Title: BIOCHEMICAL, METABOLIC AND HEMATOLOGIC EFFECTS OF INTRAOPERATIVE PROCESSING OF CPDA-1 AND AS-1 PACKED RED CELLS

Authors: Kumar G. Belani, M.B.B.S., M.S., Jorge A. Estrin, M.D., Ph.D.

Affiliation: Department of Anesthesiology, University of Minnesota Health Sciences Center, Mayo Bldg, Box 294, 420 Delaware Street, S.E., Minneapolis, Minnesota 55455

Introduction. Transfusion of CPDA-1 and AS-1 preserved blood (B) is usually well tolerated. However, acute, rapid usage during massive B loss can cause dangerous hyperkalemia and hypothermia (↓T)[1]. Leukocytes (WBCs) in packed red cells (PRBCs) increase the risk of non-hemolytic febrile reactions;[2] the platelet (plt) and WBC debris may play a role in ARDS[3] and the increased ammonia (NH_3) may be detrimental during liver (L) transplantation (Tx)[3]. While the usage of the rapid infusion system (RIS)[1] has overcome ↓T and B replacement efficacy, the other problems still remain. Hence, we employed rapid intraoperative washing and reconstitution (processing) of PRBCs for usage with the RIS during surgeries involving major B loss. This report describes the processing technique and the biochemical, metabolic and hematologic effects.

Methods. CPDA-1 or AS-1 preserved PRBCs (< 35 or 42 days respectively) needed for surgery were brought to the operating room (O.R.) at 4° C. The PRBCs (3-4 units) were mixed in a cardiotomy reservoir (prewash specimen). After filtration (20μ) they were transfered to the Cell Saver System I (Haemonetics®, Braintree, MA) for washing in normal saline (NS, 500 ml/min) at 5260 RPM. The washed PRBCs (room temperature) were resuspended in fresh frozen plasma (FFP) in a Harvey H1700 bubble oxygenator primed with Plasmalyte-A (targeted Hct 30%). This reconstituted B was then recirculated by means of a Sarns® roller pump through a heat-exchanger and oxygenated (100% O_2, 0.5-1 L). At 37° C (10 min) it was available for transfusion at rates of 5-3000 ml/min (roller pump). Laboratory measurements (see Table) were made in the prewash, postwash and resuspended specimens. Statistical analysis was done by the Friedman test and Wilcoxon paired rank test. ($p < 0.05$ = significant).

Results. (Table) Stored PRBCs were severely acidotic and hypoxic. Mean pH of 6.69 improved significantly but minimally after washing (pH 6.74) and resuspension (pH 6.77). The change in pH was mainly due to a significant reduction in PCO_2 after washing (PCO_2 98 → 36 mmHg); ventilation and resuspension decreased mean PCO_2 to 17 mmHg. Mean PO_2 improved only after oxygenation. Serum Na^+ and K^+ composition changed significantly. Their mean concentrations prewash were 127 and 52 mEq/L respectively. Na^+ increased significantly because of NS washing and resuspension in FFP. Washing was very effective in reducing mean K^+ level to 7.8 mEq/L; resuspension in FFP decreased it to 4.8 mEq/L. There was a 20% decrease in Hgb and Hct with washing. With FFP the resultant mean Hgb and Hct were 11 gms% and 33%. Mean Plt and WBC levels prewash were 146000 and 6926/cumm. Washing and resuspension resulted in significant (80%) reductions. Processing was effective in significantly reducing NH_3, lactate and pyruvate. Mean levels of NH_3 decreased from 596 to 141 umol/L; lactates 19.2 to 8.2 mMol/L and pyruvates 0.35 to 0.19 mMol/L. Processing by this technique did not improve the low P_{50} and 2-3 DPG. The total calcium (mg/dl) level prewash was 8.3 ± 0.4; washing decreased this to levels < 4.5 with no change on resuspension. Glucose (mg/dl) prewash was 175 ± 58; washing decreased it to 80 ± 42; it increased to 137 ± 65 with FFP.

Discussion. Washing of PRBCs is effective in decreasing transmisison of CMV infection[4]. Our report demonstrates that washing was also effective in decreasing the serum K, lactate, pyruvate, NH_3 and the plt and WBC debris. A better B product processed rapidly in the O.R. can thus be used with the RIS. We have successfully used this in L Tx, pediatric L and vascular tumor resections and radical cystectomy; it decreased the incidence of ARDS/pulmonary edema in L Tx; this needs further investigation as does the impact of reduction of NH_3. Higher PO_2 may benefit patients with severe intrapulmonary shunting. P_{50} and 2, 3 DPG did not improve. The reduction in serum glucose may decrease hyperglycemia seen during L Tx.

References.
1. Kang YG, Gelman S. Liver Transplantation. W.B. Saunders, Philadelphia, 1987, 139.
2. Hughes A, et al. Leukocyte depleted blood. Vox Sang. 42, 1982, 145.
3. Ebert JP. Blood transplantation--blood transfusion. W.B. Saunders, Philadelphia 1987, 219.
4. Luban NLC, et al. Low incidence of acquired CMV infection in neonates transfused with washed RBCs. AJDC 141, 1987, 416.

Table. PRBC Processing
Biochemical, Metabolic and Hematologic Changes *

Test	Bank Blood (4°C)	Post-Wash (22°C	Post-Wash+O_2+FFP (37°C)	Total # of Units
pH **	6.69 ± 0.08 (n = 24)	6.74 ± 0.1† (n = 24)	6.77 ± 0.15† (n = 20)	
PCO_2 (mmHg) **	98 ± 24 (n = 24)	36 ± 22† (n = 24)	17 ± 8† (n = 20)	
PO_2 (mmHg) **	20 ± 9 (n = 24)	24 ± 10 (n = 24)	382 ± 138† (n = 20)	
HCO_3 (mEq/L)	13.5 ± 3 (n = 24)	5 ± 2.8† (n = 24)	3 ± 1.4† (n = 19)	
Na (mEq/L)	127 ± 10 (n = 24)	149 ± 2† (n = 24)	158 ± 5† (n = 20)	CPDA-1 72 Units
K (mEq/L)	52 ± 20 (n = 24)	7.8 ± 4.6† (n = 24)	4.8 ± 1.4† (n = 20)	
Hb (gms/dl)	25 ± 1 (n = 21)	20 ± 2† (n = 20)	11 ± 1.8† (n = 16)	
Hct (%)	76 ± 4 (n = 21)	60 ± 5† (n = 20)	33 ± 6† (n = 16)	
Plts (x10³/cumm)	146 ± 71 (n = 19)	24 ± 15† (n = 18)	235 ± 21† (n = 13)	
WBC (/cumm)	6926 ± 1564 (n = 19)	1744 ± 683† (n = 18)	1169 ± 600† (n = 13)	
NH_3 (umol/L)	596 ± 240 (n = 8)	231 ± 74† (n = 7)	141 ± 59† (n = 7)	CPDA-1 18 Units AS-1 6 Units
Lactates (mmol/L)	19.2 ± 7 (n = 6)	14 ± 2.7† (n = 5)	8.2 ± 3.7† (n = 6)	
Pyruvates (mmol/L)	0.35 ± 0.10 (n = 6)	0.20 ± 0.08† (n = 5)	0.19 ± 0.04† (n = 6)	
P_{50} (mmHg)	21 ± 2.8 (n = 6)	19.4 ± 2.1 (n = 5)	18.3 ± 1.8 (n = 6)	AS-1 18 Units
2-3 DPG (umol/gmHgb)	1.88 ± 2.1 (n = 6)	1.85 ± 1.9 (n = 6)	1.06 ± 2.2 (n = 6)	

* all values mean ± SD ** temperature corrected † $p < 0.05$ vs. control