 50.5 ± 11.9 ml/mn) sessions were analysed. **Conclusions:** Compared to conventionnal femoral catheters, soft tunnelled silicone catheters decrease significantly the discrepancy between prescribed and delivered dialysis dose and therefore improve it whether in IHD or in HDF. Difficulties and time of insertion may however limit their use in life-threatening situation like hyperkalemia or uncontrolled acidosis. Nonetheless, tunnelled catheter's performance and tolerance make them useful to optimize renal replacement therapy for long term hemodialyzed ICU-acute renal failure.

	NTKT (15 patients)	TKT (15 patients)	p
HDF sessions, n	48	42	
IHD sessions, n	59	83	
Hematoma, n	2	5	<0.05
Infection, n	2	1	NS
Thrombosis, n	1	0	NS
Np, n	1.93 ± 1.09	1 ± 0	<0.01
% QB	98.7 ± 4.8	99.8 ± 1.4	NS
RVP/eQB	0.67 ± 0.14	0.62 ± 0.12	<0.05
% Kt/V	83.8 ± 14.7	104.5 ± 23.1	<0.01
% Qef	82.5 ± 14.3	88.9 ± 10.6	<0.01

31

A Simple Trisodium Citrate Protocol that Provides Metabolic Control and High Solute Clearance in Continuous Renal Replacement Therapy: An Update

R.R. Speer, M.B. Prendergast, A.J. Tolwani

University of Alabama at Birmingham, AL, USA

Background: Continuous renal replacement therapy (CRRT) with a high ultrafiltration rate of 35 mL/kg/hr has recently been associated with improved survival in critically ill patients with acute renal failure. Its application is limited by the need for anticoagulation and specialized custom-made CRRT solutions. Although regional anticoagulation with citrate has gained acceptance for CRRT, there are no published protocols that can achieve excellent metabolic control, effective anticoagulation, and high ultrafiltration rates by a simplified method. We developed a simple protocol using only three solutions, a standardized bicarbonate-based dialysate, a standardized 0.67% trisodium citrate replacement solution, and a systemic calcium infusion, with the aim of providing adequate anticoagulation and metabolic control at high effluent rates without requiring frequent changes to the composition of the fluids or membrane filters. **Methods:** We retrospectively evaluated the metabolic control and adequacy of anticoagulation with CRRT using this protocol in 24 critically ill patients at effluent rates of 35 mL/kg/hr. **Results:** Kaplan-Meier curve demonstrates 80% dialyzer filter survival at 48 hours, with no episodes of bleeding or citrate toxicity. **Conclusion:** These standardized solutions provide adequate metabolic control, high convective clearance, and excellent dialyzer patency in patients requiring CRRT. This protocol offers a significant step forward for CRRT in terms of simplicity, effectiveness and safety.

32

Regional Citrate Anticoagulation for Continuous Veno-Venous Hemodiafiltration Using a Commercially Available Dialysate Containing Calcium

M. Gupta[1], J. Boglia[2], R. Bukovsky[2], N. Wadhwa[2]

[1]Medical University of South Carolina, Charleston, SC, USA, [2]SUNY at Stony Brook, Stony Brook, NY, USA

Current regional citrate anticoagulation (RCA) protocols for continuous veno-venous hemodiafiltration (CVVHDF) use calcium free dialysate. Our previous work has demonstrated the efficacy, ease and safety of RCA for CVVHDF using dialysate containing 2.5 mEQ/L of calcium. However, at present commercially available bicarbonate containing dialysate (PrismaSate BK0/3.5, Gambro, USA) contains 3.5 mEQ/L of calcium. We evaluated the impact of PrismaSate BK0/3.5 on RCA. Gambro PRISMA M100 set with AN69 hemofilter was used and changed every 96 hours. Anticoagulant Citrate Dextrose Formula A (ACD-A) was initiated at 150 ml/hr and the rate was adjusted to maintain postfilter ionized calcium (iCa) between 1.5 and 1.8 mg/dL. Calcium chloride (10%)

was administered 6 hourly to maintain serum iCa 4.0 mg/dL. Blood flow rate was set at 100 ml/min. PrismaSate BK0/3.5 was delivered at 500 ml/hr. Sodium Chloride was infused at 1000 ml/hr as the replacement fluid. Effluent total calcium, iCa and citrate were measured 1 hour post initiation of CVVHDF and then daily. Systemic and post-filter iCa was measured 6 hourly. 15 patients received citrate based CVVHDF for a total of 75 days using 26 M100 sets. The mean hemofilter life span was 69 hours. None of the patients developed signs of citrate toxicity. The mean serum total calcium, systemic and postfilter iCa was 7.59 ± 0.82 mg/dL, 3.60 ± 0.46 mg/dL and 1.61 ± 0.26 mg/dL respectively. The mean effluent total calcium and citrate was 6.27 0.85 mg/dL and 664 122 mg/L respectively. Importantly, the mean effluent iCa decreased from 7 mg/dL at initiation of CVVHDF to 1.29 0.22 mg/dL, 1 hour post initiation. Hence, the filtered citrate chelated most of the free calcium in the dialysate. In conclusion, RCA for CVVHDF using commercially available dialysate containing 3.5 mEQ/L of calcium is safe and effective and saves pharmacy time.

33

Current Trends in CRRT – Toronto, Ontario Region

E. Khankin[1], L. Knechtel[2], S. Tobe[2]

[1]Department of Nephrology, Rambam Medical Center, Haifa, Israel, [2]Department of Nephrology, University of Toronto, Sunnybrook & Women's College Health Sciences Centre, Canada

Continuous renal replacement therapy (CRRT) techniques aim to substitute altered renal function during a period of time, presenting advantages compared to conventional hemodialysis (CH). Though this technique was introduced relatively recently, great diversity in approach and treatment modalities is available for clinical practice. CRRT protocols vary widely among clinical users despite growing evidence and expert opinion on many modality and treatment options. **Purpose and Methods:** This study aims to determine the 'CRRT diversity' in Intensive care units (ICU) of the Ontario Canada region, using an internet survey distributed to nurse educators, each educator representing one ICU (n = 14). Our study evaluates different aspects of common CRRT techniques: treating staff, machinery utilized, preferred CRRT modalities, anticoagulation protocols, solutions used, common flow rates, as well as criteria for selection of CRRT over conventional hemodialysis. **Results:** Our results show great variation in many aspects (CVVHF use, solution preparation, and flow rates), while almost unanimous choices in others (ordering physician, machinery, CVVHD use). Nephrologists were found responsible for CRRT orders in 100% of cases and all units prefer 1 on 1 nurse/patient ratio, while main apparatus used for performing the treatment is PRISMA machine. Main modalities used for providing care are CVVHDF (100%) and CVVHD (79%). Leading anticoagulation method was found to be Heparinization, while Saline flushes and ACDA based regional citrate anticoagulation were second and third most common respectively. Most centers prepare solutions at bedside, while Hemosol (Gambro) is a most common solution used both as dialysate and as replacement, with second most common being Saline; Normocarb (Bialysis) reserved mostly for cases where citrate anticoagulation is preferred. In terms of criteria for preferring CRRT over conventional hemodialysis, hemodynamic instability was most common, with Sepsis/Multi Organ Failure and potentially reversible acute renal failure were second and third most commonly stated criteria respectively. **Conclusion:** Great diversity of approaches to CRRT initiation and maintenance is demonstrated. It is anticipated that dissemination of this data will assist new users in selecting treatments and modalities, and facilitate information sharing, protocol unification and the direction of future research in our region.

34

Application of F60 Dialyzer in CRRT

Q. Jin

Renal Division, Department of Medicine, Peking University First Hospital, Beijing, P.R. China

Objective: To investigate use of F60 (Fresenius, Polypropylene) high flux dialyzer in CRRT. **Method:** 5 patients with severe acute renal failure who require CRRT were put on daytime slow low-efficient daily hemofiltration (SLEDHF). F60 (modality A, 20 times) and AV600 (modality B, 20 times) were used alternately in each patient in a self-controlled manner. Machine used was ADM08, Low molecular weight heparin (LMWH) was administered for anticoagulation. Each treatments had the same blood flow (150 ml/min) and the same volume of replacement fluid (3000 ml/hr). Blood was taken before and after treatment and various parameters were measured including Scr, Na, K, Cl, HCO_3, β2MG. Dose of heparin, venous pressure and transmembrane pressure (TMP) were also recorded during the treatment. **Results:** The average treatment duration were 10.13 ± 3.25 hours in A and 10.25 ± 4.61 hours in B (P > 0.05), average UF rate were 380.00 ± 59.38 ml/hr in A and 477.5 ± 49.94 ml/hr in B (P < 0.001), average venous pressure were 69.35 ± 21.33 mmHg in A and 65.43 ± 20.53 mmHg in B (P > 0.05), average TMP were 70.56 ± 25.67 mmHg in A and 83.21 ± 27.23 mmHg in B (P < 0.05), average LMWH dose were 5068.90 ± 132.44 U in A and 5137 ± 150.10 U in B (P > 0.05). Changes of various parameters were as follow: Scr from 264.00 ± 149.09 μmol/L to 200.05 ± 129.85 μmol/L in A (P < 0.001), from 171.20 ± 36.64 μmol/L to 126.25 ± 25.99 μmol/L in B (P < 0.001), K+ from 4.35 ± 0.47 mmol/L to 3.55 ± 0.35 mmol/L in A (P < 0.001), from 4.25 ± 0.62 mmol/L to 3.50 ± 0.31 mmol/L in B (P < 0.001), Na+ Cl− $HCO-3$ maintained at the normal range. β2MG from 17.60 ± 2.31 μg/mL to 12.50 ± 3.49 μg/mL in A (P < 0.05), from 17.63 ± 3.12 μg/mL to 11.30 ± 3.42 μg/mL in B (P < 0.05). **Conclusions:** F60 high flux dialyzer can effectively clear water and solute of small and medium molecular weight. Heparin dose and pressure in the tubing were similar with AV600 during the treatment. Our study showed that CRRT could be carried out with relatively cheaper F60 dialyzer, particularly in those patients whose purpose of treatment were removal of water and solute of small and medium molecular weight.

35

Influencing Factors to the Filter Life in ARF Patients on CVVHDF Without Anticoagulant

I.E. Young, H.Y. Mi, C.J. Won, P.J. Ha, P.J. Sik, P. Su-Kil

ASAN Medical Center, Univ. of Ulsan College of Medicine, Seoul, Korea

Backgrounds: CVVHDF is advantageous to increase dialysis dose in the ARF patients with the unstable hemodynamics and multi-organ failure. However, these patients have the high bleeding risk and required CVVHDF without anticoagulation. In these cases, it is very difficult to deliver optimal dialysis dose due to the shortness of filter life. **Objective:** We performed the retrospective study to investigate the influencing factors to the filter life in ARF patients on CVVHDF without anticoagulant. **Methods:** Among 286 patients who underwent CVVHDF for ARF at ASAN Medical Center, 23 patients who required over 8 filters without anticoagulation were included for this study. We measured clinical parameters, such as filter life, clotting time, hemoglobin, platelet count, blood flow rate, dilaysate flow rate, replacement fluid flow rate and blood pressure just before the initiation of every filter. We also measured mechanical pressures relevant to the filter, such as access pressures, filter pressure, return pressure and transmembrane pressure (TMP) within the last 6 hours before termination of every filter. **Results:** The patients (age 57 ± 16, M:F $= 19:4$) who required CVVHDF without anticoagulation showed the median of filter life 9 hours 20 minutes (range, 4 hours 20 minutes ~55 hours 15 minutes). The filter life was not influenced by the insertion site of catheter, length of catheter, clotting time, hemoglobin, platelet count, blood flow rate, and ultrafiltration rate. Only TMP significantly increased every hour within 6 hours before termination of filter. **Conclusion:** Although it was known that TMP with the range of 350 to 450 mmHg was reflected filter clotting, we have to confirm the patency of filter at the lower range of TMP in the case of CVVHDF without anticoagulation. Although we did not find any influencing factors to filter life, there would be significant risk of filter clotting when TMP will be greater than 120 mmHg. Anticoagulant therapy should be performed without increasing the bleeding risk, prospectively.

*P<0.01 compared with TMP at previous 1 hour

36
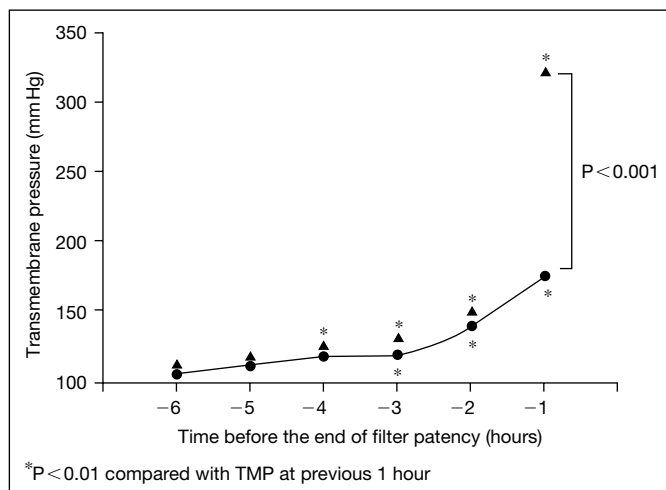
Methotrexate Transmembrane Clearance During Albumin Based Continuous Venovenous Hemodialysis

D.A. Pasko, M. Grio, S. Thomas, T. Mottes, P.D. Brophy

CS Mott Children's Hospital, University of Michigan, Ann Arbor, MI, USA

Introduction: This is a case report of an 18 yo female that has osteosarcoma for which she received high-dose methotrexate (20 grams). Seven days after the chemotherapy treatment the patient was noted to be oliguric (Scr 0.7 to 1.8). As a result, the patient demonstrated delayed methotrexate clearance despite leukovorin rescue every 3 hours for several days. Eight days post-treatment the patient's methotrexate level was 0.6 mmol/L. To enhance methotrexate clearance as well as manage fluid balance the patient was started on continuous veno-venous hemodialysis (CVVHD). Per previous literature reports methotrexate should be effectively removed given its low molecular weight and ~50% protein binding. After almost 72 hours of CVVHD the methotrexate concentration had only decreased from 0.64–0.42 mmol/L. Given that methotrexate is bound to albumin, albumin-based CVVHD was started to further enhance removal. There is only one previous report of enhanced drug removal using albumin-based CVVHD in the literature. **Methods:** Patient was placed on CVVHD using a Prisma CRRT circuit, HF 1000 (1.15 m2, Kuf 37 mL/hr/mmHg, Gambro) hemodialfilter at dialysate rate of 2000–2500 mL/hour, and a mean ultrafiltrate rate of 604 mL/hour. Albumin-based CVVHD was started 9/6/04 at 2300 and the patient was continued on albumin-dialysis until 9/10/04 0500. During this time period samples of blood (arterial and venous) and effluent were obtained approximately every 2–3 hours. The saturation coefficient was calculated using the equation: $Sa = Ce/(Ca + Cv)/2$, where Ce is the concentration in the effluent, Ca is the serum concentration of the patient pre-filter, and Cv is the serum concentration post-filter. Clearance was then calculated using the equation: $Clcrrt = (Qd + Qe) * Sa$. The concentration of albumin used in the dialysate was 5% (50 grams/L). **Results:** While on CVVHD without albumin the patient's methotrexate half-life was approximately 115.5 hours. After initiating albumin-based CVVHD the methotrexate half-life decreased to 28.8 hours with a dialysate rate of 2500 mL/hour, and 35.5 hours at a rate of 2000 mL/hour. In addition, the methotrexate Sa pre-albumin therapy was 0.62 and was enhanced approximately 20% by the addition of the albumin to the dialysate (0.77–0.8). **Conclusions:** Albumin-based CVVHD seems to enhance drug removal of methotrexate, and possibly other drugs moderately to highly protein bound to albumin. Further clinical studies are needed to determine the possibilities of this treatment.

37

Quantification of Inadvertent Heparin Leak from Hemodialysis Catheters: An in vitro Study

M.S. Ozcan[1], A. Gabrielli[1], J.A. Layon[1], A. Bihorac[2], M. Sungur[1]

[1]Department of Anesthesiology, University of Florida, Gainesville, FL, [2]Department of Medicine, University of Florida, Gainesville, FL, USA

Percutaneous dual lumen hemodialysis catheters (HDC) are widely used in critically ill patients with acute renal failure needing hemodialysis (HD). High concentration of heparin is routinely used for catheter-lock in order to maintain catheter patency after a HD session with assumption that the volume of catheter-lock recommended by manufacturer will not have any systemic effect. We have suspected for the long time that catheter-lock with heparin can cause systemic anticoagulation based on anecdotal observation of unexplained elevation of PTT or generalized blood oozing. This complication may be particularly detrimental for patients in the post-operative intensive care unit. We perform this in vitro study to quantify the amount of heparin that leaks into circulation immediately following catheter-lock. 12 F double lumen HDC of two different lengths (15 and 20 cm) were used. Both lumens of the catheter were completely filled with distilled water and locked. The tip of the catheter was immersed into test tube (TT1) containing 50 mL distilled water. Each lumen of the catheter was then filled and locked with 5% dextrose, using the volumes indicated on the catheter by the manufacturer (1.2 or 1.4 mL per lumen for 15 or 20 cm catheter, respectively). The catheter was removed after 30 seconds and a sample was obtained from the test tube to measure dextrose concentration. The volume of 5% dextrose solution used to fill and lock each catheter (2.4 and 2.8 mL for 15 and 20 cm catheters, respectively) was also added to a second test tube (TT2) containing 50 mL of distilled water as control. Dextrose concentration of solutions from both test tubes was measured. We found that catheter-locks with heparin in the volumes recommended by manufacturer resulted in a 28% leak in both 15 and 20 cm 12 F double lumen HDC (Table 1). Our in vitro study demonstrated that filling and locking the dialysis catheter lumen with the exact volume recommended by the manufacturer results in considerable leakage outside the catheter. Depending on the final concentration of intraluminal heparin, a patient may receive between 3500 and 7000 IU of heparin within 30 seconds after performing catheter lock. While the volume and optimal concentration of heparin to be used for each type of hemodialysis catheter remains to be determined, we recommend systematic monitoring of the coagulation system after heparin lock.

Table 1.

	Vas-cath (20 cm)	Vas-cath (15 cm)
Dextrose concentration in TT1 (after catheter-lock)	121 ± 15	108 ± 9
Dextrose concentration in TT2	436 ± 16	389 ± 9
% Volume Lost (TT1/TT2)	27.8%	27.8%

38

Regional Citrate Anticoagulation for Continuous Veno-Venous Hemodiafiltration in Patients with Liver Failure

S. Sutaria, G. Hoffert, J. Fitzpatrick, R. Bukovsky, H. Suh, N. Wadhwa, S. Akhtar

S.U.N.Y at Stony Brook, New York, USA

Introduction: Regional citrate anticoagulation for continuous veno-venous hemodiafiltration (CVVHDF) using calcium containing dialysate is safe and effective. However the safety of regional citrate anticoagulation in liver failure patients has not been well documented. **Purpose:** The current study evaluated the safety of regional citrate anticoagulation during CVVHDF in nine liver failure patients. **Method:** Anticoagulant Citrate Dextrose ñ Formula A (ACD-A) was initiated at 150 ml/hr via a 'Y' connection at the junction of a double lumen hemodialysis catheter and prefilter tubing of Gambro PRISMA M100 set with AN69 hemofilter. The rate was adjusted to maintain postfilter ionized calcium (iCa) between 1.5 and 1.8 mg/dl. Calcium chloride (10%) was administered 6 hourly as needed to maintain systemic serum iCa more than 4.0 mg/dl. Blood flow rate was 100 ml/min. PRISMASATE BK 0/3.5 (Gambro, USA) was delivered at 500 ml/hr as a dialysate. PRISMASATE BGK 2/0 in six patients and 0.45% sodium chloride in three was infused at 1000 ml/hr as replacement fluid. Serum and effluent citrate levels were measured daily. Systemic and postfilter serum ionized calcium were measured 1-hour after initiating CVVHDF and then every six-hour. **Results:** During the period of January 2004 to September 2004, 9 patients with liver failure (1 female, 8 males) underwent citrate based CVVHDF using calcium-containing dialysate. Their mean AST, ALT and total bilirubin were 5081U/L, 2016U/L and 13.5 mg/dl respectively. The mean ACD-A infusion was 130 ml/hr. The mean serum systemic total calcium and ionized calcium were 7.8 mg/dl and 3.6 mg/dl at onset and 7.2 mg/dl and 3.7 mg/dl at 48 hours of CVVHDF. The total calcium to ionized calcium ratio was at a mean of 2.1 at onset and 1.9 at 48 hours of CVVHDF. The mean post filter ionized calcium was 1.5 mg/dl. The mean effluent total calcium, ionized calcium and citrate 48 hour post initiation of CVVHDF were 6.47 mg/dl, 1.4 mg/dl and 692 mg/l respectively. The mean serum citrate levels at 24 and 48 hours after onset of CVVHDF were 4.2 mg/dl and 3.8 mg/dl respectively. **Conclusion:** CVVHDF with regional citrate anticoagulation using calcium containing dialysate can be safe and effective in liver failure patients.

39

A Double-bag System Filled with Pre-measured Bicarbonate Substitution Fluid Reduces Preparation Time Regardless of Experience

O. Toshiya[1], H. Iwaki[1], H. Miyamoto[1], S. Ito[1], Y. Ohnishi[2], M. Tamura[3]

[1]Department of Digestive and Cardiovascular Medicine, The Tokushima University of Graduate School of Medicine, [2]Division of Intensive and Critical Care Medicine, Tokushima University Hospital, Tokushima City, Tokushima, Japan, [3]Research and Development Department, Fuso Pharmaceutical Industries, LTD., Osaka City, Osaka, Japan

Purpose: A bicarbonate substitution fluid for continuous replacement therapy (CRRT) requires mixing two solutions prior to use. Therefore, we have developed a new double-bag system filled with a pre-mixed fluid (Sublood-BD, Fuso Pharmaceutical Industries, LTD., Japan) which can be prepared in a matter of minutes, very little experience is required. The seal in the middle of the bag holds the solutions on either side. When the caregiver is ready to administer treatment, the bag is simply flexed and compressed. The inner seal is broken, releasing the fluids; thereby, the fluid is accurately mixed and ready to administer to the patient. In this study, we assessed the effectiveness of this system to reduce preparation time for inexperienced staff preparing for CRRT. **Method:** The preparation time of two groups were analyzed. Group A consisted of medical staff who had prepared the fluid set for CRRT less than 5 times ($n = 6$), and group B greater than 50 times ($n = 6$). Each were instructed to prepare conventional bicarbonate substitution fluid set (Sublood-B, Fuso Pharmaceutical Industries, LTD., Japan) using a syringe, and Sublood-BD. The time was started when the exterior package was opened and stopped when hung on the CRRT machine. **Results:** Results are shown in the table below and the mean $\pm$ standard deviation(s). The preparation time for Sublood-BD was shorter than Sublood-B. The preparation time for group A was longer in comparison to group B when using the conventional set, but there was no difference between the two groups when they used the double-bag type bicarbonate substitution fluid system. **Conclusion:** The double-bag type bicarbonate substitution fluid system requires very little experience, and reduces preparation time regardless of experience.

Preparation time

	Sublood-BD	Sublood-B
Group A	370 $\pm$ 52*	550 $\pm$ 99†
Group B	332 $\pm$ 54*	423 $\pm$ 66(s)

*$P < 0.05$ versus Sublood B; †$P < 0.05$ versus Group B.

40

Anticoagulation with Dermatan Sulphate for Renal Replacement Therapy in Intensive Care Units

F. Bermond, C.M. Fenocchio, V. Cantaluppi, C. Guarena, A. Pacitti

Chair of Nephrology, University of Turin, Turin, Italy

Background: Anticoagulation strategy represents one of the most important problem during Renal Replacement Therapy (RRT) in Intensive Care Units (ICU). Dermatan sulphate (DS) is a selective thrombin inhibitor with antithrombotic properties and low bleeding potential. DS has been found clinically effective and safe during haemodialysis in chronic renal failure, especially for patients with heparin-induced thrombocytopenia (HIT). **Aim:** The aim of the study was to describe our experience about the use of DS during RRT, as an alternative option to conventional anticoagulation methods. **Material and Methods:** During a period of six months (January–June 2004) we performed 1360 dialysis sessions in 113 patients with acute or chronic renal failure, observed in nine different ICU. Slow hemofiltration (SHF) as employed in our Center is standardized using 150–200 ml/min blood flow, sodium 140 mEq/l and bicarbonate 35 mEq/l concentration in substitution fluid; polyamide, polysulfone or AN69 filters (membrane surface area 0.6 m2 in most cases) were used; ultrafiltration was limited to that needed for overall fluid balance in the ICU. Anticoagulation methods included heparin (standard doses: 1250 U as a predialysis bolus, followed by continuous infusion of 125–250 U/h), high dose heparin with regional protamine, low molecular weight heparin (LMWH), DS or no anticoagulant at all. DS was used in case of diagnosis or suspicion of HIT or in case of multiple episodes of extracorporeal circuit coagulation in patients with no or low bleeding risk. **Results:** We used heparin in 572 sessions, LMWH in 8 sessions, DS in 294 sessions; no anticoagulant at all in 484 sessions; in 2 cases we used high dose heparin with regional protamine without good results. DS low doses were used: 150 mg (median value; minimum 150 mg, maximum 600 mg) as a predialysis bolus, followed by continuous infusion of 15 mg/h (median value; minimum 7.5 mg/h, maximum 90 mg/h). No bleeding episodes occurred. Extracorporeal circuit coagulation occurred in 21,7% of the cases (19.9% using heparin, 12.5% using LMWH, 19% using DS, 25.6% without anticoagulant). **Conclusion:** Low dose DS regimen maintained its anticoagulant efficacy and was safe in daily use during RRT in critical patients.

41

Molecular Adsorbent Recirculating System: Clinical Experience in Patients with Acute and Acute on Chronic Liver Failure

X. Ding, L. Chen, J. Zou, J. Teng, Y. Fang, Y. Zhong

Zhongshan Hospital, Fudan University, Shanghai, China

Objective: The aim of this study is to evaluate the effect of treatment with the Molecular Adsorbents Recirculating System (MARS)

in liver failure patients. Methods 49 patients with acute and acute on chronic liver failure received 103 intermittent MARS treatments. Each treatment session lasted 6 to 8 hours. Results Among 49 patients (38 males, 11 females) with average age of 50.69 ± 11.65 years, 19 cases were of acute liver failure and 30 cases were of acute on chronic liver failure. 23 patients received single session of MARS treatment and other 26 patients received twice or more sessions. Significant decreases in serum total bilirubin (24.20%), conjugated bilirubin (28.18%), bile acid (37.36%) and ammonia (30.75%) were observed after the single treatment.

42

Comparison of the Efficacy of Different Prescriptions for Replacement Fluids in Continuous Renal Replacement Therapy

G.-Q. Xiao, Y.-Z. Kong, Y.-W. Huang, Y.-H. Shao, L.-H. Lin

The First People's Hospital of Foshan, Guangdong, P.R. China

Objective: To compare the effects of different prescriptions for replacement fluids in continuous renal replacement therapy (CRRT). **Method:** Thirty-four patients of MODS, including 29 males and 5 female, with average age 56.7 ± 14.4 ($25 \sim 83$) years, were treated with continuous venovenous hemofiltration (CVVH). CVVH was carried out continuously for $48 \sim 72$ h, with BM25 CRRT system and AN69 hemofilter ($1.6\,m2$), and the ultrafiltration (UF) flow rate at $4\,L/h$, blood flow rate was $250 \sim 300\,ml/min$, and the substitute fluid was by a pre-dilution route. Port's prescription (prescription 1) for replacement fluids was adjusted (prescription 2 and 3) for CVVH. The three prescription: (1) Prescription 1 (Pot's prescription): The total dose is $2000\,ml$, including A fluids (NS $1500\,ml$ + 5% GS $500\,ml$ + 5% $CaCl_2$ $10\,ml$ + 25% $MgSO_4$ $1.6\,ml$) and B fluids (5% $NaHCO_3$ $125\,ml$). A fluids and B fluids were infused at the same time in two different access. The ion concentration was respectively: $Na+$ $143.6\,mmol/L$, $Cl-$ $116.7\,mmol/L$, $Ca2+$ $2.15\,mmol/L$, $Mg2+$ $1.57\,mmol/L$, $HCO3-$ $35.0\,mmol/L$, Glu $65.4\,mmol/L$. (2) Prescription 2: using Prescription 1 and Prescription 3 without glucose by turns. (3) Prescription 3: A fluids (NS $1500\,ml$ + Water $500\,ml$ + 5% $CaCl_2$ $10\,ml$ + 25% $MgSO_4$ $1.6\,ml$ + 50% GS $5 \sim 10\,ml$). Glucose concentration of replacement fluids was adjusted whenever necessary according to blood glucose level. The effects of different prescriptions were observed in different. **Results:** Serum CO2CP (24.4 ± 3.6 vs. $19.4 \pm 4.6\,mmol/L$), $Ca2+$ (2.14 ± 0.17 vs. $1.87 \pm 0.25\,mmol/L$) levels were raised obviously ($P < 0.05$). High serum glucose levels was found in 71.4% cases who used prescription 1, the serum glucose level fluctuated between 5.5 to $15\,mmol/L$ in 80% cases when used prescription 2, and 6.0 to $10.1\,mmol/L$ in all cases used prescription 3. **Conclusions:** The electrolytes and acid-base equilibrium were satisfactorily maintained by continuous renal replacement therapy in critically ill patients. The effect of prescription 3 was the best than those two others.

Future Trends

43

Cost Analysis of Intensive Care Renal Replacement Therapies: Continuous versus Extended Hemodiafiltration

S.G. Gilibert[1], Z. Ahmed[2], L.E. Krevolin[3]

[1]Hahnemann Hospital, Drexel University College of Medicine, Philadelphia, PA, USA, [2]Drexel University College of Medicine, Philadelphia, PA, USA, [3]Clinical Nephrology Associates, Drexel University College of Medicine, Philadelphia, PA, USA

Purpose: To determine actual daily cost to deliver continuous renal replacement therapy (CRRT) with a Fresenius 2008 K (Sustained Low Efficiency Dialysis, SLED) versus a Prisma, Gambro (Continuous Veno-Venous Hemodiafiltration, CVVHDF). **Methods:** We determined itemized costs to administer our typical 12-hour SLED and 24-hour CVVHDF prescriptions (pricing both lactate-based, pharmacy-mixed and bicarbonate-based, pre-mixed PrismaSate, Gambro solutions). Financial information was obtained by review of invoices, billing records and personnel costs. Daily expenditures to purchase materials (filters, tubing, dialysate and replacement solutions) and provide skilled labor (hemodialysis nurses, intensive care nurses and pharmacy staff) were calculated. SLED was performed with a Fresenius 2008 K machine with CRRT capabilities using F6 filter, blood flow rate (BFR) of $200\,mL/min$, and dialysate flow rate (DFR) of $200\,mL/min$. CVVHDF was delivered with a Prisma, Gambro using M60/M100 filter, BFR $150–180\,mL/min$, DFR $1000\,mL/hr$ and replacement solution rate $1000–2000\,mL/hr$. **Summary:** A 12-hour SLED was \$423.05 (7.8% materials, 92.2% labor). The 24-hour CVVHDF treatment with pharmacy-mixed dialysate and replacement was \$1,062.13 (28.8% materials, 71.2% labor) versus \$1,062.10 (32.2% materials, 67.8% labor) using PrismaSate. CVVHDF was found to be \$639 more to administer versus SLED per day at our hospital. The higher materials cost for pre-mixed solutions negated pharmacy labor, thus equalizing overall cost. When replacement with PrismaSate was maximized at $2000\,mL/hr$, there was an additional \$90 per 24-hours ($28.6\,mL/kg/hr$ for 70 kg patient). There were unquantifiable expense differences due to variable clinical need for electrolyte replacements and nursing intervention. The pre-mixed CVVHDF solutions are 5-liter bags. Nursing staff reported less frequent replacements (based on a sliding scale replacement protocol) with both SLED and the use of PrismaSate compared with pharmacy-mixed solutions. **Conclusions:** There is continued debate in the literature regarding the efficacy and appropriateness of various continuous renal replacement therapies. A prospective, randomized controlled study between continuous versus extended hemodiafiltration has yet to be published. Actual institutional costs can facilitate decision-making when choosing a CRRT modality. Despite the higher cost to deliver CVVHDF at our institution, we have found that irrespective of this difference, both modalities continue to be actively used at our institution, each when deemed clinically appropriate.

44

A Model to Assess the Benefits of Renal Bio-Replacement Therapy for Acute Renal Failure Patients

M. Aldrich, R. DaSilva

Nephros Therapeutics Inc., Lincoln, RI, USA

In 2003 an estimated 700,000 patients experienced acute renal failure (ARF) from various diagnosis related groups (DRG) and of these patients 130,000 required Renal Replacement Therapy (RRT) such as dialysis or hemofiltration. These RRT patients cost healthcare providers up to $120,000 extra and had an average mortality ranging from 55% to 70%. Nephros Therapeutics conducted a review of patient records and cost data of 240 patients treated for ARF with RRT at the University of Michigan. This review looked at patients in 5 categories and provided a framework to conduct pharmacoeconomic assessment of new treatments for ARF requiring RRT. This article demonstrates the use of that framework for conducting benefits assessment of the Renal Bio-Replacement Therapy (RBT) in two patients that were treated under a ten patient phase I/II trial at the University of Michigan and Cleveland Clinic Foundation. These patients from separate DRG's showed a savings ranging between 40% to 56% when compared to the average cost of RRT patients with similar DRG's treated with conventional therapy. This savings came directly from decreasing medication, days spent in the ICU and length of stay in the hospital. This framework will be used to assess the benefits of RBT and in an on going phase II trial.

CRRT Research

45

Short Filter Lifespan during Hemofiltration in Sepsis: Antithrombine (AT) Supplementation Should be a Good Way to Sort Out this Problem

O. Joannes-Boyau[1], M. Lafargue[1], P.M. HonorÈ[2], B. Gauche[3], C. Fleureau[1], G. Janvier[1]

[1]University Hospital of Bordeaux, Pessac, France,
[2]St-Pierre Para-University Hospital, Ottignies, Belgium,
[3]R. Boulin Hospital, Libourne, France

Introduction: Continuous renal replacement therapies (CRRT) is widely used in the management of patients with severe sepsis and acute renal failure. Nevertheless, short filter lifespan (<24 hours) is still a major concern, and could be the result of a procoagulating state secondary to sepsis. The aim of this work is to study the possible relationship between AT deficit and early filter's clogging, and also if supplementation of AT could increase the filter lifespan. We did also compare two different methods for supplementation: Bolus versus Continuous Infusion. **Materials and methods:** A two center prospective study, realized from march 2003 till may 2004 in three

Relationship AT rate/filter longevity
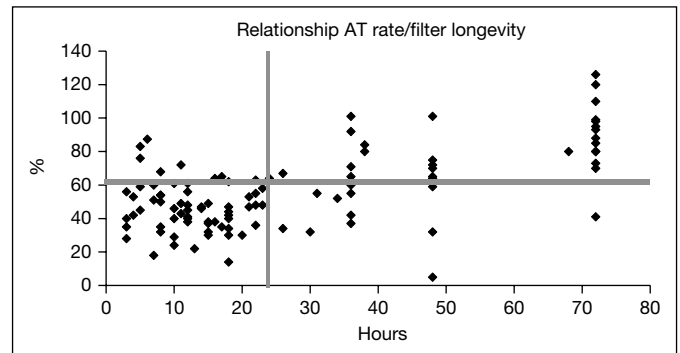
different intensive care units. Twenty eight patients in septic shock with acute renal failure were included. All of them were treated by CRRT and Un Fractionated Heparin (UFH) was used for anticoagulation. The level of AT was measured before CRRT and every day, and a supplementation was started after two early filter's clogging, with two different methods: half of the patients was supplemented by bolus of AT, and the other half with continuous infusion. **Results:** The initial level of AT was low in most of the patients with a median level at 45.4% (16%–69%). The risk of thrombosis of the filter increase dramatically when the level of AT felt under 60%. The supplementation in AT was able to restore a level over 60% and increase the filter lifespan from 15,2 to 33,2 hours. Patients treated with a continuous infusion method had a level of AT above 60% a longer period of time when compared with the bolus method, and obviously their filter lifespan increased further from 27,8 (bolus) to 48,5 hours. **Conclusion:** This study show that a level of AT under 60% increase the risk of early filter clogging. A supplementation of AT restore the activity of the synergistic effect of UFH/AT and could increase the filter lifespan by more than 100%. The continuous infusion is a better method to maintain a level of AT above 60% and can increase more significantly the filter lifespan. Cost-effectiveness should be evaluated shortly.

46

Multiple Factors Contribute to Suboptimal Delivery of the Prescribed Dose in Continuous Renal Replacement Therapy (CRRT)

W. Britton Murrill, R.L. Woodson, R.W. McLarin, A.J. Tolwani

University of Alabama at Birmingham, Birmingham, AL, USA

We performed a prospective observational study to quantify the dialysis dose delivered to patients receiving CRRT at our facility and to determine factors which prevented the prescribed dose from being delivered. All patients receiving CRRT were followed daily for 5 weeks. The delivered dialysis dose was calculated using the hourly effluent rate, patient's weight, and duration of CRRT for each 24 hour period. Twenty-eight ICU patients receiving CVVHDF CRRT were observed (14 males, 14 females) for a total of 245 treatment days.

Prisma CRRT machines with M100 filters utilizing pre-filter replacement fluid were used. Ninety three percent of the patients used pre-filter citrate (0.5% or 17 mmol/L) as anticoagulation. The mean pre-filter citrate rate was 18 +/− 3 mmol citrate/hr. The mean dialysis dose prescribed was 29.7 +/− 9.14 ml/kg/hr. An average of 79.7% (19.14 hrs +/− 5.06) of the prescribed dose was delivered/24 hrs. Forty-two percent of treatment time lost was due to elective procedures (routine filter changes, radiology exams, surgical procedures) and nursing procedures (changing of CRRT fluid bags and delays in addressing alarms). Access dysfunction (31%) and filter clotting (27%) accounted for the remainder of time lost. Femoral catheters were used most commonly (64% of treatment days) and IJ catheters were least commonly utilized (13% of treatment days). Patients with femoral catheters received 80.7% of their prescribed treatment (SCL catheters 80.1% and IJ catheters 75.5%). Our mean post-filter ionized calcium was 0.29 +/− 0.10 mmol/L and 0.33 mmol/L +/− 0.07 during loss of treatment time due to access dysfunction and filter clotting. Based on published data, our filter clotting was not due to inadequate anticoagulation. The observed patients received nearly 80% of the prescribed CRRT dose. The fraction of dialysis dose delivered at our facility is higher than has been previously reported. Elective procedures and nursing factors significantly contribute to treatment time lost. Suboptimal anticoagulation did not appear to contribute to treatment time lost. Efforts to minimize nursing-related loss of treatment time and to maximize duration of CRRT therapy should be pursued.

47

Continuous Hemodialysis (CHD) Improves the Mortality of the Critical Patients with Acute Renal Failure in Comparison with Continuous Hemofiltration (CHF)

J.-I. Ono[1], H. Horike[2], T. Tokura[2], K. Yokota[3], T. Sasaki[2], N. Kashihara[2]

[1]Kidney Center, [2]Div. of Nephrology, Kawasaki Medical School, [3]Intensive Care Medicine, Kurashiki Central Hospital, Okayama, Japan

Background: Although continuous renal replacement therapy (CRRT) is increasingly used to cure acute renal failure (ARF) including in critical state patients such as Systemic Inflammatory Response Syndrome (SIRS) or Multiple Organ Failure (MOF), the most suitable methodology for these patients has been controversial. To determine which method of CRRT is most suitable, we retrospectively analyzed the prognosis of ARF patients receiving CRRT, comparing those receiving CHF and those receiving CHD. **Methods:** A total of 176 patients with ARF caused by MOF or SIRS, with a mean age of 68.4 years old, treated by CRRT in our intensive care unit between 1997 and 2001 were retrospectively analyzed. A total of 51 patients were treated with CHF (mean APACHE-2 score: 27.1, mean filtration dose: 19.0 ml/hr/kg, mean age: 69.5 years, M = 36, F = 15). A total of 125 patients were treated with CHD (mean APACHE-2 score: 30.1, mean dialysate dose: 36.5 ml/hr/kg, mean age: 67.9 years, M = 82, F = 43). The primary endpoint was survival at 28 days after beginning CRRT. The second endpoint was survival discharge. To assess the dose of dialysate in the CHD group, we also evaluated survival rate comparing a high-dose group (more than 25 ml/hr/kg, n = 70) and a low-dose group (less than 25 ml/hr/kg, n = 55). **Result:** There were no significant differences in age, gender and APACHE-2 score between the two groups. The survival rate at the first endpoint in the CHD group was significantly higher than that in the CHF group (CHD: 60.8%, CHF: 39.2%: p = 0.0091). The survival discharge rate tended to be higher in the CHD group than in the CHF group, but the difference was not statistically significant (CHD: 37.6%, CHF: 23.5%, p = 0.072). Regarding the dose of dialysate, the survival rate was 60% at the first endpoint in the high-dose group and 61.9% in the low-dose group. The survival discharge rate was 32.9% and 45.6%, respectively. There was not significant difference between the two groups. **Conclusion:** The mortality among these patients with ARF was high, but CHD significantly improved survival in comparison with CHF. CHD can remove low-molecular substance better than CHF. As for the differences in the prognosis in each group, it is suspected that removal of the low-molecular substances is important. We emphasize here that the CHD is a beneficial therapy for critical patients with ARF.
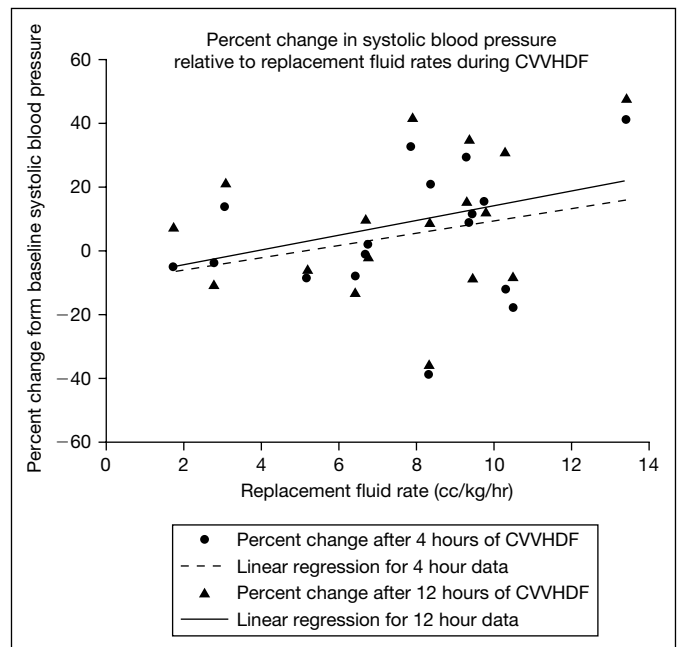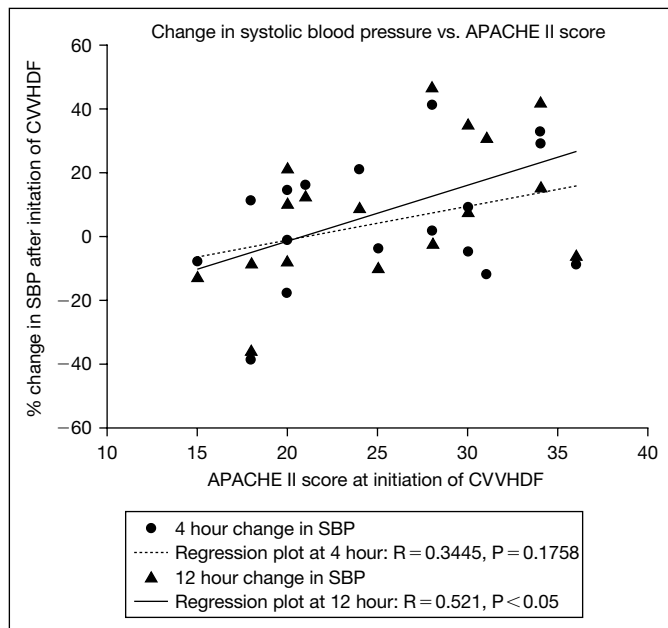
48

Effect of Illness Severity Scores on Hemodynamic Impact of CRRT

T. Hostetler[1], D. Plott[2], B. Hixon-Vermillion[1], U. Bhatt[2]

[1]Ohio State University, Colombus, Ohio, [2]University of Florida, Jacksonville, FL, USA

Continuous renal replacement therapies (CRRT) are often reserved for the most hemodynamically compromised patients. This is primarily due to the relative hemodynamic stability of CRRT compared to intermittent hemodialysis (iHD). Despite this, CRRT has not been consistently shown to be superior to iHD. A major difficulty in this comparison has been patient selection. Sicker patients are treated with CRRT, whereas more stable patients receive iHD. Studies demonstrating the hemodynamic benefit of CRRT have been done elsewhere. However, characterizing the relationship of illness severity on hemodynamic benefit has not been completely defined. On this basis, the purpose of our study was to examine the hemodynamic impact of CRRT on patients with varying APACHE II scores. To study this question, patients who received CRRT were identified. APACHE II scores were calculated for each patient at initiation of therapy. In addition, systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and heart rate (HR) were measured at the initiation of CRRT and at 4 and 12 hours after initiation. Patients were excluded if changes in dialysate or replacement fluid rates were made or if circuit clotting occurred within 12 hours. Linear regression was then used to correlate the percent change from baseline with the APACHE II score at initiation. A plot for SBP is shown in the figure. Similar results were obtained for DBP and MAP. A reduction in baseline HR (average baseline HR = 108 bpm) was noted in patients with higher APACHE II scores. **Conclusion**: Compared to patients with lower APACHE II scores, patients with higher scores had greater hemodynamic changes 4 and 12 hours after initiation of CRRT. Blood pressure and heart rate improvements were greater in patients with higher severity scores. Although the study was not randomized or controlled, it may support the contention that effective implementation of CRRT may vary with illness severity.

Change in systolic blood pressure vs. APACHE II score

- • 4 hour change in SBP
- ⋯ Regression plot at 4 hour: R = 0.3445, P = 0.1758
- ▲ 12 hour change in SBP
- — Regression plot at 12 hour: R = 0.521, P < 0.05

Percent change in systolic blood pressure relative to replacement fluid rates during CVVHDF

- • Percent change after 4 hours of CVVHDF
- – – Linear regression for 4 hour data
- ▲ Percent change after 12 hours of CVVHDF
- — Linear regression for 12 hour data

49

Hemodynamic Effects of Variable Replacement Fluid Rates in Hemodiafiltration

D. Plott[1], T. Hostetler[2], B. Hixon-Vermillion[2], U. Bhatt[1]

[1]University of Florida, Jacksonville, FL, [2]Ohio State University, Columbus, Ohio, USA

Continuous renal replacement therapies (CRRT) are powerful tools for renal replacement. These modalities are typically utilized in the ICU population due to greater hemodynamic stability than intermittent hemodialysis. In continuous hemofiltration, the primary clearance mechanism is via convection. Higher convective clearance rates in hemofiltration are associated with improved patient outcomes. Hemodiafiltration utilizes both convection and diffusion. However, the effect of increased convective clearance in hemodiafiltration has not been completely defined. On this basis, the purpose of this study was to examine changes in hemodynamic parameters associated with varying replacement fluid (and therefore convective clearance) rates in continuous venovenous hemodiafiltration (CVVHDF). Retrospective review was done on patients who received CVVHDF for renal replacement. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and heart rate (HR) were measured at the initiation of CVVHDF and at 4 and 12 hours after initiation. Percent changes in these parameters from baseline were then determined. Replacement fluid rates (RF, cc/kg/hr) were also determined. After exclusion of patients who had changes in dialysate or RF rates or had circuit clotting within 12 hours of initiation, 17 patients were evaluated. Linear regression was then used to correlate percent changes in hemodynamic parameters as a function of RF rates. The results for systolic blood pressure are illustrated in the figure. SBP and heart rate improved with increasing RF rates, while DBP and MAP decreased with increased RF rates.

Conclusion: Although this study was not randomized and did not control for vasopressive medications, it suggests that higher RF rates may impact, and in some cases improve, patient hemodynamics during CVVHDF. This supports the contention for further studies examining the dose and modality of CRRT and its clinical impact.

50

Dialysis Perscription Improvement by Mathematical Modeling of Ultrafiltration

J.J. Bissler[1], N. Hemasilpin[1,2], M.M. Polycarpou[2]

[1]Cincinnati Children's Hospital Medical Center, University of Cincinnati College of Medicine, [2]College of Electrical Engineering and Computer Sciences, University of Cincinnati, OH, USA

Avoiding hypotension and possibly ischemia adverse events for patients undergoing hemodialysis or hemofiltration requires a detailed understanding of the cardiovascular response to ultrafiltration. Patient ultrafiltration tolerance depends on the net balance of lymphatic return and ultrafiltration over time. Lymphatic return contributes to blood pressure control and is affected by a property called vascular stress-relaxation. A precise quantitative knowledge of the lymphatic return rate and vascular stress-relaxation property is required to optimize a physiologically appropriate ultrafiltration rate. To this end, we designed a method to model both the lymphatic return rate and the vascular stress-relaxation property. We derived a set of dynamical equations to represent the cardiovascular system including capillary dynamics, lymphatic flow, interstitial fluid dynamics, and vascular stress-relaxation property based on physiological data. This set of equations allows the prediction of the blood pressure response

during ultrafiltration, and fellows can perform virtual experiments using this 'model patient' to begin to appreciate the different responses to ultrafiltration given different pathological states and avoid perscriptions that lead to hypotension.

51

Pre-existing Renal Disease – A Predictor of Increased Survival in Patients on CRRT

C.J. LeBrun

University of Mississippi Medical Center, Jackson, MS, USA

Background: Mortality rates with Continuous Renal Replacement Therapy (CRRT) remain high. Issues that remain unanswered include the timing of initiation, the dose of CRRT, and patient characteristics that predict mortality. **Objective:** We compared survival of patients with acute renal failure (ARF) with or without pre-existing renal dysfunction on admission and evaluated the timing of initiation of CRRT by reviewing the time from the initial increase in serum creatinine (Scr) to initiation of CRRT. **Design:** We carried out an observational study of 95 consecutive CRRT patients at our institution from Jan 2003 to June 2004. Patients were divided into two groups: those without pre-existing renal disease who developed acute renal failure while an inpatient (Inpt-ARF; defined as a Scr of less than 1.3 mg/dl prior to ARF and CRRT) and those with renal dysfunction on admission (CKD-ARF; Scr of greater than or equal to 1.3 mg/dl prior to ARF and CRRT). We compared: the mortality of the two groups (Inpt-ARF versus CKD-ARF); timing of initiation of CRRT from initial increase in Scr (defined as increase in creatinine of greater than 0.4 mg/dl); age; Apache II score; and BUN and Scr at initiation of CRRT. **Results:** Overall survival at 30 days post-initiation of CRRT was approximately 50%. Despite lower Apache II scores, lower BUN and Scr at CRRT initiation and less time from increase in Scr to CRRT initiation, the Inpt-ARF group had 35% survival while the CKD-ARF group had 60% survival. The mean change in BUN and Scr from lab values at CRRT initiation to the values at termination of CRRT in the CKD-ARF group was greater than the Inpt-ARF group (delta BUN/Scr 86.3/2.7 (CKD-ARF); versus delta BUN/Scr 79.3/1.3 (Inpt-ARF)). This implies that improved clearances played a role in improved survival. The percentage of survivors needing dialysis support at 30 days post initiation of CRRT was lower in the CKD-ARF group than in the Inpt-ARF group. **Conclusion:** Timing from renal insult to initiation of CRRT did not play a role in predicting survival in our CRRT database. Patients on CRRT without pre-existing renal disease had a decreased overall survival versus patients with pre-existing renal dysfunction. The patients with pre-existing renal disease also had an increased creatinine clearance during CRRT and a decreased risk of needing dialysis 30 days after CRRT initiation. This implies a baseline elevated BUN and Scr influence the amount of dialysis prescribed and lead to an improved survival.

Author Index for Abstracts

Numbers refer to abstract number

Abosaif, N.Y. 1
Ahmed, Z. 43
Akhtar, S. 38
Albright, R.C. 5
Aldrich, M. 44
Alexander, S.R. 17, 20, 23, 24, 28
Amigues, L. 30
Anderson, S.S. 5

Barletta, G.-M. 8
Baum, M.A. 17, 20, 23, 24, 28
Beck, L.L. 2
Beraud, J.J. 30
Bermond, F. 9, 14, 40
Bhatt, U. 48, 49
Bihorac, A. 6, 37
Bin, R. 22
Bin, X. 22
Bing, R. 26
Bing, X. 26
Bissler, J.J. 50
Blowey, D.L. 17, 20, 23, 24, 28
Boglia, J. 32
Borazan, A. 29
Brophy, P.D. 17, 20, 23, 24, 28, 36
Bukovsky, R. 32, 38
Bunchman, T.E. 8, 17, 20, 23, 24, 28

Canaud, B. 30
Cantaluppi, V. 9, 14, 40
Casciani, S. 16
Chand, D.H. 17, 20, 23, 24, 28
Chen, L. 41
Chen, Y. 25
Chua, A.N. 17, 20, 23, 24, 28
Churchwell, M.D. 12
Comert, M. 29

DaSilva, R. 27, 44
Daxi, J. 21, 22, 25, 26
De Angelis, S. 16
Dehua, G. 21, 22, 25, 26
Deleuze, S. 30
Dess, M.R. 16
Ding, X. 41
Djurdjev, O. 7
Dorscheid, D. 7

Ellsworth, K. 19

Fang, Y. 41
Fenocchio, C.M. 9, 14, 40
Ferrannini, M. 16
Fitzpatrick, J. 38
Fleureau, C. 45
Flores, F.X. 17, 20, 23, 24, 28
Fortenberry, J.D. 17, 20, 23, 24, 28
Friederichs, G. 18, 19

Gabrielli, A. 6, 37
Gajic, O. 5
Gauche, B. 45
Gilibert, S.G. 43
Goldstein, S.L. 17, 20, 23, 24, 28
Gong, D. 15
Grant, G. 7
Grio, M. 36
Guarena, C. 40
Gupta, M. 32

Ha, P.J. 35
Hackbarth, R.M. 8, 17, 20, 23, 24, 28,
Hahn, H. 3
Haugen, E.N. 4
Heap, M. 1
Hemasilpin, N. 50
Hixon-Vermillion, B. 48, 49
Hoffert, G. 38
Honglang, X. 26

HonorÈ, P.M. 45
Horike, H. 47
Hostetler, T. 48, 49
Howk, K. 27
Huang, Y.-W. 42
Hussaini, S. 11

Ito, S. 39
Iwaki, H. 39

Janvier, G. 45
Ji, D. 15
Jin, H.-S. 3
Jin, Q. 13, 34
Jing, T. 22, 26
Joannes-Boyau, O. 45
Jones, N. 27

Kashihara, V. 47
Khankin, E. 33
Kiaii, M. 7
Klouche, K. 30
Knechtel, L. 33
Kong, Y.-Z. 42
Kraus, M. 19
Krevolin, L.E. 43

Lafargue, M. 45
Layon, J.A. 6, 37
LeBrun, C.J. 51
Leishi, L. 21, 22, 25, 26
Leonardis, F. 16
Levin, A. 7
Li, L. 15
Lim, Y.J. 3
Lin, L.-H. 42
Liu, Y. 15
Long, K.H. 5
Louvar, D.W. 4

Madarasu, R.C. 11
Mahan, J.D. 17, 20, 23, 24, 28
Massanet, P. 30
Maxvold, N.J. 8

McBryde, K.D. 17, 20, 23, 24, 28
McLarin, R.W. 46
Meguid El Nahas, A. 1
Mi, H.Y. 35
Miyamoto, H. 39
Mottes, T. 36
Murray, P. 18, 19
Murrill, W.B. 46

O'Keefe, H.J. 2
Oh, S.H. 3
Ohnishi, Y. 39
Ono, J.I. 47
Ortis, P. 16
Ozcan, M.S. 37

Pacitti, A. 9, 14, 40
Park, S.J. 3
Park, Y.S. 3
Pasko, D.A. 12, 36
Plott, D. 48, 49
Podda, G. 9, 14
Polycarpou, M.M. 50
Prendergast, M.B. 31

Rauf, A. 5
Reddy, K. 11
Reddy, S.R. 11
Ren, B. 15
Rosenbaum, D. 7

Sanfilippo, D.J. 8
Sasaki, T. 47
Segal, M.S. 6
Segoloni, G.P. 9, 14
Sert, M. 29
Shao, Y.-H. 42
Sik, P.J. 35
Smoyer, W. 12
Somers, M.J.G. 17, 20, 23, 24, 28
Speer, R.R. 31
Splendiani, G. 16
Suh, H. 38

Su-Kil, P. 35
Sungur, M. 37
Suri, P. 10
Sutaria, S. 38
Swaminathan, L. 5
Symons, J.M. 17, 20, 23, 24, 28

Tamura, M. 39
Tartaglione, A. 16

Teng, J. 41
Thomas, S. 36
Tobe, S. 33
Tokura, T. 47
Tolba, Y.Y. 1
Tolwani, A.J. 10, 31, 46
Toshiya, O. 39
Treu, D. 18

Venti, E. 16

Wadhwa, N. 32, 38
Weixing, H. 26
Won, C.J. 35
Woodson, R.L. 46

Xiao, G.-Q. 42
Xu, B. 15

Yidan, Z. 22, 26
Yokota, K. 47

Young, I.E. 35
Yun, L. 22, 26

Zhaohong, C. 25
Zhihong, L. 25, 26
Zhong, Y. 41
Zhonghua, J. 22
Zou, J. 41