

The Effect of Circuit “Down-Time” on Uraemic Control During Continuous Venovenous Haemofiltration

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ABSTRACT

Objective: The term continuous venovenous haemofiltration (CVVH) suggests a treatment without interruption. However, interruptions do occur and the duration of the haemofiltration circuit “down-time” may influence uraemic control. We conducted a prospective study to ascertain the percentage of operative “down-time” for CVVH in our intensive care unit and to test the hypothesis that it significantly affected uraemic control.

Patients and methods: Prospective data measuring the time spent off the filter in ten patients receiving CVVH were collected. Continuous venovenous haemofiltration was performed at 2 litres per hour of ultrafiltration. Anticoagulation was maintained using unfractionated heparin administered pre-filter and infused at a rate to achieve a systemic APTT varying between 30 - 45 seconds. The circuit functional life was documented for each CVVH circuit as progressive cumulative hours of operation. The time off treatment was calculated for each 24-hour period. These data were then correlated with the change in plasma urea and creatinine concentrations for each 24-hour cycle. The APTT, INR, haemoglobin and platelet count were measured and levels were correlated with the filter duration.

Results: Ninety three days of CVVH treatment were assessed in 4 female and 6 male patients. The mean circuit “down-time” in these patients for this period was 22% or 5.27 hours per day. The most common cause of circuit “down-time” was circuit clotting, followed by a need for radiological procedures, time spent in the operating theatre and catheter malfunction requiring replacement. There was a strong correlation between circuit “down-time” and increase in plasma urea ($p = 0.0017$) and creatinine ($p = 0.0451$) concentrations. Circuit “down-time” was also inversely correlated with the platelet count ($p = 0.0048$) but not significantly correlated with the APTT, INR or haemoglobin values.

Conclusions: In our study the average daily duration of an interruption in CVVH (i.e. circuit “down-time”) represented > 20% of the potential operative time. There was a strong correlation between time without treatment and solute control during CVVH. The percentage of “down-time” may be a useful marker of operative quality during CVVH. (**Critical Care and Resuscitation 2002; 4: 266-270**)

Key words: Continuous venovenous haemofiltration, uraemia, renal replacement therapy circuit failure

The use of renal replacement therapy (RRT) in the treatment of acute renal failure (ARF) in the intensive care setting is well documented.¹⁻³ The indications for the introduction of RRT in critically ill patients often include oliguria, anuria, azotaemia, severe acidemia, hyperkalaemia and fluid overload.⁴ In critically ill patients,

continuous techniques are the preferred method because they are associated with little haemodynamic instability and are effective in achieving azotaemic control.^{4,5}

Continuous renal replacement therapy (CRRT) techniques include continuous arteriovenous haemofiltration

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(CAVH), continuous arteriovenous haemodiafiltration (CAVHDF), continuous venovenous haemofiltration (CVVH), and continuous venovenous haemodiafiltration (CVVHDF).⁶ All these techniques suggest the treatment is ongoing and without interruption with an expectation that the plasma urea and creatinine levels would reduce and/or stabilise during such therapy. Interruptions to treatment, however, do occur when the circuit clots and/or when the patient requires procedures to be performed outside the intensive care unit such as surgery or radiological investigations. This means that in practice CVVH is not truly continuous and raises the question as to what effect such time "not on CRRT" might have on plasma urea and creatinine concentrations. At present, there is little evidence to indicate what level of continuous haemofiltration will maintain a particular target urea control over a 24 hour period. There is also little information of how many hours are spent off the filter each day in intensive care units that regularly perform CVVH. To address these issues we conducted a prospective observational study.

PATIENTS and METHODS

This study was classified as an anonymous and confidential quality improvement activity. Our ethics committee waives the need for informed consent for such activities. Consecutive patients treated with continuous veno-venous haemofiltration (CVVH) via a dual lumen catheter inserted in the femoral, internal jugular or subclavian veins were observed. Blood flow rate was maintained at 200 mL/min and ultrafiltration rate at 2 L/hour. Anticoagulation was achieved using low-dose (500 - 800 IU) unfractionated heparin infusions administered pre-filter with systemic activated partial thromboplastin time measured 24 hourly at 05:00 a.m. and regulated to achieve a range between 30 - 45 seconds. Continuous veno-venous haemofiltration was performed with a Hospal AN69S membrane (Hospal, Lyon, France) or an Asahi APS650 membrane (Asahi, Tokyo, Japan). Fluid replacement was administered into the circuit before the roller pump and filter. Fluid replacement therapy included either lactate-based or bicarbonate-based solutions to maintain fluid balance and acid-base balance as appropriate in a given patient.

The functional life was documented for each CVVH circuit as the progressive cumulative hours of operation for that circuit. This meant that the time "off treatment" and the overall filter life could be calculated for each 24 hour period. Filter life and corresponding "down-time" data were collected from a bedside data record. For all patients, plasma urea and creatinine measurements were obtained at 05:00 a.m. each day and retrieved from biochemistry department records. In addition, daily

blood platelet count, INR, APTT and haemoglobin values were recorded.

Statistical analysis

Descriptive statistics were obtained using a commercially available statistical package (Statview, Abacus Inc, Berkeley, CA) and are presented as means with standard deviation. The filter "down-time" data were then correlated with the change (delta) in plasma urea and creatinine for the corresponding 24-hour period using Spearman's test. Spearman's test was also used to measure any correlation between "down-time" and haematological variables of APTT, INR, haemoglobin and platelet count. A $p < 0.05$ was considered statistically significant.

RESULTS

Ninety three days of CRRT treatment were assessed in a cohort of 6 male and 4 female patients with an average age of 60.1 ± 18.4 years. The mean haemoglobin concentration during CRRT was $88 \text{ g/L} \pm 11.5$, the mean APTT was 35.7 ± 15.1 seconds, the mean INR was 1.37 ± 0.94 and the mean platelet count was $76 \pm 64 \times 10^9/\text{L}$. The filter "down-time" was calculated at 5.27 ± 5.6 hours indicating that in each 24 hour period the patient was without treatment for approximately 22% of the time.

The majority of "down-time" was due to circuit clotting, followed, in order of importance, by time needed for radiological procedures, time spent in the operating theatre and time required for insertion of a new double-lumen catheter. There was a strong correlation between circuit "down-time" and the change in plasma urea concentration ($p = 0.0017$), such that the longer the "down-time" the greater the increase in plasma urea concentration over a given 24-hour cycle (Figure 1). This was also true for the plasma creatinine ($p = 0.045$). There was no correlation between APTT, INR and haemoglobin and filter "down-time". However, there was an inverse correlation between platelet count and filter "down-time" ($p = 0.0048$) (Figure 2).

DISCUSSION

Previous reports suggest that continuous renal replacement therapy (CRRT) techniques such as CVVH are an efficient and safe form of solute control in the critically ill patient.⁵ Patients with acute renal failure will have a reduction or stabilisation of urea and creatinine concentrations over time with this therapy. Much work has recently focussed on the issue of adequacy of dialysis⁷ and the difference between prescribed and delivered dialysis dose,^{8,9} but little information is available on the difference between prescribed and delivered CRRT dose.^{10,11}

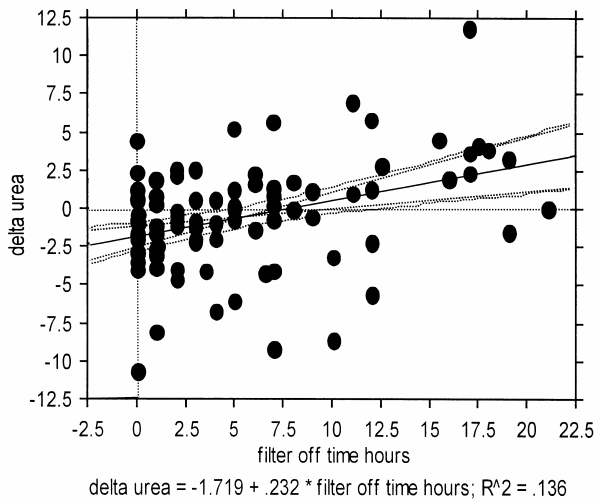


Figure 1. A scattergram displaying the relationship between the circuit “down-time” and change (delta) in plasma urea concentration (mmol/L) over a 24-hour period. The longer the “down-time” the greater the plasma urea concentration (mmol/L).

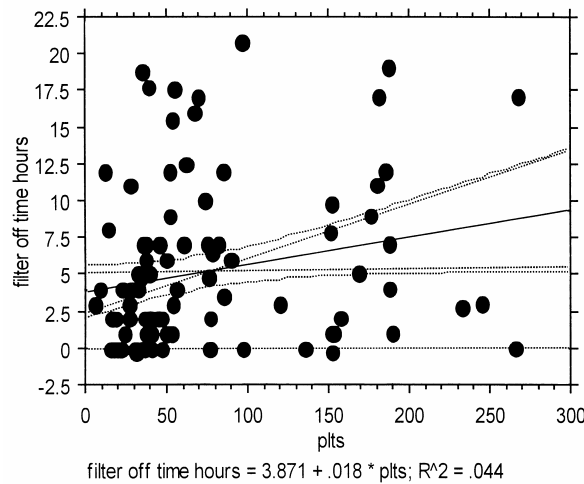


Figure 2. A scattergram displaying the relationship between the circuit “down-time” and the platelet count (pts) x 10⁹/L. The lower the platelet count the shorter the “down-time” over a 24-hour period.

The difference between delivered and prescribed CRRT will depend on several factors including the relationship between pre-dilution and overall blood flow, the number of episodes of poor access function during which blood flow falls below the set value and the function of the membrane over time, but none are likely to be as important as the time spent without treatment (e.g. “down-time”). However, despite the importance of such CRRT-free periods, very little information is provided on such “down-time” in studies of CRRT. Furthermore, although many studies of filter

life have been reported,¹¹ none have focussed on the practical implications of filter clotting on solute clearance. In terms of uraemic control and adequacy of dialysis, it may be preferable to have a mean filter life of 16 hours if the “down time” is one hour, than a filter life of 30 hours, if the “down time” is 6 hours. Thus, in terms of operational performance, it is as important to know mean filter “down-time” as it is to know mean filter “on” time. Our study represents the first formal investigation of the epidemiology and extent of filter “down-time” and its consequences on uraemic control.

In a cohort of > 90 filters, the mean 24-hour circuit “down-time” was 5.27 hours. This represents > 20% of potential operative time. Thus, the CRRT dose delivered in our unit appears to be significantly less than the dose prescribed. The effect of such “down-time” will be particularly marked if the initial prescribed dose is limited in amount (i.e. UF rate of 1L/hr) as is the case in several units internationally. In our patients, the greater the “down-time” the more likely the urea and creatinine concentrations were to increase rather than remain stable or decrease over a 24 hour cycle. Thus, “down-time” is a powerful determinant of adequacy of renal replacement therapy.

The clinical importance of delivering an adequate dose of CRRT was recently underscored by a randomised controlled trial, which showed that increasing the UF rate from 20 mL/kg/hr to 35 mL/kg/hr decreased mortality.¹¹ Importantly, in that study, attention was paid to avoiding significant “down-time”, such that all patients had all circuits in operation > 80% of the time. Others, however, have recently reported that their mean “down-time” was approximately 8 hours/day.¹⁰ If one is treating an 80 kg patient with a prescribed dose of UF at 2 L/hr and the “down-time” is on average 8 hours a day, that patient would receive a CRRT dose of less than 17 mL/kg/hr, a dose that has been reported to be associated with a significant increase in mortality.¹¹

We specifically obtained information about the events surrounding every period spent “off” CRRT and found that filter clotting was the most important cause. Frequent filter clotting inevitably increases filter “down-time”. In this regard and consistent with this observation, we found that the lower the platelet count, the shorter the filter “down-time”. This effect is clearly mediated by the previously noted effect of thrombocytopenia on prolonging filter life. Thus, “down-time” is secondary to the time required for the priming of a new filter and the renewed connection of the patient to another circuit. We found that although 43 episodes of “down-time” were due to filter clotting and filter change, the average time required for the re-insitution of therapy was 1.9 hours. We consider such time interval within expectations for the procedure of filter change

and believe that only limited improvements can be made to speed of execution in this area. The second observation is that a variety of procedures interrupted CRRT (e.g. surgery, CT scanning, MRI, etc). The impact of these procedures on "down-time" however, depended on the ability of the unit to plan and prepare for the immediate re-introduction of therapy once the patient returned to the unit. Our findings suggest that there could be scope for improvement in this area given the average duration of 7.7 hours for these episodes. The same appeared to be true for operative procedures. The third observation was that the quality of vascular access was also an important determinant of circuit "off" time. Poor vascular access induces frequent filter clotting and ultimately requires a change of site or a change of catheter. This procedure requires the availability of a physician with the expertise to safely insert such catheters and inevitably requires additional time. The average period for the procedure and circuit re-institution was 6.5 hours, suggesting significant scope for improvement in this component of "down-time". Fourth, nursing expertise is likely to impact upon "down-time". The limited availability of nurses who can prepare, prime and institute the CRRT circuit with ease will inevitably delay the re-commencement of CRRT in a given unit. Attention to the above components of care are likely to decrease "down-time" and improve the level of uraemic control.

The epidemiology of "down-time" is undefined. Our study represents the first simple investigation of this phenomenon and provides an initial impression of its magnitude and clinical impact. More detailed information is now needed to plan interventions aimed at minimising it. A large North American centre, recently reported a mean "down-time" > 8 hours¹⁰ as an incidental component of a large randomised controlled trial of CRRT versus intermittent haemodialysis. However, we believe that a reasonable goal would be a "down-time" < 15% of operative time, although we realise that such a cut-off point is arbitrary.

Our study has several limitations. First, it is a descriptive epidemiological study, which does not test any intervention. However, it is prospective in nature and aimed at understanding the nature and magnitude of a previously poorly described phenomenon. Furthermore, we prospectively studied the biochemical consequences of this phenomenon and report a clear impact. The study involved 10 patients and is, therefore, relatively small in size. However, we studied 93 filter days under variable daily conditions of operation which probably represented a sufficient sample of our average activity over time. Thus, we believe that our findings are representative of the operational performance of our unit and we were able to adequately test our hypothesis that

this phenomenon was significant and had clear biochemical consequences. We established the etiology of the reported "down-time" and consider this an important step in trying to develop an effective preventive strategy. As our study was a single centre study it may not apply to other institutions. However, given our unit's long standing commitment to excellence in CRRT, we believe that this is unlikely to be the case and consider it more likely that this phenomenon and its consequences have not been widely appreciated.

In conclusion, we have conducted a study to determine the actual percentage of "down-time" for CRRT in a tertiary adult intensive care unit. We found that the "off" filter time represents > 20% of potential operative CRRT time and that there is a direct correlation between this and loss of uraemic control. We also found that several causes exist for such "down-time" and that most appear amenable to improvement. Further research is now required to determine what interventions might be effective in diminishing its duration.

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