
Poor Blood Mixing in the Shiley Hardshell Venous Reservoir Proven by Changes in Hematological Data on Different Volume Levels

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Abstract

Low values in hematological data at the end of cardiopulmonary bypass (CPB) brought us to the hypothesis that this could be caused by a visible poor blood mixing phenomenon in the Shiley Hardshell Venous Reservoir (HSVR). To study this phenomenon, we designed an instrument enabling us to take blood samples from the venous reservoir at a level of 1000 ml (A), 500 ml (B) and 100 ml (C). Besides this blood sampling during CPB, we also took samples from the venous line (D). Twenty patients were studied during CPB. The first set of samples was taken 10 minutes after the aorta was occluded and cardioplegia was administered. Successive sampling took place at half hour intervals. The last set of samples were taken shortly after removal of the aortic crossclamp. We observed a marked decrease in the value of the hematocrit (Ht) at level A in the venous reservoir within 30 minutes. The Ht at this level dropped from 23.7% (SD \pm 2.8) to 6.5% (SD \pm 7.3). This showed to be a significant difference in comparison with the values at the other sampling points after 30 minutes ($P < 0.001$) which were respectively at level B: 24.7% (SD \pm 2.9), C: 25.1% (SD \pm 2.8) and D: 24.9% (SD \pm 2.6). The differences between the Ht-values of B, C, and D showed no significant changes. The difference in Ht at level A versus level B, C and D remained until removal of the aortic crossclamp, at which time mixing in the reservoir appeared, due to short time volume changes. It is concluded that poor mixing of blood occurs in the Shiley HSVR depending on the amount of volume. However we could not prove

in this study that unexpectedly low values in hematological data at the end of CPB are due to this phenomenon.

Introduction

The use of a hardshell venous reservoir has led to an easy and quick setup of the extra-corporeal circuit. A few years ago we could only choose between two extra-corporeal circuits. Using a bubble oxygenator we were dealing with an open system and using a membrane oxygenator we had a closed system. Many investigators have reported advantages using a membrane oxygenator.¹⁻⁵ The introduction of the hardshell venous reservoir, whether or not integrated in the oxygenator, made it possible to use a membrane oxygenator also in an open circuit. The advantages of the open circuit (a smaller priming volume, larger storage capacity, easier elimination of air which also makes the circuit comfortable to debubble) in combination with the safety of a membrane oxygenator can make the use of a hardshell venous reservoir a preferable choice.^{6,7}

In our hospital we decided to use the Shiley M2000 membrane oxygenator in combination with the Shiley Hardshell venous reservoir.⁸ Using this system during a certain period, however, we observed a color separation of the blood in the HSVR and we assumed sedimentation of blood cells to be the cause. This assumption worried us, because a high hematocrit during hypothermia can lead to a higher incidence of blood trauma⁸ and the plasma visible at the top of the reservoir could after remixing cause an unexpectedly low Ht during normothermia at the end of CPB. Both effects can cause uneven tissue perfusion.^{9,10} Considering these consequences we decided to study the degree of mixing in the Shiley HSVR.

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a Shiley, Inc., Irvine, CA

Materials and Methods

To find out at what level the assumed sedimentation of erythrocytes occurs, we designed an instrument enabling us to take blood samples on different volume levels within the HSVR.

The designed sampling device consists of three stainless steel needles (RVS 163) (Biomedical Center, University of Limburg) each with a different length, with luer lock connections on the top. This instrument was placed through one of the outer priming ports on top of the reservoir. Disposable stopcocks were put on the luer lock connections to enable a sterile sampling process. The levels at which the samples could be taken are A: 1000 ml, B: 500 ml and C: 100 ml (Figure 1). Besides the samples we took from the venous res-

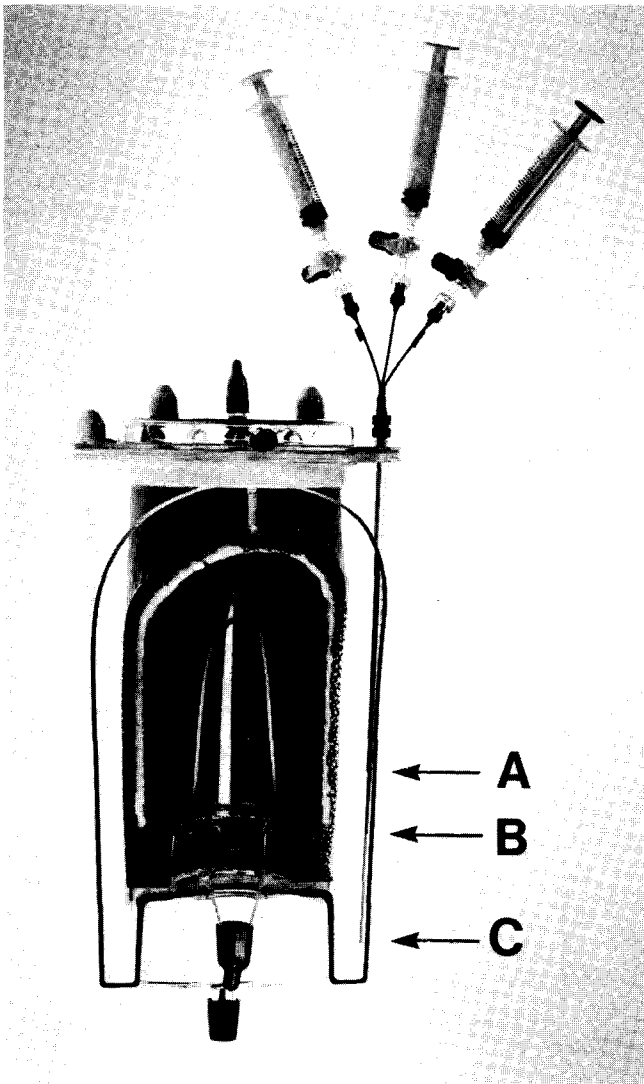


Figure 1: Hardshell Venous Reservoir with sampling device. Level indication A at 1000 ml, B at 500 ml and C at 100 ml.

ervoir, samples were taken from the venous line, which was indicated as D. This sample was taken through a monitoring line with a stopcock approximately 120 cm before the venous line is connected with the reservoir. The sampling process was initiated 5–10 minutes after aortic cross-clamping and the cardioplegia solution was administered. Successive sampling took place at half hour intervals.

The last set of samples was taken approximately 10 minutes after removal of the aortic crossclamp (Figure 2). In this period the blood in the HSVR was mixed due to short time volume changes. Hematocrits from

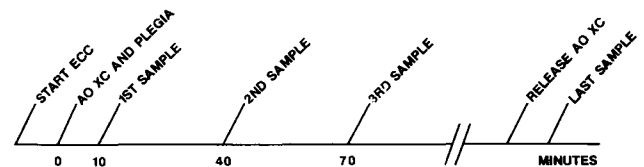


Figure 2: Sampling schedule. ECC = extra-corporeal circulation; AO XC = aortic crossclamping.

the venous line (D) before and after removal of the aortic crossclamp were compared to see if the amounts of plasma at the top of the venous reservoir would decrease the Ht after the volume was mixed. All samples were sent to the laboratory to be examined on hematological value changes.

To achieve hemoglobin (Hb) and hematocrit (Ht) values the blood samples were analyzed by a Sysmex cc 180 microcell counter.^b The Hb was calculated by the cyanomethemoglobin method (within range of coefficient variation, CV, = 0.6%) and the Ht is calculated by the instrument from the sum of the individual erythrocyte cell volume (within range CV = 0.8%).

Patients were selected prior to operation on the bases of their pre-operative Hb and body surface area (Hb had to be larger than 12.8 gm%, or else body surface area had to exceed 2.0 m²) in order to achieve a final group of 20 patients with a relative high blood volume (patient characteristics are listed in Table 1). The operation procedures performed on these patients are listed in Table 2.

The extra-corporeal circuit consisted of a Cobe heart-lung machine,^c a Shiley M2000 membrane oxygenator, a Shiley hardshell venous reservoir, a Bentley BCR 3500^d cardiotomy reservoir and a Swank HF 6000 filter^e in the arterial line. The priming of the extra-corporeal circuit is listed in Table 3.

^b Sysmex Toa, Kobe Japan

^c Cobe Laboratories, Lakewood, CO

^d Bentley Laboratories

^e Swank

Table 1:
Patient Characteristics

Age:	55 years mean (range 17–71)
BSA:	1.87 m ² mean (range 1.76–2.28)
Sex:	all male
Hematocrit:	42.5% mean (range 38–52)
Abbreviation:	BSA = body surface area

Table 2:
Procedures

CABG:	13 pts
Wolff-Parkinson-White syndrome:	2 pts
Valve replacement:	2 pts
Valve replacement + CABG:	2 pts
CABG + RA myxoma:	1 pts

Abbreviations:

CABG	= Coronary Aortic Bypass Grafting
RA	= Right Atrium
Pts	= Patients

Table 3:
Priming

Haemaccel 1870 ml (range 1650–2000 ml)	
Mannitol 20%	200 ml
Albumin 20%	100 ml
NaHCO ₃ 4,2%	100 ml
Heparin	2500 IU/500 ml
Potassium	20 mmol

Arterial cannulation was performed by a straight Argyl 24 French cannula^f and venous cannulation by a Sarns 2 stage venous catheter.^g In four cases we applied double venous cannulation using a 36 and a 40 French USCI cannula type 1956. The degree of hypothermia during the crossclamp period was limited to 25 degrees Celsius according to the blood temperature at the outlet of the oxygenator. The mean aortic crossclamp time was 74.8 minutes (ranging from 43 to 133 minutes) and mean CPB time was 117 minutes (ranging from 73 to 186 minutes). Bloodflow and total volume in the venous reservoir were also registered. The mean amount of cardioplegia given was 765 ml (500–1300 ml). We allowed the level in the HSVR to rise to a maximum of 1400 ml. This was a maximum, preventing a situation that changes in hematological data on top of the volume could not be notified, considering the highest sample point in the HSVR was at 1000 ml.

^f Argyl
^g Sarns

Results

As a result of our measurements we noticed a marked decrease in Ht at level A (1000 ml) within 30 minutes after the first set of samples. The Ht at this level dropped in this period from 23.7% (SD ± 2.8) to 6.5% (SD ± 7.3). This showed to be a significant difference compared with the previous value and the values at the other sampling points after 30 minutes (P<0.001), which were respectively at level B: 24.7% (SD ± 2.9), C: 25.1 (SD ± 2.8) and D: 24.9 (SD ± 2.6) showing no significant changes (Figure 3). This difference in Ht at level A versus level B, C and D remained until the aortic crossclamp was removed, at which point mixing in the reservoir appeared due to the short time volume changes (Figure 4).

The results of the Hb measurements showed the same tendency as the Ht values did. To simplify the presentation only Ht levels are shown. The visible amount of plasma on top of the blood in the HSVR during the crossclamp period varied from 200 to 700 ml.

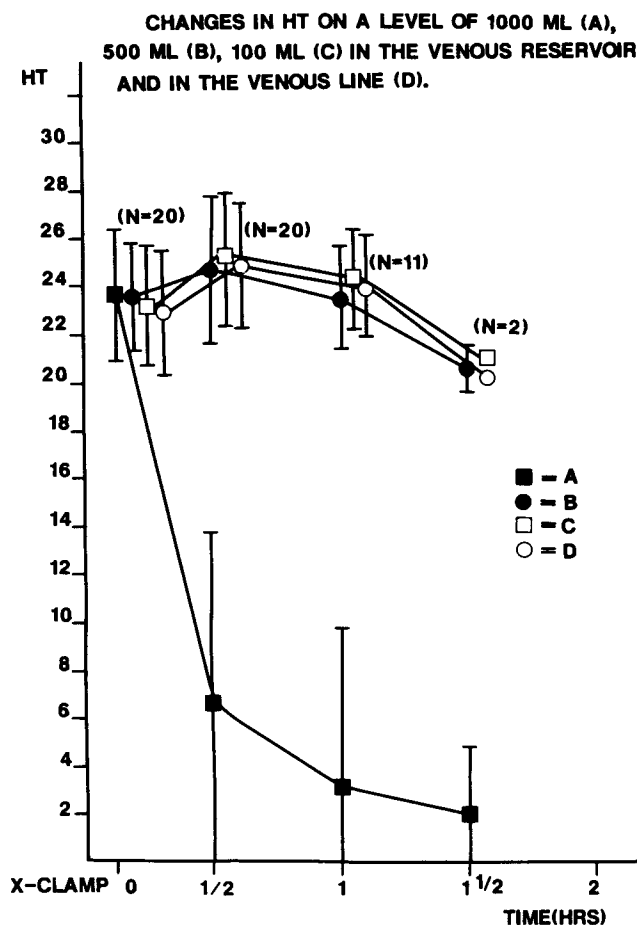


Figure 3: Changes in hematocrit (Ht) expressed in %. X-clamp = aortic crossclamping.

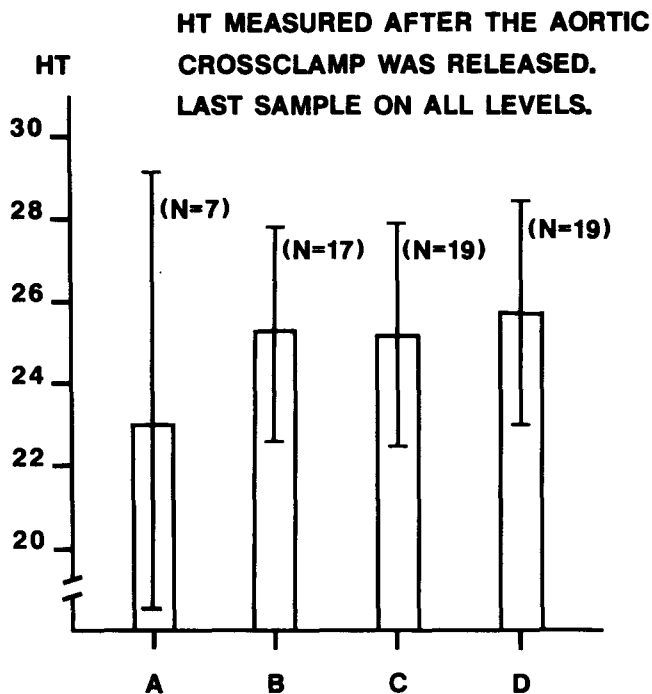


Figure 4: Hematocrit (Ht) after aortic crossclamping, expressed in %.

The Ht taken from the venous line D before and after release of the aortic crossclamp did not show a statistical difference in the studied patient group.

Discussion

In spite of the fact that there was no statistical difference in the Ht in the venous line before and after mixing, we still believe that in some instances the poor mixing phenomenon can cause unexpected hematological value changes; especially in cases dealing with higher volumes in the venous reservoir than we are used to (500–600 ml) and when cardiotomy suction during the aortic crossclamp period is extremely limited. In these operations cardiotomy suction will not have a significant effect on the mixing of blood in the HSVR, therefore we opt for the use of a cardiotomy reservoir connected to a movable mast. This gives us the opportunity to shift the volume from one reservoir to the other. Another potentially dangerous effect of the poor mixing phenomenon may appear, when drugs or electrolytes are administered through one of the ports on top of the venous reservoir. These drugs will probably be sequestered in the upper part of volume

in the venous reservoir with the hazards of overdose after remixing. We supply drugs and electrolytes through a monitoring line on a Y connector connecting the cardiotomy line with the venous line before entering the reservoir.

Conclusion

We proved that poor mixing of blood can occur using a HSVR in combination with a membrane oxygenator. This phenomenon is potentially hazardous when drugs or electrolytes are administered during a period of poor mixing. Sequestration is possible, with the danger of overdosage after sudden remixing. However, in this study, we could not demonstrate unexpectedly low values in hematological data at the end of CPB, due to the phenomenon described.

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