INTRADIALYZER PRESSURES:
Limits, measurement pitfalls and influence of surface area

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INTRODUCTION

Recent evidence from RCTs suggests that post-dilutional haemodiafiltration (HDF) has an associated benefit in survival, provided it is performed with high convection volumes (HCV). To obtain HCV – HDF, significant pressure has to be applied to the dialyzer membrane, frequently surpassing the advised TMP limits with a consequent increase in the number of alarms and interruptions during the dialysis procedure.

The question arises whether the safe TMP limits given by the recommendations (ERBP) remain appropriate and adapted to modern technology dialysis systems.

The aim of this study was to assess the actual pressure in the different parts of the dialyzer in HCV-HDF, and testing the consequences of varying dialyzer surface area on TMP.

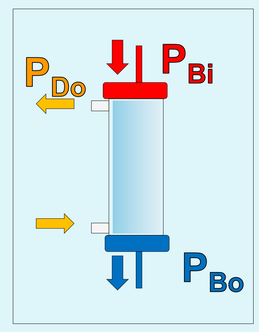
METHODS

Twelve stable dialysis patients were treated with post-dilutional HCV-HDF with high flux AMEMBRIS® membrane dialyzers (B BRAUN Avitum, Melsungen, Germany) of 1.8 m² (K_{UF} = 99 ml/h/mmHg) and 2.3 m² (K_{UF} = 124 ml/h/mmHg) for 3 treatments of the week each.

Blood inlet (P_{Bi}) and outlet (P_{Bo}) and dialysate outlet (P_{Do}) pressures were continuously recorded and a sample of 450 values per session were retained to assess the dialysis session (Monitor DIALOG plus, B BRAUN Avitum, Melsungen, Germany). Transmembrane pressure (TMP) was calculated with three pressure points ($TMP3 = (P_{Bi} + P_{Bo})/2 - P_{Do}$) and two pressure points ($TMP2 = P_{Bo} - P_{Do}$).

Three time points were assessed: at the start of the session (Start), just before TMP alarms and the first manually decreased in infusion by the nursing staff (Modif) and before stopping dialysis (End). For each time point, 10 readings were obtained and the average, minimal and maximal values were considered.

The results are given separately for the two membrane surface areas as mean ± SEM.



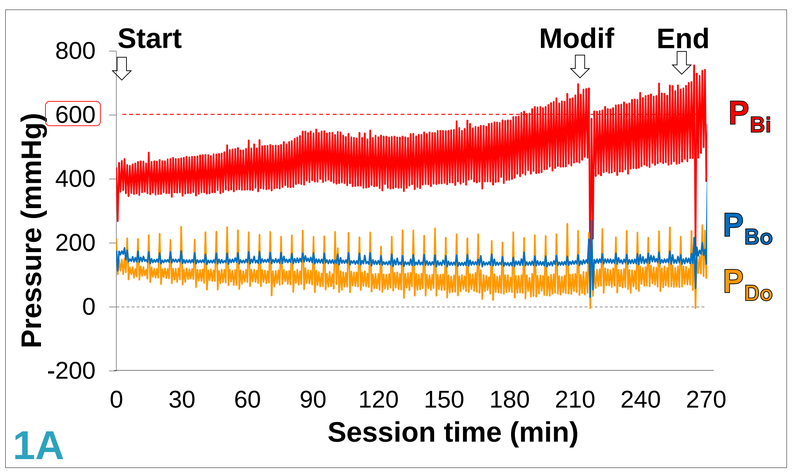
RESULTS

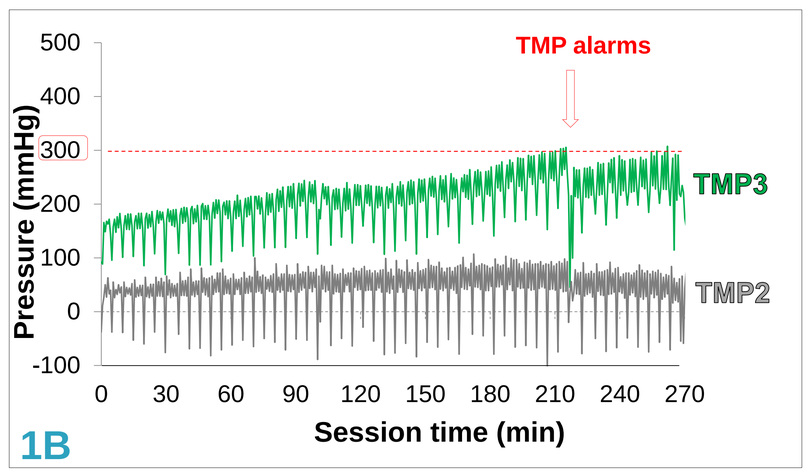
Intradialyzer pressures during one on-line post-dilution hemodiafiltration session for one patient

During a representative HCV-HDF session, inlet blood pressure (P_{Bi}) increased over time and exceeded 600 mmHg (Fig 1A), a limit given by the dialyzer manufacturer, while outlet blood pressure (P_{Bo}) was relatively constant.

The infusion flow was reduced when TMP, calculated with 3 sensors (TMP3), reached 300 mmHg (Fig 1B). Unlike P_{Bi} and TMP3, TMP2 decreased after infusion flow change.

TMP2 was lower and varied less than TMP3. When TMP3 reached 300 mmHg, TMP2 was under 100 mmHg.





Session data:

Membrane: 1.8 m²
Q_B = 350 mL/min

Q_{UF} Start = 102 mL/min
Q_{UF} End = 94 mL/min
Mean Q_{UF}/Q_B = 28 %

Total UF volume = 27 L
Total infusion volume = 23.2 L

Fig 1: Intradialyzer pressure variation over session time.

Intradialyzer pressures at three time points during dialysis sessions for 12 patients

Measured pressures in the blood compartment (inlet) were as high as 745 mmHg for the 1.8 m² dialyzer and 702 mmHg for the 2.3 m² dialyzer (Fig 2A and 2C).

Lowest pressures in the dialysate compartment were -51 and 12 mmHg for the 1.8 and 2.3 m² dialyzers respectively (Fig 2A and 2C).

Differences between coinciding measurements of P_{Bi} and P_{Do} could be as high as 794 and 656 mmHg for the 1.8 and 2.3 m² dialyzers respectively.

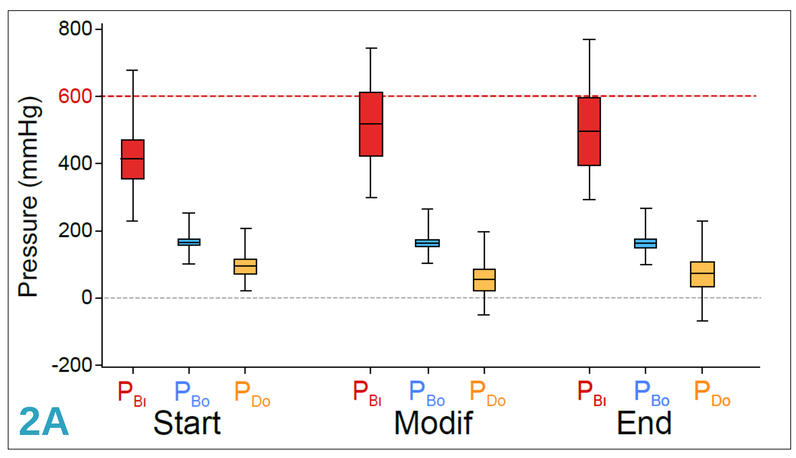
TMP3 exceeded TMP2 at all time points, by a factor ranging from 2.6 to 2.9 with the 1.8 m² dialyzer and 2.8 to 2.9 with the 2.3 m² dialyzer (fig 2B and 2D).

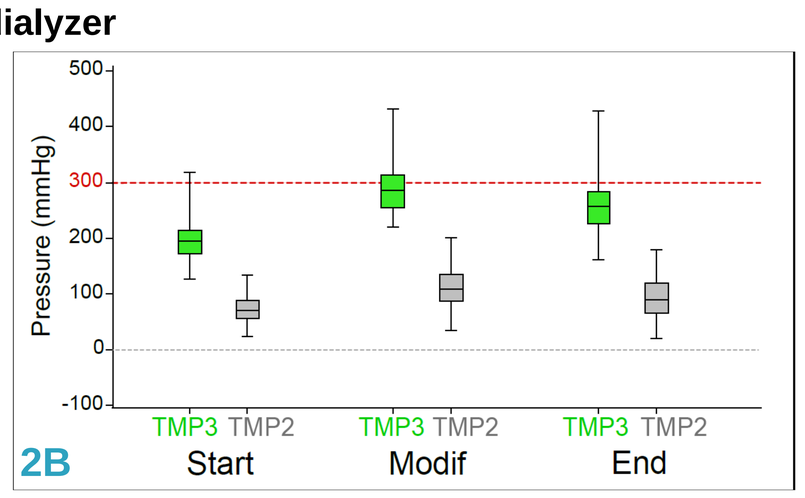
Increasing the surface area from 1.8 to 2.3 m² reduced the absolute value of TMP3 (fig 2B and 2D).

TMP alarms appeared after 137 ± 11 min with the 1.8 m² and about 45 minutes later with the 2.3 m² dialyzer (182 ± 18 min; $p < 0.05$).

The proportion of sessions with infusion reductions was 72% with the 1.8 m² and 21% with the 2.3 m² dialyzer.

1.8 m² dialyzer





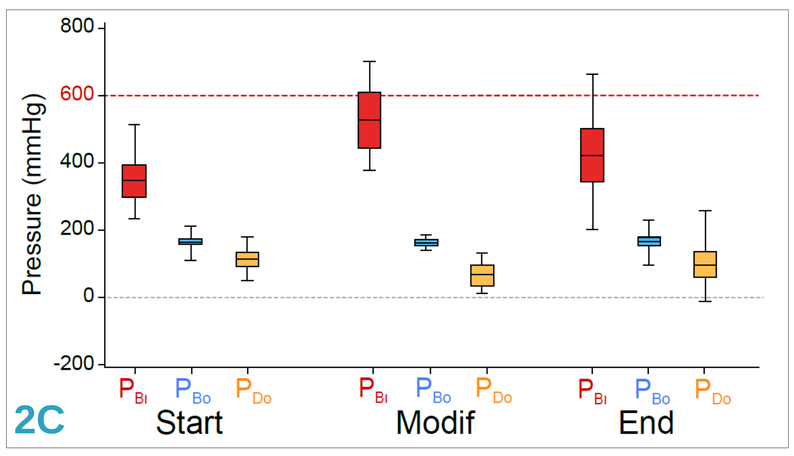
Sessions data:

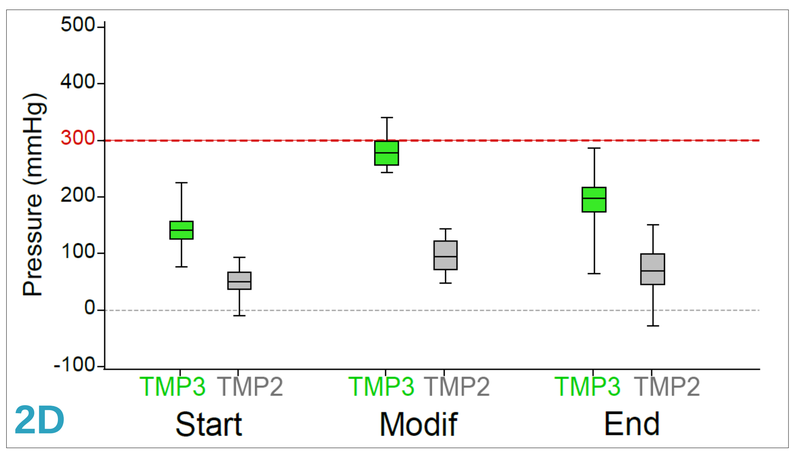
n = 36 sessions
Membrane: 1.8 m²
Q_B = 368 ± 5 mL/min

Q_{UF} Start = 115 ± 2 mL/min
Q_{UF} End = 102 ± 2 mL/min
Mean Q_{UF}/Q_B = 28.1 ± 0.4 %

Total UF volume = 24.5 ± 0.6 L
Total infusion volume = 21.8 ± 0.4 L
Session time = 232 ± 3 min

2.3 m² dialyzer





Sessions data:

n = 33 sessions
Membrane: 2.3 m²
Q_B = 365 ± 5 mL/min

Q_{UF} Start = 108 ± 2 mL/min
Q_{UF} End = 105 ± 2 mL/min
Mean Q_{UF}/Q_B = 28.0 ± 0.3 %

Total UF volume = 24.3 ± 0.6 L
Total infusion volume = 21.5 ± 0.5 L
Session time = 235 ± 3 min

Fig 2: Pressure values at three time points during dialysis sessions.

CONCLUSIONS

Even when applying the recommended limit of 300 mmHg for average TMP3 from the guidelines, blood inlet pressure and transmembrane pressure in some areas of the dialyzer may exceed manufacturer safety limits.

From the same data, calculating TMP with a 3 point approach, compared to a 2 point approach, resulted in more than a 2.6-fold increase.

Increasing the surface area from 1.8 to 2.3 m² reduced TMP3 and the number of infusion reductions during dialysis procedures.

To achieve high-volume convection in post-dilution HDF under safe pressure limits, the pressure at the blood inlet should be monitored and taken into account in the TMP calculation.

These aspects must be considered in clinics and are particularly relevant when elaborating the recommendations for convection and pressure limits in haemodialysis and haemodiafiltration.

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