Hemofiltration in Cardiac Patients
How to Choose the Parameters

RJ Leor-Librach$^{1,2,3}$

$^1$The Heart Institute, Laniado Hospital, Netanya, Israel
$^2$The Heart Institute, Sheba Medical Center, Ramat Gan, Israel
$^3$The Sackler School of Medicine, Tel Aviv University, Ramat Aviv Tel Aviv, Israel

Abstract

Continuous veno-venous hemofiltration (CVVH) is a method of renal replacement therapy suitable for patients with cardiogenic shock and renal failure. Water and solute are removed from the blood by convection without causing hypotension. The tuning of hemofiltration parameters is mainly based on empirical rules of thumb and is aimed at efficient fluid and solute removal while keeping hemodynamic stability and preventing hemofilter clotting from exaggerated hemoconcentration at the hemofilter level. We have built an educational computer program that simulates the hemofiltration process and calculates the desirable relations between blood flow through the hemofilter, the infusion rate and net negative fluid balance. This program also tries to predict the rate of urea and creatinine removal by the device according to the chosen parameters.

1. Introduction

Continuous veno-venous hemofiltration (CVVH) has gained wide acceptance within intensive care units as a method of renal replacement therapy [1,2]. Small and medium sized molecules are removed by convection and replacement fluid is infused, thus preserving hemodynamic stability. Hemofiltration is most suitable in patients with cardiogenic shock and renal failure, where conventional hemodialysis may cause hemodynamic instability. It may also be used in patients with severe heart failure complicated with edema, fluid accumulation and renal failure [3] and in patients after out of hospital cardiac arrest [4]. Hemofiltration has been shown to be effective in preventing the deterioration of renal function due to contrast-agent–induced nephropathy after coronary interventions [5]. The hemofiltration apparatus is a microprocessor-based device which controls pumping venous blood through a special hemofilter where the ultrafiltrate leaves the blood through special pores in the hemofilter. The device adds infusion fluid to the blood to exactly match the fluid loss in the hemofilter or enables a controlled preprogrammed negative fluid balance (The Edwards hemofiltration device). The mixed blood and infusion are then returned to the body. The tuning of hemofiltration parameters is mainly based on empirical rules of thumb, and is aimed at efficient fluid and solute removal while preserving hemodynamic stability, and preventing hemofilter clotting from exaggerated hemoconcentration at the hemofilter level. The aim of our present project was to build a computer program that will help to choose the right parameters in order to prevent hemofilter clotting and at the same time will try to predict changes in several blood constituents, mainly urea and creatinine, during hemofiltration.

2. Methods

Figure 1 demonstrates the hemofiltration process.

Figure 1. The hemofiltration Scheme

As blood is pumped through the hemofilter the filtrate moves to the filtration chamber and the hematocrit and protein concentration may rise to a point were the hemofilter may clot. In order to prevent extreme
blood concentration within the hemofilter, the blood is
prediluted with replacement fluid and heparin. Three
empirical criteria have been proposed for the
assessment of desirable relationship between the blood
flow and the ultrafiltration rate [6]:
1) the hematocrit at the end of the hemofilter should
   not exceed 0.5
2) \( Quf / Qbl \leq 0.25 \) where \( Quf \) is the ultrafiltration
   rate and \( Qbl \) is blood flow.
3) \( Quf / Qpw \leq 0.5 \) where \( Qpw \) is the rate of flow of
   plasma water.

The hematocrit and protein concentration in the filter
depends on the following parameters:
\( Qbl \)- the rate the blood is pumped out of the patient.
\( HCTin \)- the hematocrit of the patient
\( Quf \)- the rate of ultrafiltration.

The anticipated hematocrit level at the filter outlet is:
\[
HCTout = HCTin \times \frac{Qbl}{(Qbl - Quf)}
\]

The plasma water flow entering the hemofilter is:
\[
Qpw = Qbl \times (1 - HCTin) \times (1 - 0.0107 \times TP)
\]

Where:
\( Qpw \) is plasma water flow through the hemofilter
\( TP \)- total protein concentration of the patient
\( (1 - 0.07 \times TP) \) is a correction factor for plasma protein
[6].

The first part of the present program uses these
equations and the aforementioned criteria and
calculates the desirable relationship between blood
flow through the hemofilter and the rate of
ultrafiltration.

The second part of the program tries to simulate the
hemofiltration process and to predict the course of
solute removal. CVVH is a pure ultrafiltration process
and blood water solutes are removed by convection.
The clearance of a solute may be calculated by the
following formula [7]:
\[
Cr = Quf \times S
\]

Where:
\( Quf \) – the rate of ultrafiltration
\( Cr \) is clearance of a specific solute
\( S \) is the sieving coefficient which for Urea and
creatinine approaches 1.0

If predilution is employed, the clearance formula
changes:
\[
Cr = Quf \times S \times \left( \frac{Qpw}{Qpw + Qpre} \right)
\]

Where:
\( Quf \) – the rate of ultrafiltration
\( Cr \) is clearance of the specific solute
\( S \) is the sieving coefficient for the specific solute
\( Qpw \) - Plasma water flow

3. Results

Figure 2-4 show the desirable relationship between
blood flow and the rate of ultrafiltration according to the
restricting criteria.

![Figure 2](image1)

Figure 2. At the vertical axis blood flow in ml/min, at
the horizontal axis ultrafiltration rate in ml/hr. The
limiting criterion was \( Quf/Qb<0.25 \) and patient's
hematocrit: \( HCT=0.39 \). The small black circles
represent undesirable areas.

![Figure 3](image2)

Figure 3. At the vertical axis blood flow in ml/min, at
the horizontal axis ultrafiltration rate in ml/hr. The
limiting criterion was \( HCTout < 0.5 \) and patient's
hematocrit: \( HCT=0.39 \). The small black circles
represent undesirable areas.
on gathering experience with hemofilter performance and
durability, and the fluid regimen is usually based on the
results of clinical trials like the one by Ronco et al [1]. A
frequent starting dose is 35ml/kg/min divided as 1/3
predilution and 2/3 post dilution. Following promising
results of hemofiltration in a variety of cardiac conditions
[3-5] cardiologists start to show interest in this technique.
The basic concepts of hemofiltration are new to
cardiologists who have to start thinking in "a nephrologic
mind". This was the reason for this program to be built.
The program easily enables the physician to choose the
right parameters in order to keep hemofilter functionality.
The ability to simulate the process of hemofiltration gives
the clinician the opportunity to change the hemofiltration
parameters on the computer, and gain intuitive feeling on
the anticipated influence of these changes on the rate of
solute removal from the body. Although very instructive,
This program is only a preliminary necessary step. There
is still much to be done in this very fascinating new area.

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Address for correspondence
Ron Joseph Leor-Librach M.D., Ph.D., The Heart Institute, Laniado Hospital, Divrei Chaim St. 1 Kiriat Sanz, Netanya, ISRAEL.