Automated electronic monitoring of circuit pressures during continuous renal replacement therapy: a technical report

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ABSTRACT

Background: Automated electronic monitoring and analysis of circuit pressures during continuous renal replacement therapy (CRRT) has the potential to predict failure and allow intervention to optimise function.

Methods: Current CRRT machines can measure and store pressure readings for downloading into databases and for analysis. We developed a procedure to obtain such data at intervals of 1 minute and analyse them using the Prismaflex CRRT machine, and we present an example of such analysis.

Results: We obtained data on pressures obtained at intervals of 1 minute in a patient with acute kidney injury and sepsis treated with continuous haemofiltration at 2 L/hour of ultrafiltration and a blood flow of 200 mL/minute. Data analysis identified progressive increases in transmembrane pressure (TMP) and prefilter pressure (PFP) from time 0 until 33 hours or clotting. TMP increased from 104 mmHg to 313 mmHg and PFP increased from from 131 mmHg to 185 mmHg. Effluent pressure showed a progressive increase in the negative pressure applied to achieve ultrafiltration from 0 mmHg to –168 mmHg. The inflection point for such changes was also identified. Blood pathway pressures for access and return remained unchanged throughout.

Conclusions: Automated electronic monitoring of circuit pressure during CRRT is possible and provides useful information on the evolution of circuit clotting.

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Extracorporeal circuit (EC) clotting is the main reason for the disconnection of continuous renal replacement therapy (CRRT). Such clotting may contribute to inadequate treatment, increased blood loss, greater costs and additional nursing time dedicated to CRRT instead of direct patient care.[1] Circuit dysfunction with changes to pressures measured from the circuit can precede this event and may or may not be recognised.[2] Understanding which pressure or combination of pressures are responsible for circuit failure may result in better management of CRRT and may be associated with longer function and more effective treatment goals.

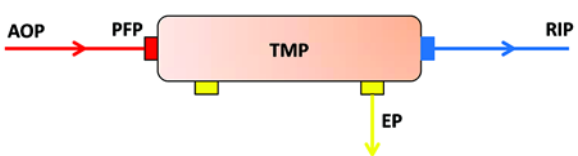
A previous study recorded circuit pressures manually on an hourly basis during CRRT and showed that different patterns of pressure profiles might be associated with different circuit life spans.[3] However, this approach may miss important circuit events between measurements, which are not recorded but which may have more impact on the circuit function afterwards.

Current CRRT machines are now capable of providing continuous pressure measurements at different points of the extracorporeal circuit,[4] and these data can be downloaded for analysis. We report a method for obtaining and analysing such data.

Methods

Our study was approved by the Austin Hospital Human Research Ethics Committee (LNR/14/Austin/596), which waived the need for informed consent because the study involved no direct intervention on patients and all data were de-identified.

Figure 1. Circuit pressure monitoring during continuous renal replacement therapy



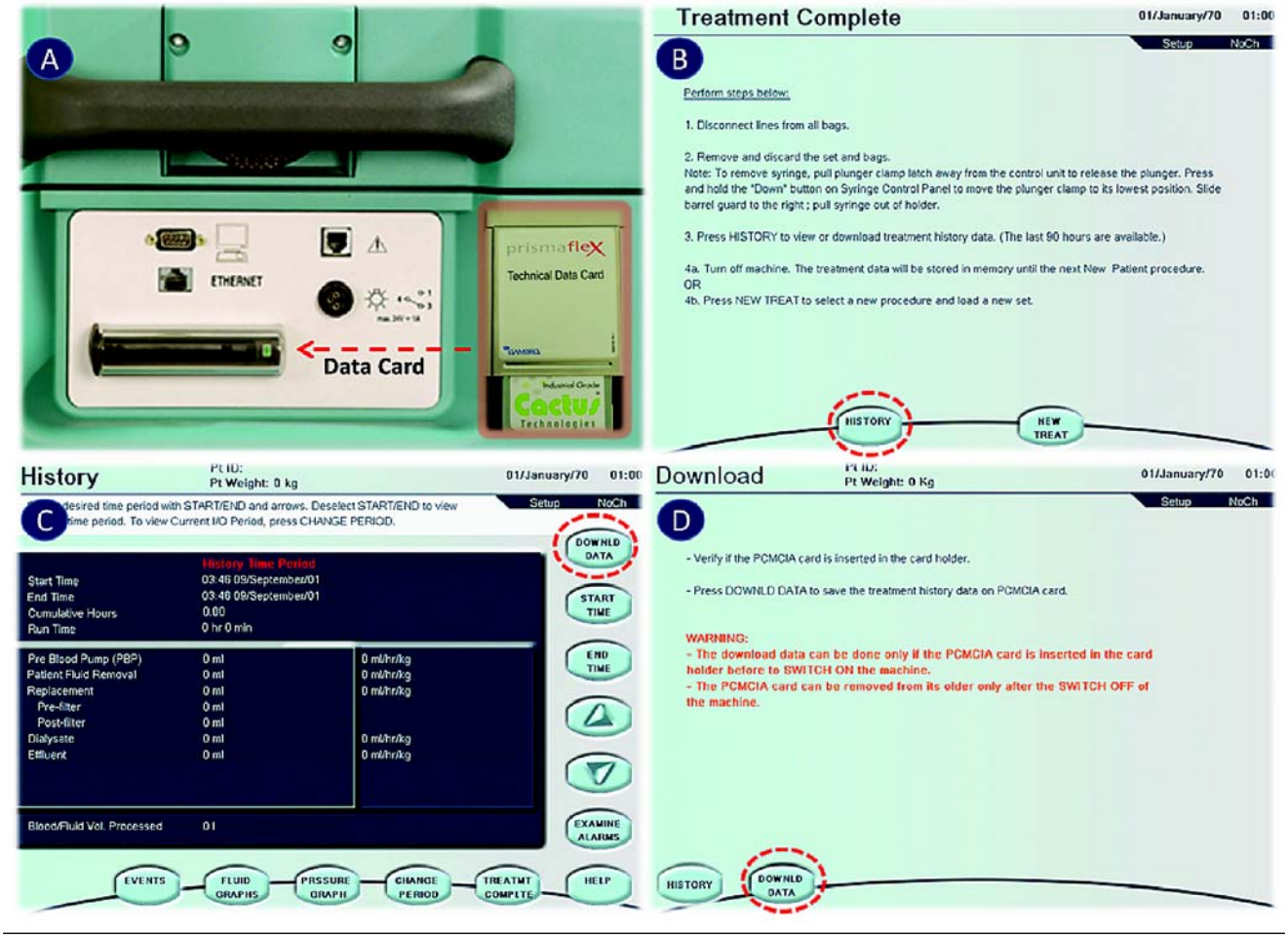
AOP = access outflow pressure. PFP = prefilter pressure.
TMP* = transmembrane pressure. EP = effluent pressure.
RIP = return inflow pressure. * TMP = (PFP + RIP)/2 – EP (mmHg).

As shown in Figure 1, data on circuit pressures from vascular access outflow, filter, effluent, vascular return inflow and across the filtering membrane were collected from different circuit points. The following method was used.

Data download

In the Prismaflex machine (version 4.10), all data history of circuit pressures is stored from the beginning of each "new patient" treatment until a "new patient" entry is registered. Data can then be permanently downloaded onto a rear "PCMCIA" technical data card any time from "end treatment" until "new patient" is selected the next time.

Figure 2. Process of downloading the data from the Prismaflex machine



A: insertion of data card reader. B: from the "choose patient" screen, select "last history". C and D: download data.

As shown in Figure 2, the PCMCIA technical data card must first be installed in the Prismaflex PCMCIA card reader (A); second, the Prismaflex machine must be switched on; and third, from the "choose patient" screen, one must select "last history" (B) and "download data" (C and D) and follow the prompts.

Data importing

The PCMCIA card is inserted into the PCMCIA card slot in any computer, and the computer should automatically display the files (*.txt files); then an Excel (Microsoft) spreadsheet can be opened and the Data/Import External Data/Import data can be selected from the drop-down menu. The next step is to select the desired *.txt file from the PCMCIA files. After selecting "delimited" as the file type and choosing "next", the third step involves the following actions: deselect "tab"; select "semicolon"; click "finish"; and finally, press "OK" as prompted in the choice box.

Data extraction

In the second page of the data, the circuit pressures including "access pressure", "filter pressure", "effluent pressure" and "return pressure" are presented every minute from the beginning to the end of treatment.

The transmembrane pressure (TMP) using prefilter pressure (PFP), return inflow pressure (RIP) and effluent pressure (EP) can be calculated using the following equation:

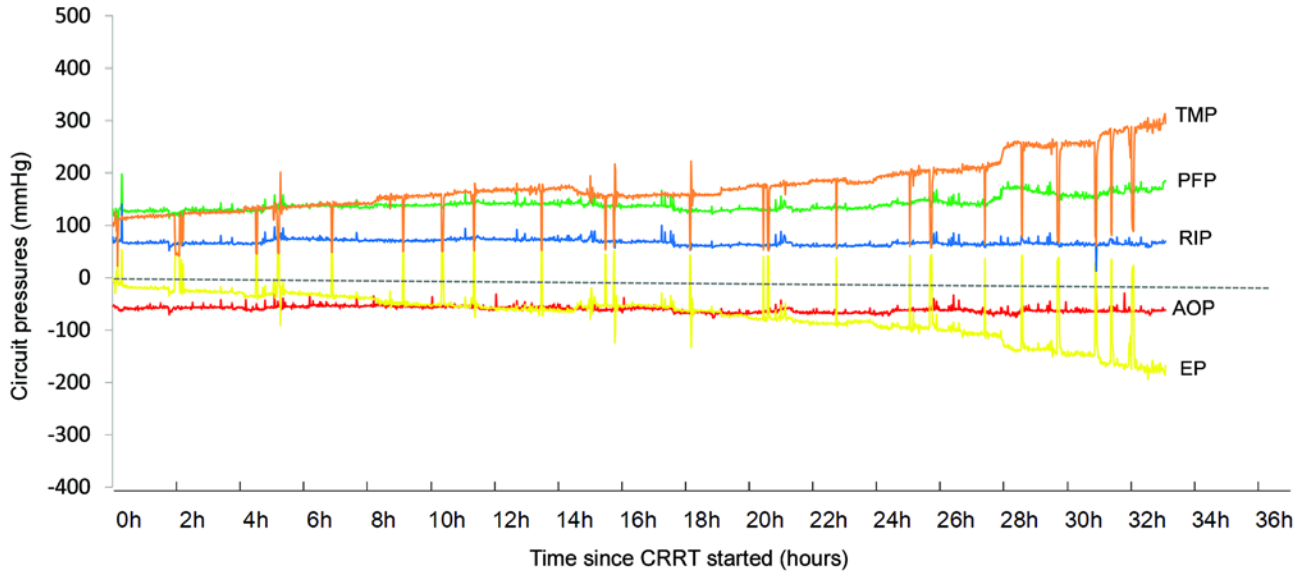
$$TMP = (PFP + RIP)/2 - EP \text{ (mmHg)}$$

Finally, line graphs can be drawn to display the dynamic changes of all pressures during CRRT treatment.

Results

We observed one EC CRRT treatment and present the dynamic changes of circuit pressures and obtained data for close to 2000 minutes. The mode of treatment was continuous venous–venous haemofiltration (50% postdilution) per-

Figure 3. Dynamic changes of circuit pressures during continuous renal replacement therapy (CRRT)



TMP = transmembrane pressure. PFP = prefilter pressure. RIP = return inflow pressure. AOP = access outflow pressure. EP = effluent pressure. The process of clotting becomes more obvious after about 20 hours, when the increase in TMP shows a steeper gradient.

formed on a 48-year-old man with a septic acute kidney injury, at a rate of 2 L/hour of effluent flow with the blood flow rate set at 200 mL/minute. Although heparin was used, the filter clotted at 33 hours with a high TMP (313 mmHg). As shown in Figure 3, the dynamic changes in access outflow pressure (AOP), PFP, EP, RIP and TMP could be displayed every minute in graphic format. The AOP and RIP remained close to baseline values, but the TMP and PFP progressively increased (TMP, 104–313 mmHg; PFP, 131–185 mmHg). EP also showed a progressive decrease from 0 to –168 mmHg, indicating a greater and greater suction pressure being applied to achieve the prescribed effluent rate.

Discussion

We have developed and identified a method for the automated electronic monitoring of circuit pressures every minute during CRRT. The graphical representation of this treatment in Figure 3 reflects the likely natural life for some extracorporeal circuits, in which resistance slowly increases across the filter membrane over time, due to microclotting-induced loss of filtering membrane surface.[1] As a consequence, the TMP progressively increases until the machine software calculates that the combination of the PFP increase (absolute $\Delta = 54$ mmHg) or calculated TMP (absolute $\Delta = 209$ mmHg) exceeds the limits acceptable by its software. The machine then sounds an alarm and indicates "filter clotted". Alternatively, the bedside nurse managing the treatment could observe these pressure changes and decide ahead of the alarm to stop the treatment. In addition, the reduction in the EP (absolute $\Delta = -168$ mmHg) reflects the increasing negative pressure being applied due to the effect of a constant ultrafiltrate demand across a clogging membrane. This example clearly shows a clotting or clogging event rather than a blood flow failure as the AOP and RIP, which represent blood flow, remained unchanged over the 33 hours of observation. Spikes or changes are noted in the TMP (less positive) and the EP (less negative) associated with stoppages in fluid flow (substitution and effluent) for changes to provide new full substitution fluids or to empty the full effluent bag. These events are distributed throughout the period and are noted at about 2.5-hour intervals.

The graph shown in Figure 3 is consistent with that reported by Ejaz and colleagues, who showed progressive membrane failure over time with no blood flow (access catheter) dysfunction.[3] However, we have previously observed failure of the EC due to mechanical factors.[5] This technical study allows initiation of studies to estimate the incidence of catheter dysfunction as a cause of filter failure in populations of CCRT patients. We plan to perform such studies in the near future.

Conclusion

We report a technique to obtain, record, analyse and graphically display circuit pressures during CRRT in an automated, electronic minutely rate and present in one case example of about 2000 minutes of observation. This technique has the potential to define patterns of failure for the many different causes of circuit failure and provide the CRRT equivalent of the black box used to analyse adverse events in aviation.

Competing interests

None decla .

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