www.jmscr.igmpublication.org
Impact Factor 5.84
Index Copernicus Value: 71.58
ISSN (e)-2347-176x ISSN (p) 2455-0450
crossref DOI: https://dx.doi.org/10.18535/jmscr/v5i9.118

IGM Publication
Journal Of Medical Science And Clinical Research
An Official Publication Of IGM Publication

Normovolemic Hemodilution Prior to Cardiopulmonary Bypass: An Approach to Autologus Blood Transfusion Reduces Post Operative Homologous Blood Requirement

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Abstract
Cardiac surgery requires large amount of blood transfusions. Homologous blood transfusion is the commonest method to procure the blood loss, which may lead various complications (endotoxemia, septicemia, and transfusion related lung injury) throughout the perioperative period. Normovolemic hemodilution (a type of autologous blood transfusion) may avoid this type of complications.
The concept of withdrawing a percentage of blood and leaving the patient anemic and normovolemic, is intended to minimize the loss of red blood-cells during surgery [1,2,3].
As the hemoglobin concentration is reduced through dilution, the blood that is lost during surgery will contain less hemoglobin, and at the same time autologous blood components can be preserved. We found in our study, autologous blood transfusion is also effective to reduce the homologous blood substitute (like platelets) and post operative drainage which helps in early recovery.
Keywords: *Autologous blood transfusion, Normovolemic hemodilution, blood conservation, blood loss, Adult cardiac surgery.*

Introduction

Cardiac valve surgery is considered a major surgery with a high chance of hemorrhage and extracorporeal circulation dilution[4] Normovolemic hemodilution is a type of autologus blood transfusion i.e, percentage of blood volumeis withdrawn from the patient and infusion of acellular fluids in order to maintain the volume and retransfuse back the same amount in same patient[5,6]. This procedure will make the patient anemic, although patient will remain normovolemically and hemodynamically stable[7]. With the exception of extreme hemodilution situations, the capacity for tissue oxygen supply and demand will not be affected[8]. During allogenic blood transfusion a patient receives large number of allogenic donor leucocytes and these are recognized as foreign cells by the recipient which leads to immunosuppression, hemolytic reaction, allergic reaction. Homologous blood transfusion

may also cause infectious complication, endotoxemia, septicemia[9], transfusion related lung injury[10]. The innovation in equipments like cell saver, preoperative normovolemic hemodilution techniques in cardiac surgery eliminate these types of complication by using the autologus blood transfusion. In contrast to cell saver only washed RBCs can be obtained but with this normovolemic hemodilution technique RBCs, as well as all other blood components i.e fresh plasma, platelets can be obtained and it is simple method and cost effective.[11]

Materials Methods

In this study 30consecutive adult patients were prospectively randomized in a non blinded manner into two groups: Group-A , ANH group (n=15) patientsblood was withdrawn before systemic heparinization and replaced with a cellular solutions, and a control group ,Group-B(n=15) patients, where no blood withdrawn was performed,underwent elective open heart surgery like closure of Atrial Septal Defect ,Mitral valve replacement, Coronary artery bypass grafting off pump/on pump under general anesthesia , moderate hypothermia (28-32°C) and alpha-stat pH management. Prior to induction blood was collected from the central venous catheter in a CPD bag(s) and at the same time the volume was replaced with a cellular fluid *i.e.* for each 1 ml of blood removed; 3 ml of crystalloid solution was infused[12]. Lactated Ringer solution is preferable because it has a lower incidence of acidosis, (a larger charge of chlorine in the saline solution tends to cause hyperchloremic metabolic acidosis) [13,14]. The bag (s) should be gently agitated to ensure adequate mixing. Target Hb Prior to cardiopulmonary bypass was fixed 11grm/dl in all cases to prevent massive hemodilution. Preoperative exclusion criteria for normovolemic hemodilution were age less than 18 years, left ventricular ejection fraction (LVEF) less than 50%, preoperative hematocrit less than 36% or hemoglobin less than 12 g/dl, history of hematologic diseases, chronic renal insufficiency (plasma creatinine 2 mg/dl), and history of hepatic diseases (*e.g.*, active hepatitisor cirrhosis). Preoperative treatment with aspirin or subcutaneous slow molecular weight heparin was not a contraindication to enrollment of this study. Packed red blood cells (PRBC) were transfused, during CPB if hemoglobin value was less than 6 g/dl and hematocrit value was less than 18%, Pump was primed with 1300-1500 ml of RL, heparine 1000-2500IU/ Litter of prime[15]. Antegrade venous blood priming and retrograde arterial blood priming in cardio pulmonary bypass was performed with the replacement of crystalloid priming solution just prior to initiate bypass to prevent massive hemodilution and ischemic insult of various organ. Bolus dose of Nor-adrenaline (conc. - 2mg/50ml) was administrated to maintain mean arterial pressure 50-70mmHg. Conventional ultrafiltration and modified ultrafiltration was performed whenever feasible because in some cases crystalloid cardioplegia was used. After successful weaning from heart lung machine the same blood was retransfused with in 4-6 hours [7, 16] in reverse order because the first unit collected and the last to be reinfused will have the highest hematocrit and platelets[17], after full neutralization of heparin with protamin. Blood loss was recorded during the first 24 h. Reinfusion of shed mediastinal blood was not performed during post operative period. Calcium Gluconate and antifibrinolytic drugs such as tranexamic acid were used prophylactically, depending on bleeding risk.[18]

Calculation: [19]

- *STEP-1*:Calculate the ideal/estimated body weight
- IBW = 50 kg for male (or 45.5 kg for females) +2.3 kg for each inch > 60 inches
- Example: 90 kg male (actual body weight)
- 70 inches (height)
- IBW = 50 kg + (2.3 kg x 10) = 73 kg
- STEP2: Calculate the patient's Estimated Blood Volume (EBV)
- EBV = (75 mLs/kg of IBW in males or 70 mLs/kg of IBW in females)

- Example: 73 kg male (IBW)
- EBV = 75 mLs/kg X 73 kg = 5,475 mLs
- *STEP3:*
- Calculate the maximum amount of blood to be removed(discovered by GROSS in 1983)
- BV = EBVX(Hbi or Hcti – Hbd or Hctd)/ AVERAGE Hb or HCT
- Average Hb=(initial Hb or HCT+desired Hb or Hct)/2

Hbi/Hcti=initial hemoglobin/ hematocrit
Hbd/Hctd=desired hemoglobin/hematocrit

For the patient body weight below 45.5 kg the maximum amount of blood can be withdrawn 20% of actual body weight. we kept the desired hemoglobin 11 grm/dl fixed in all cases, due to 1100-1300 ml of priming volume otherwise excessive lower hematocrit may cause anemic hypoxia to the end organs.

Calculation of adequate priming volume:[20]

C1VI = C2V2
C1=Patient initial hematocrit
V1=Patient initial blood volume
C2=Patient desired hematocrit
V2=Patient's estimated blood volume+CPB prime volume+pre-CPB intravenous fluid volume

One CPD bag contains 49 ml of CPD, which is adequate for 301 ml of whole blood,so the blood should be in adequate amount ,1ml of whole blood weights 1.06 grms.[19]So 301 ml of whole blood weights 319.06 grms.

Monitoring

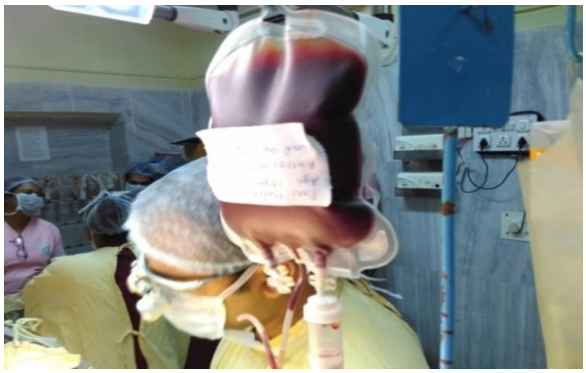
Hemodilution to a hematocrit of 33%

Continuous monitoring: ECG monitor (lead II and V5) -On-line ST-segment analysis
Invasive arterial pressure
Pulse oximetry
Urine output

Intermittent monitoring i. Centralvenous pressure
ii. Arterial blood gas analysis

Additional monitoring -Facultative i. Non invasive cardiac output measurements
ii. Continuous cardiac output measurement (pulmonary or arterial catheter)
iii. Continuous mixed venous O2 saturation (SvO2) measurement
iv. Transesophageal echocardiography

A 

B 
C 
D 

A=empty CPD bag B=Bag is connected to central venous line and blood is being withdrawn, C=weighing of during blood collection, D=Retransfusion of autologous blood

Discussion

In routine Cardiopulmonary bypass using false membrane oxygenator with large surface area (1.8m2) direct blood gas interference takes place as are result of which destruction of plasma protein and platelet occur, high viscous blood can cause hemolysis in roller pump so it needs lower hematocrit[21,22]. Normovolemic hemodiluton prior to cardiopulmonary bypass causes hemodilution in patient`s own body at the same time it preservers the blood components. Whole blood withdrawan and administration of crystalloid solution decreases arterial oxygen content, but compensatory hemodynamic mechanisms and the existence of surplus oxygen delivery capacity make ANH safe [23]. Sudden decrease of RBC concentration lowers blood viscosity, thereby decreasing peripheral resistance and increasing cardiac output. Some studies demonstrated that acute preoperative hemodilution improves tissue oxygenation because of decreased blood viscosity [24,25]. In our study the relatively small degree of hemodilution and the attention paid to maintain normovolemia, and it preserves fresh autologous blood units to be retransfused after control of surgical bleeding heart rate and possibly myocardial contractility have been shown to increase during hemodilution [26,27] but can be successfully managed by β-blocking agents and coronary vasodilating agent. We consider blood transfusion in cases where the hemoglobin level is lower than10 grm/dL

Result Analysis

Significant decrease in the number of homologous red blood cell transfused in Autologous norm-ovolemic group [group-A (n=15)], (26.67%) versus homologous group [group-B(n=15)] (100%). P valueis 0.00006 (using software r version 3 analysis). No FFP, Platelet were transfused in group-A, where as in control group [group –B] average fresh frozen plasma per patient (2.8 units) and Platelet (2.46 units) were transfused. In Group-A during CP Bone patient required, reinfusion of blood previously withdrawn because the values of hemoglobin and hematocrit were lower than the values fixed for transfusion of PRBC. Post-opertavie chest tube drainage was significantly reduced in group-A (average drainage 330 ml) compared to Group-B (average drainage 540ml). Average Cross clamp time (66.6minutes) was same in both group. Post-Operative average Activated clotting time (119.8 sec) after transfusion of blood was same in both groups.

Group-A: Autologous Normovolemic hemodilution group

SL No.	Age/Sex	Procedure	Pre-op Hb(grm/dl)	Blood withdrawn(unit)	Cross clamp time (minutes)	Post-op Hb(grm/dl)	Homologous blood req.	ACT(sec) at immediate post op in ITU	Post-operative drainage(first24 hrs)
1	23/F	OS-ASD closure	13	01	37	10.4	NIL	110	250 ml
2	25/F	OS-ASD closure	13	01	32	11.2	NIL	110	350 ml
3	30/F	MVR	12.9	01	90	10	02 PRBC	130	350 ml
4	36/F	MVR	13	02	120	10.6	01PRBC	128	500 ml
5	55/M	On pump CABG	13	02	106	9	02PRBC	130	450 ml
6	28/M	OS_ASD closure	13	01	32	10.6	NIL	120	350 ml
7	32/M	MVR	14	03	112	10	NIL	110	350 ml
8	43/M	On pump CABG	14	03	120	10	NIL	120	300 ml
9	45/M	Off-pump CABG	13	02	___	11	NIL	120	250 ml
10	22/M	OS-ASD closure	13	02	30	11	NIL	120	250 ml
11	35/M	MVR	14	03	117	11	NIL	124	400 ml
12	52/F	Off Pump CABG	13	02	___	10	NIL	118	300 ml
13	38/F	MVR	12	01	140	9	01 PRBC	117	350 ml
14	25/F	OS-ASD closure	13	02	33	11	NIL	120	250 ml
15	29/M	OS_ASD Closure	14	02	30	11	NIL	120	250 ml

Group-B: Control group -Homologous blood transfusion

SL No.	Age/Sex	Procedure	Pre-op Hb(grm/dl)	Post-pump Hb(grm/dl)	Cross	Homologous blood req.	ACT(sec) at immediate post op in ITU	Post-operative drainage(first24 hrs)

1	25/M	OS-ASD	1	3	8	2PRBC,3FFP,3Platelet	1	2	0	600 ml
2	40/M	MVR	1	4	8.4	3PRBC,4FFP,4Platelet	1	2	5	750 ml
3	55/F	ON-Pupm CABG	1	2	7.5	4PRBC,4FFP,4Platelet	1	2	0	600 ml
4	60/M	On-Pump CABG	1	2	8	2 PRBC,4FFP,4 Platelet	1	1	0	550 ml
5	22/F	OS-ASD closure	1	3	8	2 PRBC,2FFP,2Platelet	1	1	5	500 ml
6	35/M	MVR	1	3	9	1 PRBC,2FFP,2 Platelet	1	2	0	500 ml
7	45/F	Off Pump CABG	1	3	9	1 PRBC,1FFP,0Platelet	1	2	0	400 ml
8	32/M	MVR	1	2	7	4 PRBC,4FFP,4 Platelet	1	2	0	550 ml
9	26/M	OS-ASD closure	1	2	9	1PRBC,1 FFP,2 Platelet	1	2	0	400 ml
10	23/F	OS-ASD closure	1	2	8	2PRBC,2FFP,2Platelet	1	1	8	500 ml
11	56/M	Off pump CABG	1	2	9	1PRBC,2FFP,0Platelet	1	1	5	400 ml
12	37/F	MVR	1	3	8	4 PRBC,4FFP,4platelet	1	3	0	650 ml
13	28/M	OS-ASD closure	1	2	9	2 PRBC,2FFP,2 Platelet	1	2	0	550 ml
14	50/F	Off Pump CABG	1	3	9.5	1PRBC,3 FFP,0Platelet	1	1	9	500 m
15	36/M	MVR	1	4	9	2PRBC,4FFP,4Platelet	1	2	5	650 ml

Conclusion

Pre-operative normovolemic hemodilution of autologous blood transfusion is desirable in attempt to reduce or eliminate homologous blood transfusions. Nomorbidity and mortality has occurred due tothis procedure. So cardiac surgery may be successfully performed without the administration of homologous blood or blood products using autologous blood transfusion (pre-operative normovolemic hemodilution) with goodsurgical outcome.

Financial support and sponsorship-Nil

Conflicts of interest: There are no conflicts of interest.

References

1. L. T. Goodnough, “Acute Normovolaemic Haemodilu-tion,” Vox Sanguinis, Vol. 83, No. 1, 2002, pp. 211-215. doi:10.1111/j.1423-0410.2002.tb05304.x
2. A. Shander and T. S. Rijhwani, “Acute Normovolemic Hemodilution,” Transfus-ion, Vol. 44, No. 12, 2004, pp. 26S-34S. doi:10.1111/j.0041-1132.2004.04293.x
3. T. G. Monk, “Acute Normovolemic Hemodilution,” An-esthesiology Clinics North America, Vol. 23, No. 2, 2005, pp. 271-281. doi:10.1016/j.atc.2005.03.002
4. Blood Conservation Strategy during Cardiac Valve Surgery in Jehovah’s Witnesses: a Comparative Study with Non-Jehovah’s Witnesses Tae Sik Kim, Jong Hyun Lee and Chan-Young Na Korean J Crit Care Med 2016 May 31(2):101-110 / http://dx.doi.org/10.4266-/kjccm.2016.31.2.101 ISSN 2383-4870 (Print) · ISSN 2383-4889 (Online)
5. Kreimeier U, Messmer K. Perioperative hemodilution. Transfus Apheresis Sci 2002;27:59-72.
6. Jamnicki M, Kocian R, Van der Linden P, Zaugg M, Spahn DR. Acute normovolemic hemodilution: physiology, limitations, and clinical use. J Cardiothorac Vasc Anesth 2003;17:747-54.
7. L. T. Goodnough and T. G. Monk, “Autologous Transfu-sion, Recombinant Factor VIIa, and Bloodless Medicine,” In: R. D. Miller, Ed., Miller’s Anesthesia, 7th Edition, 2009.
8. Liana Maria Torres De Araújo1, Luis Vicente Garcia
9. G. J. Crystal and M. R. Salem, “Hemodyn-amic Compen-sation during Acute Normo-volemic Hemodilution,” An-esthesiology, Vol. 100, No. 4, 2004, pp. 1034-1035
10. Klein HG: Immunomodulatory aspects of transfusion: A once and future risk? ANESTHESIOLOGY 1999; 91:861–5
11. Popovsky MA, Davenport RD: Transfusion-related acute lung injury: Femme fatale? Transfusion 2001;41:312–5
12. L. Davies, T. J. Brown, S. Haynes, K. Payne, R. A. Elliott and C. McCollum, “Cost-Effectiveness of Cell Salvage and Alternative Methods of Minimising

Perioperative Allogeneic Blood Transfusion: A Systematic Review and Economic Model," Health Technology Assessment, Vol.10, No. 44, 2006, pp. 1-210.

13. S. B. Jones, C. W. Whitten and T. G. Monk, "Influence of Crystalloid and Colloid Replacement Solutions on Hemodynamic Variables during Acute Normovolemic Hemo-dilution," Journal of Clinical Anesthesia, Vol. 16, No. 1, 2004, pp. 1-17. doi:10.1016/j.jclinane.2003.03.003
14. D. S. Prough and A. Bidani, "Hyperchloremic Metabolic Acidosis Is a Predictable Consequence of Intraoperative Infusion of 0.9% Saline," Anesthesiology, Vol. 90, No. 5, 1999, pp. 1247-1249. doi:10.1097/00000542-199905000-00003
15. E. L. Williams, K. L. Hildebrand, A. S. McCormick and M. J. Bedel, "The Effect of Intravenous Lactated Ringer's Solution versus 0.9% Sodium Chloride Solution on Se-rum Osmolality in Human Volunteers," Anesthesia and Analgesia, Vol. 88, No. 5, 1999, pp. 999-1003.
16. Cardiopulmonary Bypass Edited by Sunit Ghosh,Florian Falter,David J.Cook Chapter 3:Priming solutions for CPB circuits Table 3.2,Page-39
17. L. T. Goodnough, "Acute Normovolaemic Haemodilu-tion," Vox Sanguinis, Vol. 83, No. 1, 2002, pp. 211-215. doi:10.1111/j.1423-0410.2002.tb05304.x
18. A. Shander and T. S. Rijhwani, "Acute Normovolemic Hemodilution," Transfusion, Vol. 44, No. 12, 2004, pp. 26S-34S. doi:10.1111/j.0041-1132.2004.04293.x
19. Blood Conservation Strategy during Cardiac Valve Surgery in Jehovah's Witnesses: a Comparative Study with Non-Jehovah's Witnesses Tae Sik Kim, M.D., Ph.D.1, Jong Hyun Lee, M.D.2, and Chan-Young Na, Korean J Crit Care Med 2016 May 31(2):101-110 / http://dx.doi.org/10.4266/kjccm.2016.31.2.101 ISSN 2383-4870 (Print)
20. Clinical Guidelines† Acute Normovolemic Hemodilution Guidelines for Cardiac Surgery‡ Department of Anesthesiology and Perioperative Medicine Date: 12-30-2012
21. Cardiopulmonary Bypass :Principle and Practice Glenn P.Gravlee,Richard F.Davis, Alfred H.Stammers Ross M.Ungerleider Chapter-19 Hemodilution & Priming Solution Edmunds LH Jr. Blood-surface interactions during cardiopulmonary bypass. J Card Surg 1993;8:404.
22. Edmunds LH Jr. Inflammatory response to cardiopulmonary bypass. Ann Thorac Surg 1998;66:S12.
23. Intraoperative Minimal Acute Normovolemic Hemodilution In Patients Undergoing Coronary Artery Bypass Surgery Alireza Mahoori, Farhad Heshmati, Heydar Noroozinia;et.al
24. Messmer K. Blood rheology factors and capillary blood flow. In: Gutierrez G, Vincent J-L, eds. Tissue Oxygen Utilization. Berlin, Heidelberg, New-York: Springer-Verlag, 1991:103-13.
25. Lipowsky HH, Firrel JC. Microvascular hemodynamics during systemic hemodilution and hemoconcentration. Am J Physiol 1986;250:H908-22.
26. Weiskopf RB, Feiner J, Hopf H, et al. Heart rate increases linearly in response to acute isovolemic anemia. Transfusion 2003;43:235-40.
27. Habler OP, Kleen MS, Podtschaske AH, et al. The effect of acute normovolemic hemodilution (ANH) on myocardial contractility in anesthetized dogs. Anesth Analg 1996;83:451-8.