Port J Nephrol Hypert 2009; 23(4): 323-330
Advance Access publication 06 September 2009

A comparative study of cardiovascular tolerability with slow extended dialysis *versus* continuous haemodiafiltration in the critical patient

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Received for publication: 05/01/2009
Accepted in revised form: 20/06/2009

ABSTRACT

Background: In the haemodynamically unstable patient the method of treatment of acute renal failure is still largely controversial. The purpose of our study was to compare slow extended dialysis with continuous haemodiafiltration in the critical patient with indication for renal replacement therapy and haemodynamic instability. **Patients and Methods**: This is a cohort study comparing in 63 ventilated critical patients a 12 month period when only continuous haemodiafiltration was used (n=25) with an equal period of slow extended dialysis (n=38). Our primary objective was to evaluate the impact of the dialytic procedure on cardiovascular stability in those patients. As secondary aims we considered system coagulation/thrombosis and predictors of mortality. In the two groups we analysed the first session performed, the second session performed and the average of all the sessions performed in each patient. **Results**: In these patients, mortality in the intensive care unit was high (68% in the continuous haemodiafiltration group and 63% in the slow extended dialysis group). We did not find any association between the dialytic technique used and death; only the APACHE score was a predictor of death. Slow extended dialysis was a predictor of haemodynamic stability, a negative predictor of sessions that had to be interrupted for haemodynamic instability, and a predictor of achieving the volume removal initially sought. Slow extended dialysis was also associated with less coagulation of the system. **Conclusions**: Our data suggested that slow extended dialysis use was not inferior to continuous haemodiafiltration use in terms of cardiovascular tolerability.

Key-Words:
Acute renal failure; cardiovascular tolerance; continuous haemodiafiltration (CHDF); haemodynamic instability; slow extended dialysis (SLED)

INTRODUCTION

Acute renal failure in critical care is a worrisome condition, associated with significant mortality. It is usually a part of multiorgan failure with an expressive burden in the intensive care unit.

In the haemodynamically unstable patient the method of management of renal failure is still largely controversial[1-10]. In a critical care unit setting, several variations of the classic modalities of renal replacement therapy are emerging for the treatment of those

patients. The so-called sustained low-efficiency dialysis (SLED), extended daily dialysis, or even hybrid renal replacement technique, differs from conventional haemodialysis mainly in the length of treatment (duration over 6 hours) and in blood and dialysate pump velocities (lower than 200 and 300 ml/min, respectively)[11-13]. This hybrid technique that brings together conventional haemodialysis and slow continuous therapies features is becoming increasingly used and appears to add advantages from both kinds of techniques with minimisation of respective inherent limitations. Data are pointing to the fact that it can potentially replace traditional continuous therapy, given the lesser cost and logistic and technical complications[11,12,14-19].

Continuous haemodiafiltration (CHDF) has both diffusive and convective clearances and is considered the most complete form of continuous therapy[20]. There are studies comparing continuous haemofiltration (CHF) with SLED or CHDF with intermittent haemodialysis, but to our knowledge there has not yet been any comparison between SLED and CHDF.

In our intensive care unit SLED has become the renal replacement therapy of choice for haemodynamically unstable patients, but previously only continuous renal replacement therapy was available. In this cohort study we compared patients submitted only to CHDF and patients submitted only to SLED. Our primary objective was to evaluate the impact of the dialytic procedure (SLED and CHDF) on cardiovascular stability in those patients. As secondary aims we considered system coagulation/thrombosis episodes and predictors of mortality.

We compared, in 63 ventilated critical patients of that unit with indication for renal replacement therapy and haemodynamic instability, a 12 month period when only CHDF was used (GROUP I, n=25) with an equal period of SLED (GROUP II, n=38).

PATIENTS AND METHODS

The study was carried out in a 14-bed medical-surgical intensive care unit. In 2003 all patients presenting haemodynamic instability and need for renal replacement therapy (RRT) were treated with CHDF. SLED was performed in all such patients starting in February 2004. The study period was 2003-2005.

Inclusion criteria for this study were: 1) admission to the intensive care unit, 2) need for renal replacement therapy defined as one of the following – oliguria (urinary output ‹ 200ml in 12 hours), urea › 180mg/dl, fluid overload and pulmonary oedema, uraemic syndrome (encephalopathy, pericardial effusion, feeding intolerance), metabolic acidosis with pH‹7.15, K›6.5mmol/l or rapidly progressing, Na‹115mmol/l and 3) presence of hypotension (mean arterial pressure ‹80mmHg) and/or vasopressor support. Critical patients with indication for conventional haemodialysis (meaning need for RRT but with mean arterial pressure ›80mmHg without vasopressor support) were therefore excluded from the study.

The decision to treat was evaluated daily, considering the haemodynamic status of the patient, diuresis and laboratory parameters. Whenever appropriated, patients who recovered and needed further renal replacement therapy were treated on conventional dialysis and left the study.

CHDF was performed using a Gambro Prisma® monitor, AN 69 M60 or M100 filter, dialysis solution Hemosol BO® with potassium added as needed, blood flow rate (Qb) =150 to 180 ml/min, mean dialysate flow rate (Qd) =1730±630ml/h, mean replacement fluid (predilution) infusion rate =1260±340 ml/h. In Group II SLED was obtained using Gambro AK200® monitors, with Polyflux 14L® filtre, Qb =150 to 200 ml/min, Qd =300 ml/min. Time on SLED was 6 to 12 hours per session. Non-fractioned heparin was used in both techniques, in a dose of 1000 units bolus followed by 500 units/h, adjusted to an activated partial thromboplastine time of 1.5 times the control value.

Since we are dealing with procedures of different durations (continuous *versus* non-continuous), in order to have a comparable unit to a SLED session, we defined as an “isolated session” of CHDF the one realised in each 24-hour period (beginning at the time of the initiation of CHDF for each patient).

We used as comparative terms in each of the two groups of patients (CHDF *versus* SLED): A – the first session performed; B – the second session performed (thus overcoming the initial adaptation period allowing a comparison in what we designated the steady state); C – the average of all the sessions performed in each patient.

Variables studied were number of sessions in which the ultrafiltration (UF) volume sought was

achieved; number of haemodynamic instability episodes – defined as episodes of pressure lowering with need for therapeutic intervention (fluids, UF changing, increase or beginning of vasopressor) –; number of haemodynamic instability episodes that led to stopping of the dialytic technique; number of filter/circuit thrombosis and mortality. These variables were adjusted for age, severity scoring indexes (APACHE II and SAPS II), sepsis, heart failure, hourly UF rate, total UF rate and heparin units per hour.

Using multivariate analysis we analysed predictors of haemodynamic instability, predictors of interruption of dialytic procedure, predictors of achieving the volume removal clinically judged as adequate and tolerable for that patient, predictors of system coagulation and intensive care unit death.

Statistical analysis

Data are expressed as frequencies for categorical variables, mean values with SD for normally distributed variables. Comparison between groups was performed by the Student t-test, Mann-Whitney U (numerical variables) and chi-square tests (categorical variables). Multivariate analysis was performed by linear regression models, for the average of all sessions, and logistic regression models, when the first and second sessions isolated were considered, in which we integrated the enter model with a selection of variables based on relevant clinic criteria. Using the Hosmer and Lemeshow test we confirmed the quality of the adjustment in all models.

Statistical analyses were performed with the SPSS system 14.0 (SPSS Inc., Chicago, IL). For all comparisons a $p<0.05$ was considered significant.

RESULTS

Table I

Main characteristics of patients studied, according to the dialytic procedure

	GROUP I (CHDF)	GROUP II (SLED)	*p*
Age	59.2±18	66.9±15	0.069
Gender (M/F)	13/12	18/20	0.719
Under vasopressors	57.8%	62%	0.878
Oliguria	48%	64%	0.069
Sepsis	36%	36.8%	0.946
Heart failure	8%	13.2%	0.052
APACHE II	29.5±8	27.9±10	0.051
SAPS II	55.5±23	66.9±19	0.043
Admission days	12.5±13	23.4±25	0.048
Mechanical ventilation days	7±8	18.5±21	0.010
TOTAL OF SESSIONS	64	112	
SESSIONS / PATIENT	2.6±1.8	2.9±2.3	
REAL DURATION / SESSION	19±6	7.5±2.5	

The values in the centre columns correspond to the respective averages or percentages

Table II

Technical characteristics of first, second and the average of all sessions

	First Session			Second Session			All 174 Sessions		
	GROUP I (CHDF) n=25	GROUP II (SLED) n=38	*p*	GROUP I (CHDF) n=16	GROUP II (SLED) n=26	*p*	GROUP I (CHDF) n=25	GROUP II (SLED) n=38	*p*
Total UF (ml)	2577±1430	1644±1278	0.014[2]	2563±433	1814±174	0.029[1]	2346±1260	1730±910	0.028[1]
UF/hour (ml/h)	127 ml/h	238 ml/h	0.001[1]	154	280	0.006[2]	130	261	<0.01[1]
Heparin/hour (U/h)	380 U/h	487 U/h	0.014[2]	391	481	0.028[2]	394	474	0.050
UF achieved = intended	14 (56%)	33 (87%)	<0.001[2]	7 (44%)	23 (89%)	<0.001[2]	48%	89%	<0.001[2]
Haemodynamic instability	16 (64%)	15 (40%)	0.057[3]	7 (44%)	5 (19%)	0.075[3]	60%	28%	0.004[2]
Stopping for haemodynamic instability	4 (16%)	4 (11%)	0.523[3]	3 (19%)	1 (4%)	0.101[3]	25%	12%	0.065[2]
Filter/circuit thrombosis	9 (36%)	3 (8%)	0.005[3]	6 (38%)	3 (11%)	0.040[3]	34%	8%	0.000[2]

Univariate analysis by groups considering first session, second session and average of all sessions [1]Student t, [2]Mann-Whitney U, [3]$\chi 2$

Tables III

Multivariate analyses of the parameters studied

A. Independent variable: haemodynamic instability

	First Session (n=63)				Second Session (n=45)				All Sessions (n=63)		
	B	OR	95%CI (OR)	*p*	*p*	OR	95%CI (OR)	*p*	B	95%CI (B)	*p*
SLED	-1.876	0.15	0.02_1.05	0.056	-1.194	0.30	0.04_2.53	0.270	-0.491	-0.784_-0.198	0.001
Age	0.017	1.02	0.98_1.05	0.337	-0.005	0.99	0.94_1.05	0.842	0.001	-0.004_0.007	0.601
APACHE	-0.025	0.97	0.90_1.05	0.529	-0.049	0.95	0.85_1.07	0.412	-0.007	-0.019_0.006	0.275
SAPS II	0.020	1.02	0.98_1.06	0.258	0.043	1.04	1.00_1.09	0.078	0.004	-0.002_0.010	0.184
Sepsis	0.265	1.30	0.41_4.15	0.654	1.072	2.92	0.57_15.01	0.199	0.133	-0.054_0.319	0.160
UF/session	0.000	1.00	1.00_1.00	0.355	0.000	1.00	1.00_1.00	0.560	0.000	0.000_0.000	0.036
UF/hour	0.000	1.00	0.99_1.00	0.910	-0.007	0.99	0.98_1.00	0.185	0.000	-0.001_0.001	0.805

First and second sessions – logistic regression analysis: model p=0.276 and p=0.207, respectively. Average of all sessions – multiple linear regression analysis: model p=0.001; R^2=0.34

B. Independent variable: interruption of dialytic procedure

	First Session				Second Session				All Sessions		
	B	OR	95%CI (OR)	*p*	B	OR	95%CI (OR)	*p*	B	95%CI (B)	*p*
SLED	-4.669	0.01	0.00_0.80	0.040	-7.900	0.00	0.00_20.33	0.156	-0.289	-0.532_-0.045	0.021
Age	-0.058	0.94	0.86_1.04	0.232	0.069	1.07	0.92_1.25	0.381	0.000	-0.005_0.004	0.932
APACHE	-0.085	0.92	0.76_1.11	0.373	-0.369	0.69	0.44_1.07	0.101	-0.007	-0.018_0.003	0.168
SAPS II	0.084	1.09	0.96_1.23	0.174	-0.030	0.97	0.87_1.08	0.572	0.004	-0.001_0.008	0.130
Sepsis	0.097	1.10	0.09_13.57	0.939	4.563	95.87	0.16_58329	0.163	0.152	-0.003_0.307	0.055
UF/session	-0.006	0.99	0.99_1.00	0.067	-0.001	1.00	1.00_1.00	0.146	0.000	0.000_0.000	0.008
UF/hour	0.026	1.03	0.99_1.07	0.167	0.010	1.01	0.98_1.04	0.470	0.006	-0.001_0.001	0.979

First and second sessions – logistic regression analysis: model p=0.003 and p=0.028, respectively. Average of all sessions – multiple linear regression analysis: model p=0.001; R^2=0.36

C. Independent variable: achieving planned volume removal

	First Session				Second Session				All Sessions		
	B	OR	95%CI (OR)	*p*	B	OR	95%CI (OR)	*p*	B	95%CI (B)	*p*
SLED	4.297	73.50	4.44_1216.34	0.003	5.516	248.74	2.50_24716	0.019	0.542	0.275_0.809	0.000
Age	-0.023	0.98	0.93_1.02	0.340	0.103	1.11	1.01_1.22	0.034	-0.001	-0.006_0.005	0.841
APACHE	0.105	1.11	0.99_1.24	0.062	0.108	1.11	0.91_1.36	0.296	0.006	0.006_0.017	0.327
SAPS II	-0.023	0.98	0.93_1.02	0.316	-0.038	0.96	0.90_1.03	0.280	0.000	-0.005_0.006	0.861
Sepsis	-0.935	0.39	0.08_1.91	0.247	-4.292	0.01	0.00_0.78	0.037	-0.134	-0.304_0.036	0.119
UF/session	0.001	1.00	1.00_1.00	0.024	0.000	1.00	1.00_1.00	0.336	0.000	0.000_0.000	0.031
UF/hour	-0.002	1.00	0.99_1.010	0.681	0.002	1.00	9.9_1.01	0.774	0.000	-0.001_0.001	0.599

First and second sessions – logistic regression analysis: model p=0.001 and p=0.001, respectively. Average of all sessions – multiple linear regression analysis: model p≤0.001; R^2=0.41

D. Independent variable: system coagulation

	First Session				Second Session				All Sessions		
	B	OR	95%CI (OR)	*p*	B	OR	95%CI (OR)	*p*	B	95%CI (B)	*p*
SLED	-0.946	0.39	0.07_2.01	0.259	-2.373	0.093	0.01_0.75	0.025	-0.228	-0.393_-0.062	0.008
Sepsis	-0.347	0.71	0.14_3.56	0.674	0.017	1.017	0.19_5.33	0.984	-0.095	-0.242_0.052	0.202
UF/hour	-0.009	0.99	0.98_1.00	0.087	0.001	1.00	1.00_1.00	0.556	0.000	-0.001_0.001	0.928
Heparin/hour	-0.005	0.99	0.99_1.00	0.018	0.004	1.00	1.00_1.01	0.176	-0.000	-0.001_0.000	0.047

First and second sessions – logistic regression analysis: model p=0.002 and p=0.191, respectively. Average of all sessions – multiple linear regression analysis: model p=0.002; R^2=0.25

Table IV

Independent variable: mortality in the intensive care unit.

	All Sessions (176 sessions in 63 pts)			
	B	95%CI (B)	OR	*p*
SLED	0.147	0.030_45.21	1.16	0.937
Age	0.010	0.957_1.065	1.01	0.721
Gender (M/F)	0.818	0.471_10.91	2.27	0.307
APACHE	0.118	1.003-1.262	1.12	0.043
SAPS II	-0.35	0.918_1.016	0.97	0.183
Sepsis	0.719	0.356_11.84	2.05	0.422
Heart failure	0.444	0.145_16.80	1.56	0.714
UF/session	0.001	0.999_1.002	1.00	0.515
UF/hour	0.005	0.992_1.002	1.00	0.430
UF achieved=intended	0.952	0.062_108.5	2.59	0.617
Haemodynamic instability	2.407	0.550_224.57	11.11	0.117
Stopping for haemodynamic instability	5.400	0.560_87560	221.5	0.077
Total heparin	0.000	1.000_1.000	1.00	0.353

Logistic regression analysis: model p=0.006

During the study period 907 patients were admitted. Of these, 195 (21.5%) presented a markedly altered renal function (serum creatinine ›2.5 mg/dl or urea ›100 mg/dl or urinary output ‹400 cc /24 hours) and 140 (15.4%) underwent a renal replacement technique.

Sixty three patients met inclusion criteria and were enrolled. They were divided into 2 groups: Group I (CHDF) included 25 patients that underwent 64 dialytic sessions with an average of 2.6 sessions for patient; and Group II (SLED) 38 patients were submitted to 112 dialytic sessions with an average of 2.9 sessions for patient.

Using univariate analysis the two groups of patients were similar in terms of demographic characteristics and comorbidities. Patients submitted to SLED had significantly higher SAPS II severity scoring index, admission days and, consequently, mechanical ventilation days (Table I).

Analysing the first, the second and the average of all sessions (Table II), patients submitted to SLED had lower total UF but a higher hourly UF and a higher percentage of patients achieved the desired UF. A lower percentage of patients under SLED suffered circuit or filter thrombosis. When the average of all sessions per patient was assessed, it was also shown that patients treated with SLED had a lower percentage of haemodynamic instability. There was no significant difference regarding the earlier interruption of the technique due to haemodynamic instability, by univariate analysis.

Using multivariate analysis we observed:

- The number of sessions with haemodynamic instability episodes was dependent on the dialytic procedure used and UF/session. Concerning all sessions performed, the average number of haemodynamic instability episodes decreased 51% when SLED was used instead of CHDF, with that result adjusted for age, severity scoring indexes, sepsis, heart failure, total volume of UF per session and UF per hour (Table III A).
- Premature stopping as a consequence of haemodynamic instability was again dependent on SLED and UF/session (Table III B).
- Regarding predictors of achieving the planned volume removal, UF achieved = desired was once more dependent on SLED and UF/session (Table III C).
- Filter/circuit thrombosis was dependent on SLED and heparin units/hour. SLED use was a protector factor of coagulation of the system, as well as the heparin units per hour, adjusted to UF volume per hour and for the presence of sepsis (table III D).

In these patients, mortality in the ICU was high (68% in GROUP I and 63% in GROUP II). We did not find any association between the dialytic technique used and death. APACHE score was the only predictor of death obtained (Table IV).

DISCUSSION

SLED consists of an adaptation of conventional intermittent haemodialysis, aimed to be low efficient, as it in fact was at the beginning of dialysis history. This low efficacy is achieved using low blood and dialysate pump velocities, and treatment length is extended, allowing a reduced hourly fluid removal. The name SLED comes from the Arkansas group (UAMS, Little Rock) who in 1998 described the use of a Fresenius machine 2008H® with reduced dialysate and blood flow rates for 12-hour nocturnal treatments[12-15].

It has been increasingly reported that SLED has the advantages of intermittent haemodialysis (high efficacy, simplicity, lower cost, no need for industry prepared replacement fluids) plus the advantages of continuous renal replacement therapy (prolonged and smooth metabolic control with consequent reduced haemodynamic instability). Intuitively, continuous therapy is in line with the concept of critical care management as implying achieving homeostasis, giving time for organ recovery.

Data on SLED in the intensive care unit setting are still limited. The haemodynamic stability reported here agrees with previous descriptions. Our approach is very similar to the one used by Kumar *et al*[11]. They compared SLED not with CHDF but with continuous haemofiltration and found good cardiovascular tolerability and significant less anticoagulation requirements with the first. Other studies by the same group and others have confirmed those findings[12,16-19].

In this study, SLED was well tolerated in the majority of the cases, allowing an adequate control of volume status (as well as of solutes and electrolytes, outside the range of this study).

Regression analyses showed that the use of SLED was a positive predictor of haemodynamic stability, and also that fewer sessions had to be suspended for haemodynamic instability. Likewise, SLED appeared as a predictor for achieving the UF volume initially desired.

Dialysis efficacy described in the literature is at least non-inferior to that described with continuous therapies using high dialysate and substitution fluids[11,15,18], a factor implicated in the prognosis of critically ill patients with renal impairment[21,22].

Compared to continuous therapies, a lower anticoagulation use is the rule with SLED, due to a shorter dialytic period. Moreover, in this study, SLED use appeared as a protector factor of coagulation of the system. One could argue that in the present work there is less thrombosis with SLED because the time was less and time was not considered a variable. Considerable less total heparin was used in that group, which can have some beneficial impact on such patients with high risk for haemorrhagic complications as the ones considered here.

One obvious advantage of SLED is that, due to the length of treatment, at least two patients can be treated with the same dialysis monitor in the same 24-hour period. It is difficult to establish when to stop a continuous renal replacement therapy. In patients submitted to SLED the decision to switch to a conventional intermittent haemodialysis is easier.

Lower costs and workload are other important related issues[23,24]. The economic burden is significantly less with SLED; likewise this technique was easily learned and accepted by the nurses, and required less monitoring and intervention than CHDF, as observed previously by different authors[11,12].

Despite the repeated effort that has been made over the last few decades in order to demonstrate the advantages of continuous therapy in the critical patient with acute renal failure, and especially after the widespread use of biocompatible membranes, no benefit has been shown concerning survival and renal function recovery of that modality compared with conventional haemodialysis[5-9,24-26], as was recently seen in a multicentre randomised trial with 360 critical patients[27]. The proven prognostic factor in terms of therapeutic intervention in such patients seems to be dialysis dose and not the dialytic modality *per se*[21,22]. The belief that took root in the

supremacy of continuous therapy came from various circumstances, not only the theoretically superior cardiovascular tolerability and the benefit of convection clearance of the inflammatory sepsis mediators[28], but perhaps also the freeing of nephrologists from intensive care units[12]. In the era of biocompatible membranes, the first statements have been refuted, with studies showing the primordial importance of adsorption and the lack of clinical relevance of the removal of mediators (with no distinction between pro- or anti-inflammatory ones and minimal clearance compared with the endogenous one)[29-33].

LIMITATIONS OF THIS STUDY

This was an observational study comparing two different treatments in two groups of patients with similar baseline characteristics. A prospective and randomised analysis is needed to confirm these results.

The dose of therapy was not controlled, although the dialysate and substitution fluids used in this study in CHDF were in line with the standards recommended[21].

CONCLUSION

Despite this being a comparative uncontrolled study, in this group of critical patients SLED use was definitely not inferior to CHDF in terms of cardiovascular tolerability. SLED appeared as a predictor of haemodynamic stability, a negative predictor of sessions that had to be interrupted for haemodynamic instability, and a predictor of achieving the UF volume initially intended. SLED seemed also to protect against the coagulation of the system.

We have to wait for appropriately designed studies to shed definite light into what is common practice but which so far has insufficient evidence: the predominant use of continuous techniques for renal replacement therapy in haemodynamically unstable patients, with its considerable burden on economic and practical issues.

Conflict of interest statement. None declared.

References

1. Jakob SM, Frey FJ, Uehlinger DE. Does continuous renal replacement therapy favourable influence the outcome of the patients? *Nephrol Dial Transplant* 1996;11:1250-1255
2. Kresse S, Schlee H, Deuber HJ, Koall W, Osten B. Influence of renal replacement therapy on outcome of patients with acute renal failure. *Kidney Int Suppl* 1999; 72:S75-S78
3. Teehan GS, Liangos O, Jaber BL. Uptodate on dialytic management of acute renal failure. *J Intensive Care Med* 2003;18:130-138
4. Vanholder R, Van Biesen W, Lameire N. What is the renal replacement method of first choice for intensive care patients? *J Am Soc Nephrol* 2001;12(Suppl 17):S40-S43
5. Mehta RL, McDonald B, Gabbai FB, et al. A randomized clinical trial of continuous versus intermittent dialysis for acute renal failure. *Kidney Int* 2001; 60:1154-1163
6. Tonelli M, Manns B, Feller-Kopman D. Acute renal failure in the intensive care unit: a systematic review of the impact of dialytic modality on mortality and renal recovery. *Am J Kidney Dis* 2002; 40:875-885
7. Swartz RD, Messana JM, Orzol S, Port FK. Comparing continuous hemofiltration with hemodialysis in patients with severe acute renal failure. *Am J Kidney Dis* 1999; 34:424-432
8. Kellum JA, Angus DC, Johnson JP, et al. Continuous versus intermittent renal replacement therapy: a meta-analysis. *Intensive Care Med* 2002; 28:29-37
9. Uehlinger DE, Jakob SM, Ferrari P, et al. Comparison of continuous and intermittent renal replacement therapy for acute renal failure. *Nephrol Dial Transplant* 2005; 20:1630-1637
10. Swartz RD, Bustami RT, Daley JM, Gillespie BW, Port FK. Estimating the impact of renal replacement therapy choice on outcome in severe acute renal failure. *Clin Nephrol* 2005; 63:335-345
11. Kumar VA, Craig M, Depner TA, Yeun JY. Extended daily dialysis: A new approach to renal replacement for acute renal failure in the intensive care unit. *Am J Kidney Dis* 2000; 36:294-300
12. Marshall MR, Ma T, Galler D, Rankin AP, Williams AB. Sustained low-efficiency daily diafiltration (SLEDD-f) for critically ill patients requiring renal replacement therapy: towards an adequate therapy. *Nephrol Dial Transplant* 2004; 19:877-884
13. Marshall M, Golper T, Brennan D, Glassock R, Schwab S, Rose B. Sustained Low Efficiency or Extended Daily Dialysis. *UpToDate* 2006; version 15.1
14. Marshall MR, Golper TA, Shaver MJ, Alam MG, Chatoth DK. Sustained low-efficiency dialysis for critically ill patients requiring renal replacement therapy. *Kidney Int* 2001; 60:777-785
15. Marshall MR, Golper TA, Shaver MJ, Alam MG, Chatoth DK. Urea kinetics during sustained low-efficiency dialysis in critically ill patients requiring renal replacement therapy. *Am J Kidney Dis* 2002; 39:556-570
16. Kumar VA, Yeun JY, Depner TA, Don BR. Extended daily dialysis vs. continuous hemodialysis for ICU patients with acute renal failure: a two-year single center report. *Int J Artf Organs* 2004; 27:371-379
17. Lonnemann G, Floege J, Kliem V, Brunkhorst R, Koch KM. Extended daily veno-venous high-flux haemodialysis in patients with acute renal failure and multiple organ dysfunction syndrome using a single path batch dialysis system. *Nephrol Dial Transplant* 2000; 15:1189-1193
18. Kielstein JT, Kretschmer U, Ernest T, Hafer et al. Efficacy and cardiovascular tolerability of extended dialysis in critically ill patients: A randomized controlled study. *Am J Kidney Dis* 2004; 43:342-349
19. Schlaeper C, Amerling R Manns M, Levin NW. High clearance continuous renal replacement therapy with a modified dialysis machine. *Kidney Int Suppl* 1999; 72:S20-S23
20. Saudan P, Niederberger M, De Seigneuax S, et al. Adding a dialysis dose to continuous hemofiltration increases survival in patients with acute renal failure. *Kidney Int* 2006; 70:1312-1319

21. Ronco C, Bellomo R, Homel P, Brendolan A, Dan M, Piccini P, La Greca G. Effects of different doses in continuous veno-venous haemofiltration on outcomes of acute renal failure: a prospective randomized trial. *Lancet* 2000; 356:26-30

22. Schiffl H, Lang S, Fischer R. Daily hemodialysis and the outcomes of acute renal failure. *N Engl J Med* 2002; 346:305–310

23. Vitale C, Bagnis C, Marangella M, Belloni et al. Cost analysis of blood purification in intensive care units: continuous versus intermittent hemodiafiltration. *J Nephrol* 2003;16:572-579

24. Ma, T, Walker, R, Eggleton, K, Marshall, M. Cost comparison between sustained low efficiency daily dialysis/diafiltration (SLEDD) and continuous renal replacement therapy for ICU patients with ARF [Abstract]. Nephrology 2002; 7:A54.

25. Neveu H, Kleinknecht D, Brivet F, Loirat P, Landais P. Prognostic factors in acute renal failure due to sepsis. Results of a prospective multicentre study. *Nephrol Dial Transplant* 1996;11:293-299

26. Augustine JJ, Sandy D, Seifert TH, Paganini EP. A randomized controlled trial comparing intermittent with continuous dialysis in patients with ARF. *Am J Kidney Dis* 2004; 44:1000-1007

27. Vinsonneau C, Camus C, Combes A, et al; Hemodiaf Study Group. Continuous venovenous hemodiafiltration versus intermittent hemodialysis for acute renal failure in patients with multiple-organ dysfunction syndrome: a multicentre randomized trial. *Lancet* 2006; 368:379-385.

28. Bellomo R, Tipping P, Boyce N. Continuous veno-venous hemofiltration with dialysis removes cytokines from the circulation of septic patients. *Crit Care Med* 1993; 21:522-526

29. Lonnemann G, Bechstein M, Linnenweber S, Burg M, Koch KM. Tumor necrosis factor- during continuous high-flux hemodialysis in sepsis with acute renal failure. *Kidney Int Suppl* 1999; 72:S84–S87

30. Winchester JF, Silberzweig J, Ronco C, et al. Sorbents in acute renal failure and end-stage renal disease: middle molecule and cytokine removal. *Blood Purif* 2004; 22:73-77

31. Manns M, Sigler MH, Teehan BP. Continuous renal replacement therapies: an update. *Am J Kidney Dis* 1998; 32:185-207

32. Kellum JA, Johnson JP, Kramer D, Palevsky P, Brady JJ, Pinsky MR. Diffusive vs. convective therapy: effects on mediators of inflammation in patients with severe systemic inflammatory response syndrome. *Crit Care Med* 1998; 26:1995-2000.

33. Mariano F, Fonsato V, Lanfranco G, et al. Tailoring high-cut-off membranes and feasible application in sepsis-associated acute renal failure: in vitro studies. *Nephrol Dial Transplant* 2005; 20:116-126

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