# BLOOD VOLUME MONITORING IN DIALYSIS-REQUIRED ACUTE KIDNEY INJURY AFTER CARDIAC SURGERY: A PILOT STUDY

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Intradialysis hypotension is a serious complication for patients with an acute kidney injury (AKI). Recurrent hypotension can complicate achievement of target values of ultrafiltration (UF) and cause ischemic damage of organs [1]. One of the main causes of intradialysis hypotension is an aggressive UF that emerges due to a disbalance between speed of liquid removal from the vascular bed and refilling speed [1]. However, there are still no efficient instrumental methods of control and establishing UF safety nowadays.

**Keywords: kidney, cardiac surgery, intradialysis hypotension, ultrafiltration**

Modules of Blood Volume Monitoring (BVM) have been facilitated during recent years. BVM modules are integrated into stationary dialysis apparatus and allow one to control Relative Blood Volume (RBV) in the extracorporal cutout during the process of hemodialysis (HD). RBV level does not provide an image of intravascular liquid volume, it only reflects its alteration from the initial level that is taken as 100 %. Alterations in RBV are estimated with ultrasound sensors, according to changes in values of hemoglobin and hematocrit in blood. UF speed can be regulated in manual or automated regime. Automatic regulation of UF speed operates according to the principle of biologic feedback depending on vascular bed refill rate. Besides, a parameter that limits UF speed is RBV decrease down to a manually-set «critical» level [2].

Nowadays BVM modules are available in a line of dialysis apparatus, however, there is no sufficient data on how they should be used in order to optimize dialysis. Studies mostly refer to patients with chronic kidney deficiency (CKD), and opinions on perspectives of BVM are inconsistent. Data on RBV informativity in predicting intradialysis hypotension is also ambiguous [2, 3, 4]. Special features of using BVM in treating cardiosurgical patients with AKI are not studied. Besides, legislations of Starling and capillary drain from interstice are disturbed significantly among patients with heart-vascular deficiency, and establishing a safe UV remains urgent for this category of patients [5]. The objective of this research is to define safe limits of decreasing RBV under UF and estimate a possibility to implement BVM among patients with AKI after cardiac surgeries.

## Materials and methods of research

Pilot research has been carried out, it included 26 patients in age from 31 to 79 years who experienced cardiac surgery. Research design is prospective intervention. Criterion of introducing into the research is dialysis-dependent AKI among patients with hyperhydratation. Hemotransfusion during dialysis served as an exclusion criterion as it can corrupt indexes of BVM.

Evaluation of patient's severity equaled 22,4 ± 4,5 point according to the scale APACHE II. Mechanic ventilation of lungs has been implemented in 7 cases (27 %), 8 patients (31 %) required inotropic support. AKI of stage 2–3 has been diagnosed among all patients according to classification of AKIN. Oliguria have been established among 18 patients, in other cases initial hyperhidratation and significant volumes of infusion therapy required water balance correction.

49 sessions of dialysis in SLED (Sustained Low Efficiency Dialysis) regime of 322 hours total length. Dialysis apparatus 5008, equipped with BVM modules (Fresenuis, Germany) have been facilitated. Blood flow speed equaled 140–180 ml/min, dialysis flow equaled 12,8 ± 4,6 l/hr. Managing UF speed during SLED was carried out manually. Negative balance of liquid considered infusion therapy, UF volume, and diuresis. During SLED we have been registering hourly alterations of RBV and estimated their relation with episodes of hemodynamic complications (hypotensions and rhythm disturbances). Decrease in average arterial pressure (AAP) below 70 mm of quicksilver or decrease in AAP by 20 % of its initial index have been set as criterions of hypotension. Criterions of rhythm disturbance were stable increase in heart rate (HR) above 110 beats per minute, or its increase by 20 % of initial tachiarythmia.

Statistic analysis of the received results has been carried out via program MedCalc 12.4.0 (MedCalc Software, Belgium). Inclinations have been considered statistically-significant under $p < 0,05$.

## Results of research and their discussion

The prescribed negative balance of liquid in the studied group of patients formed 1430 ± 660 ml/session that equaled to UF speed from 50 to 400 ml/hour (Table 1). 16 episodes of hemodynamic complications have been registered during SLED sessions. 6 cases were episodes of hypotension, and the rest 10 cases were tachycardia. In these cases we decreased UF speed with a simultaneous increase in SLED session duration that allowed us to achieve target values of water balance. Only two cases required additional increase in dose of inotropic support, and one – infusion of salty solutions. Overall increase in session length for these patients equaled 2 ± 0,7 (from 1 to 4) hours, and decrease in UF speed equaled 84 ± 30 (from 50 to 150) ml/hr of the plan. UF speed that has been associated with hemodynamic complications has been higher than UF speed during SLED sessions with no complications (285 ± 58 vs 173 ± 71 ml/hr; $p < 0,01$).

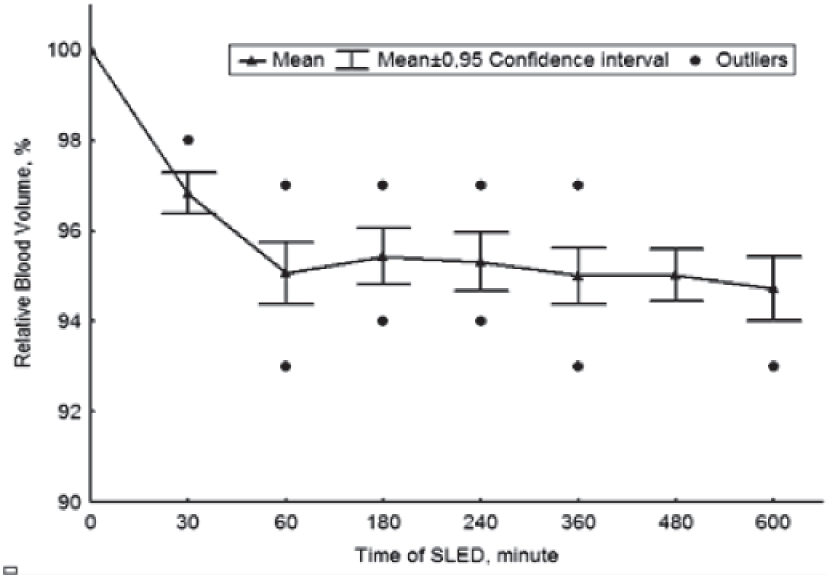
**Table 1**

Indexes of water balance during SLED

| Parameters | SLED session, (n) | UF volume, ml/session | Prescribed session length, hr | Actual session length, hr | Planned UF speed, ml/hr | Actual UF speed, ml/hr | UF speed, associated with complications, ml/hr | UF speed with no complications, ml/hr |
|---|---|---|---|---|---|---|---|---|
| Results | 49 | 1430 ± 660 | 6,7 ± 1,1 | 7,4 ± 1,5 | 210 ± 85 | 187 ± 66 | 285 ± 58 | 173 ± 71 |

The results are represented as average and standard inclination. UF is ultrafiltration.

We have estimated alterations of RBV during sessions of SLED (Figure). The most significant absolute decrease in RBV has been observed during the first hour of therapy. Probably, speed of liquid removal from vascular bed exceeded speed of its refill from interstice during this period. During later hours of SLED alterations of RBV obtained a linear nature without expressed oscillations (p > 0,05). It can testify for the balance between UF speed and refilling. A moderate backward correlation has been revealed between hourly speed and the level of RBV ($r = -0,39$; $p < 0,001$).



Dynamics of alteration in RBV level during to sessions of hemodialysis. The analysis of secondary alterations in RBV was carried out with Fridman criterion; RBV–Relative Blood Volume

Though general volume of body water decreases under UF, hypotension can be avoid if intravascular volume of liquid is preserved. While using BVM, alterations in volume of intravascular liquid are estimated indirectly according to alterations in RBV. RBV level that has been associated with hemodynamic instability in the studied group of patients, was registered in range from 96 to 90% with a average of 93 ± 1,4%.

In order to define a safe level of RBV decrease, we have carried out ROC-analysis (Receiver Operator Characteristic). «Optimal cut-off value» with an utmost sum of sensitivity and specificity corresponded to RBV level of 94% (Table 2). In other words, decrease in RBV below 94% has been associated with an increasing risk of development of hemodynamic complications.

**Table 2**

ROC-analysis results

| Parameters | Results |
|---|---|
| Optimal cut-off value | 94 % |
| Sensitivity | 94 % |
| Specificity | 72 % |
| Diagnostic efficiency | 83 % |
| Area Under Curve | 0,87 |
| 0,95 confidential interval | 0,83–0,906 |

Generally, BVM can be useful if patients are dehydrated. It is supposed that its implementation allows one to prevent sharp or continuous linear decrease in RBV that were predicted as hemodynamic complications earlier [2; 6]. However, safe limits of RBV decrease and the very method of its implementation is a subject of conflicts. Some authors have defined individual utmost RBV level for each patient during 3–5 sessions of HD, and then, generalized value has been used for future sessions [3; 7]. Another variant implies orientation not only towards a specific RBV level, but a nature of its decrease (linear, exponential, etc.) [6]. However, these methods are relatively complicated for everyday facilitation.

We have estimated possibilities of using the calculated RBV level as a universal «critical» limit for the totality of patients, treated with SLED. As you can see in Table 2, this parameter has a high sensitivity for preventing hemodynamic complication. Besides, the calculated RBV has a moderate specificity. It means that in a number of cases predicted episodes of complications will be false-positive under a decrease in RBV in range of 94–90 %, and it will require an anticipatory decrease in UF speed. However, considering the severity of intradialysis hypotension consequences, even such less-aggressive tactics of UF can prove reasonable for the severe category of patients.

For the majority of studies hypotension serves as a complication criterion that defines a necessity to decrease UF speed. In our opinion, it is also reasonable to use tachycardia as such criterion as well. A stable increase in HR under UF is a clinic expression of intravascular hypovolemia and often precedes sudden hypotension [2]. A low rate of the very hypotension in our research, when an increase in inotropic support or intravenous infusion of solutions was necessary, testifies for advantages of this approach. It allowed us not to interrupt SLED sessions and achieve target values of UF.

Thus, the suggested unified «critical» limit of RBV (94 %) is a simple and convenient criterion for application, and its high sensitivity allows one to minimize complications risk for a similar group of patients. The efficiency and safety of this method of using BVM requires confirmation within a comparative random research. We plan to devote the next stage of this study to solving this problem.

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