Southern African Journal of Anaesthesia and Analgesia 2019; 25(5):S31-34

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

PACSA SUPPLEMENT

Approach to blood conservation strategies

P Motshabi Chakane

Department of Anaesthesiology, Charlotte Maxeke Johannesburg General Academic Hospital, University of Witwatersrand, Johannesburg, South Africa
Corresponding author, email: Palesa.Motshabi@wits.ac.za

Introduction

Surgery for congenital heart defects is often performed on cardiopulmonary bypass (CPB). The prime volumes on CPB may lead to as much as 300% haemodilution.[1] The haemodilution effects may lead to severe anaemia associated with increased morbidity and mortality.[2] Use of blood products is therefore often unavoidable. Use of allogenic blood transfusion has been shown to lead to adverse events, such as: increased infections; lung injury; cardiac complications; and poor short- and long-term outcomes.[2] Societies have developed guidelines to reduce the use of allogenic blood transfusion. Hessel and Levy,[3] in their study, showed that fewer than half of the institutions they investigated did not follow their STS/SCA guidelines. Confusion over indications and risks of transfusion and concern of litigation were seen as reasons for failure to implement these guidelines.[4]

Risks of blood transfusion

Infections have been the biggest risk of blood transfusion over time. The introduction of the nucleic acid test (NAT) over two decades ago has reduced this risk.[5] However, this has not safeguarded patients from newer ever-evolving infection risks. Non-infectious risks of blood product transfusion have a great impact on clinical outcomes. These include: transfusion-related lung injury; transfusion-related circulatory overload; haemolytic and non-haemolytic transfusion reactions; alloimmunisation; and immunomodulation.[5]

Clinical impact of transfusion-related complications

Transfusion-related complications have been reported to lead to mortality, albeit at a reduced rate due to recent improvements in transfusion-related practices. Transfusion-related lung injury (TRALI), haemolytic transfusion reactions (HTR), sepsis, and transfusion-associated circulatory overload (TACO) are reported to have had mortality rates of 48%, 26%, 12% and 11% respectively in the USA in a five-year span from 2005.[5] Viral infections such as Human Immunodeficiency Virus (HIV), hepatitis B virus (HBV) and hepatitis C virus (HCV) have been on the decline due to improvements in testing such as the NAT system.[6]

TRALI is particularly common after transfusion of FFP, mostly from multiparous female donors due to alloimmunisation. Preferential donation of FFP and single donor platelets from males have reduced this rate.[7] In the 2009 Serious Hazards of Transfusion (SHOT) report, TACO was associated with a mortality rate of 12%.[8] Literature reports allude to an increase in cancer rates and metastatic disease related to transfusion-related immunomodulation (TRIM).[9]

Complications of transfusion in the paediatric population were mostly related to human error in the SHOT trial. These were reported to be related to over-transfusion and lack of knowledge of special requirements for blood product transfusion in the neonatal group such as irradiation and extensive screening for infectious causes.[5]

Challenges for blood conservation in paediatric age group

Paediatric cardiac patients are unique in that they often present with cyanosis, which is accompanied by coagulopathy. They have small blood volumes, require higher haematocrit on bypass, have an immature immune system, and often undergo a hypothermic

Table I. Perioperative blood conservation strategies

Preoperative	Intraoperative	Postoperative
Autologous blood transfusion	Target haematocrit	Point-of-care tests
Erythropoietin therapy	Monitoring of oxygen delivery	Antifibrinolytics
	Reduced Volumes of lines	Prothrombin Complex Concentrates
	Acute normo-volaemic haemodilution	Activated Factor VII
	Retrograde autologous priming	FDP
	Antifibrinolytics	Reduced blood sampling
	Miniature circuits	
	Vacuum assisted venous drainage	
	Surface modified circuits	
	Cell salvage devices	
	Other procoagulant agents	
	Topical haemostatic agents	
	Ultrafiltration	

cardiopulmonary bypass. They may have congenital deficiencies of clotting factors such as factor VII, VIII and vWF. Due to shunts and abnormal flow patterns, they also present with qualitative and quantitative platelet abnormalities.[10]

Strategies

Preoperative

Preoperative erythropoietin and iron supplements have been used to increase haematocrit, often to 35–40%. This strategy may be used together with autologous blood donation, which can be performed a few times preoperatively, with the last donation ideally one week before surgery. The process of preoperative donation can, however, be cumbersome and expensive, and may have complications.[10] Supplemental folic acid and vitamins A, C, and K are also often used.[10]

Intraoperative

The target haematocrit on bypass is a subject of debate. Following the Boston Hematocrit Trial, extrapolations and conclusions have been made that a Hct of ≥ 23.5% on bypass, especially low-flow bypass, confers benefit.[11,12] Oxygen delivery has to be maintained with adequate haemoglobin, optimum pump flow rates and monitoring with near infrared spectroscopy (NIRS) trends.[13]

CPB prime volumes are often 200–300% that of the patient's blood volume, particularly in neonates.[14] This leads to massive haemodilution. Use of low prime oxygenators, integrated arterial line filters, shorter tubing with small internal diameter can mitigate this effect. Ging et al.[15] used a total prime volume circuit of 220 ml in a case of a seven-month-old, 5.9 kg, 69 cm Jehovah's Witness infant for a ventricular septal defect (VSD). They primed their pump with 121 ml Plasmalyte A, 15 ml NaBic, 3 ml heparin, 1 ml calcium chloride, 18 ml Trasylol, 50 ml 25% albumin and 12 ml 20% mannitol.[15]

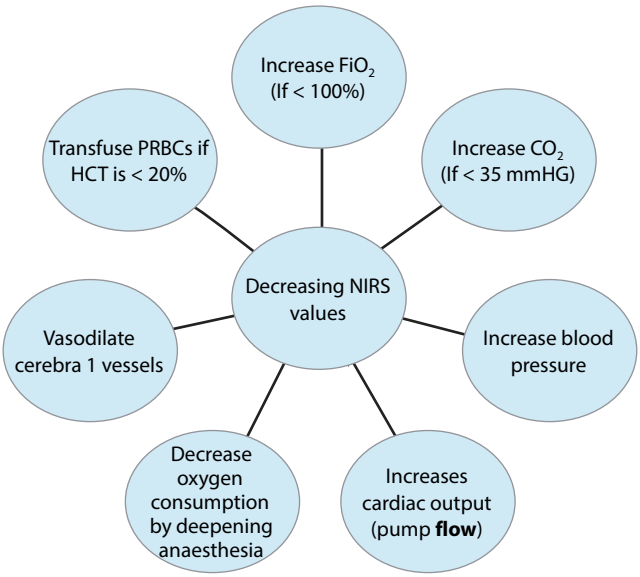

Figure 1. Strategies to optimise NIRS values[15]

Using acute normovolaemic haemodilution (ANH) they saved approximately 10 ml/kg of the patient's blood at the time of invasive line insertion. This group, using retrograde autologous priming, which removed 140 ml of the clear prime, together with vacuum assisted venous drainage, infusion of cardioplegia by syringe directly into the aorta and continuous ultrafiltration and cell salvage; managed to have a haematocrit (Hct) decrease from 35.5– 28.9% on admission to ICU. Erythropoeitin (EPO) and iron supplements were used to increase Hct preoperatively.[15]

Common strategies utilised to mitigate for a low NIRS value were: increasing blood pressure; increasing carbon dioxide if < 35 mmHg; increasing FiO2 if < 100%; transfusing blood if Hct < 20% with blood saved during ANH; vasodilating cerebral vessels; decrease oxygen consumption by deepening anaesthesia; and increasing cardiac output (pump flow).[15]

Use of ultrafiltration, conventional and modified, is extensively reported on in paediatric cardiac surgery. Conventional ultrafiltration removes excess water, electrolytes and substances with a molecular size smaller than the membrane pore size.[16] Modified ultrafiltration (MUF) is performed at the end of bypass to reduce haemodilution and oedema. There is evidence of improved coagulopathy and reduced blood transfusions. The technique, however, is not devoid of complications.[17]

Ultrafiltration has been shown to significantly reduce duration of mechanical ventilation and inotrope requirements 48-hours after surgery. Appropriate use of MUF circuits can improve the patient's Hct and whole blood compared to cell salvage which leads to losses of plasma, factors and platelets.[13]

In a study by Avgerinos et al.,[2] where they instituted a smaller volume circuit together with an intraoperative autologous donation (IAD) strategy using the DeBois nomogram (Table II), there was a significant reduction in percentage change of intraoperative haematocrit, transfusion of red blood cells, FFP and platelets, and better 30-day mortality rates in the intervention group. The nomogram uses weight and preoperative Hct to estimate volume that can be taken off during IAD.[2]

Good surgical haemostasis during surgery is paramount. The STS Blood Conservation Guideline Task Force Guidelines recommend (Class IIb) use of topical agents in their multimodal blood management programme.[18] Use of fibrin sealants in paediatric cardiac surgery, in the presence of coagulopathy, may be effective.[19,20]

Microplegia employs syringe pumps to deliver a non-diluted cardioplegia solution. Its advantages are a higher myocardial oxygen supply, with a higher haemoglobin content; a negligible fluid balance of cardioplegia; reduced tendency for tissue oedema, and reduced risk of fluid overload with associated dilution of clotting factors.[17]

Point-of-care devices such as thromboelastography and ROTEM may be useful in assessing clot firmness and lysis. Point-of-care platelet function assays allow assessment of maximum clot firmness.[21] Galas et al.[22] in their prospective study, suggested

Table II. The DeBois nomogram used to calculate IAD

Weight (kg)	30%	32%	34%	36%	38%	40%	42%	44%	46%	48%	50%
40	355	379	403	426	450	474	497	521	545	568	592
45	437	446	495	525	554	583	612	641	670	699	729
50	498	531	564	598	631	664	697	730	796	830	865
55	578	616	655	693	732	801	841	881	921	961	1002
60	658	701	745	819	865	910	956	1001	1047	1092	1138
65	737	816	867	918	969	1020	1071	1122	1173	1224	1275
70	847	903	959	1016	1072	1129	1185	1242	1298	1355	1411
75	929	990	1052	1114	1176	1238	1300	1362	1424	1486	1548
80	1010	1078	1145	1212	1280	1347	1415	1482	1549	1617	1684
85	1092	1165	1238	1311	1384	1456	1529	1602	1675	1748	1821
90	1174	1252	1331	1409	1487	1566	1644	1722	1800	1879	1957
95	1256	1340	1424	1507	1591	1675	1759	1842	1926	2000	2000
100	1338	1427	1516	1606	1695	1784	1873	1962	2000	2000	2000
105	1420	1515	1609	1704	1799	1893	1988	2000	2000	2000	2000
110	1502	1602	1702	1802	1902	2000	2000	2000	2000	2000	2000
115	1584	1689	1795	1900	2000	2000	2000	2000	2000	2000	2000
120	1666	1777	1888	1999	2000	2000	2000	2000	2000	2000	2000
125	1748	1864	1981	2000	2000	2000	2000	2000	2000	2000	2000
130	1829	1951	2000	2000	2000	2000	2000	2000	2000	2000	2000
135	1911	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
140	1993	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
145	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
150	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000

that fibrinogen concentrate was as efficient as an alternative to cryoprecipitate and FFP. Recombinant factor VIIa in extreme clinical cases where bleeding continues despite use of standard blood products, can be useful.[23] There is, however, paucity of quality data on this.

During reversal of heparin, care should be taken not to use an overdose of protamine as excess protamine inhibits platelet and serine protease and leads to an increase in bleeding.[24] Use of heparin concentration instead of ACT may be of benefit.[24]

Cell salvage, despite its reported benefits, has its disadvantages. In small children with a body weight of < 10 kg, blood collected may be insufficient for processing even when the bowl is 100 ml. The process may lead to the cost of collection of shed blood being higher than savings from reductions of homologous blood transfusion.[25] Cell saved blood is devoid of factors and platelets. In contrast, pump blood, collected at cessation of pump, has the same quality of the patient's blood at this point. This blood can be collected in a bag and re-transfused to the patient, with heparin reversed using protamine. The blood will contain platelets and plasma proteins.[17]

Postoperative

Reducing blood sampling and excessive flushing of lines reduces transfusion rates. Chollete et al.[26] showed that children with single ventricle physiology who undergo cavopulmonary anastomosis, did not benefit from a liberal transfusion strategy 9 vs 13 g/dl. However, there is a suggestion that children with cyanosis should have a higher Hct.[10] Antifibrinolytics can be used in the postoperative period. In the post aprotinin era, refractory postoperative bleeding has been treated with FVIIa 72–87 μg/kg, reducing chest tube drainage and blood product transfusion. Post-of-care testing guides transfusion of blood products where necessary.[10]

Conclusion

The success of a blood conservation strategy is depended on a multidisciplinary effort, with a concerted effort at every point to reduce haemodilution, blood product wastage and meticulous surgical haemostasis and use of haemostatic agents. Care should be taken in paediatric patients, as their blood volume is small and those with cardiac lesions may not have a normal coagulation system.

References

1. Budak AB, McCusker K, Gunaydin S. A structured blood conservation program in pediatric cardiac surgery. Eur Rev Med Pharmacol Sci 2017;21(5):1074–1079.
2. Avgerinos DV, DeBois W, Salemi A. Blood conservation strategies in cardiac surgery: more is better. Eur J Cardiothorac Surg 2014;46(5):865–70. doi: 10.1093/ejcts/ezt661. Epub 2014 Jan 30.
3. Hessel EA, Levy JH. Guidelines for perioperative blood transfusion and conservation in cardiac surgery: lessons and challenges. Anesth Analg 2010;111(6):1555–9. doi: 10.1213/ANE.0b013e3181fbb386.
4. Xydas S, Magovern CJ, Slater JP, Brown JM III, Grant BR, Parr V, et al. Implementation of a comprehensive blood conservation program can reduce blood use in a community cardiac surgery program. J Thorac Cardiovasc Surg 2012;143(4):926–35. doi: 10.1016/j.jtcvs.2012.01.003.
5. Lavoie J. Blood transfusion risks and alternative strategies in pediatric patients. Paediatr Anaesth 2011;21(1):14–24. DOI: 10.1111/j.1460-9592.2010.03470.x.
6. Nübling CM, Heiden M, Chudy M, Kress J, Seitz R, Keller-Stanislawski B, et al. Experience of mandatory nucleic acid test (NAT) screening across all blood organizations in Germany: NAT yield versus breakthrough transmissions. Transfusion 2009;49(9):1850–8. doi: 10.1111/j.1537-2995.2009.02212.x.
7. Eder AF, Herron RM Jr, Strupp A, Dy B, White J, Notari EP, et al. Effective reduction of transfusion-related acute lung injury risk with male-predominant plasma strategy in the American Red Cross (2006-2008). Transfusion 2010;50(8):1732–42. doi: 10.1111/j.1537-2995.2010.02652.x.
8. Serious Hazards of Transfusion (SHOT) Report 2009. Available on: https://www.shotuk.org/shot-reports/report-and-summary-2009/

9. Youssef LA, Spitalnik SL. Transfusion-related immunomodulation: A reappraisal. Curr Opin Hematol.2017;24(6): 551–557. doi:10.1097/MOH.0000000000000376.
10. Singh SP. Strategies for blood conservation in pediatric cardiac surgery. Ann Card Anaesth 2016;19:705–16.
11. Jonas RA, Wypij D, Roth SJ, Bellinger DC, Visconti KJ, du Plessis AJ, et al. The influence of hemodilution on outcome after hypothermic cardiopulmonary bypass: results of a randomized trial in infants. J Thorac Cardiovasc Surg 2003;126(6):1765–74.
12. Newburger JW, Jonas RA, Soul J, Kussman BD, Bellinger DC, Laussen PC, et al. Randomized trial of hematocrit 25% versus 35% during hypothermic cardiopulmonary bypass in infant heart surgery. J Thorac Cardiovasc Surg 2008;135(2):347–54, 354.e1-4. doi: 10.1016/j.jtcvs.2007.01.051.
13. Matte GS. Perfusion for congenital heart surgery: notes on cardiopulmonary bypass for a complex patient population. Oxford: Wiley-Blackwell; 2015.
14. De Somer F, Foubert L, Poelaert J, Dujardin D, Van Nooten G, François K. Low extracorporeal priming volumes for infants: a benefit? Perfusion 1996;11(6):455–460. doi:10.1177/026765919601100606.
15. Ging AL, St Onge JR, Fitzgerald DC, Collazo LR, Bower LS, Shen I. Bloodless cardiac surgery and the pediatric patient: a case study. Perfusion 2008;23(2):131–4. doi: 10.1177/0267659108095903.
16. Ziyaeifard M, Alizadehasl A, Aghdaii N, et al. The effect of combined conventional and modified ultrafiltration on mechanical ventilation and hemodynamic changes in congenital heart surgery. J Res Med Sci 2016;21:113. doi:10.4103/1735-1995.193504.
17. Durandy Y. Perfusionist strategies for blood conservation in pediatric cardiac surgery. World J Cardiol 2010;2(2):27–33. doi: 10.4330/wjc.v2.i2.27.
18. Ferraris VA, Brown JR, Despotis GJ, et al. 2011 update to the society of thoracic surgeons and the society of cardiovascular anesthesiologists blood conservation clinical practice guidelines. Ann Thorac Surg 2011;91:944–982. doi:10.1016/j.athoracsur.2010.09.075.
19. Bracey A, Shander A, Aronson S, et al. The use of topical hemostatic agents in cardiothoracic surgery. Ann Thorac Surg 2017;104(1):353– 602. doi:10.1016/j.athoracsur.2017.01.096.
20. Codispoti M, Mankad PS. Significant merits of a fibrin sealant in the presence of coagulopathy following paediatric cardiac surgery: randomised controlled trial. Eur J Cardiothorac Surg 2002;22:200–205.
21. Kozek-Langenecker SA. Perioperative coagulation monitoring. Best Pract Res Clin Anaesthesiol 2010;24(1):27–40. https://doi.org/10.1016/j.bpa.2009.09.009.
22. Galas FRBG, De Almeida JP, Fukushima JT, Vincent JL, Osawa EA, Zeferino S, et al. Hemostatic effects of fibrinogen concentrate compared with cryoprecipitate in children after cardiac surgery: A randomized pilot trial. J Thorac Cardiovasc Surg 2014;148(4):1647–1655.
23. Guzzetta NA, Russell IA, Williams GD. Review of the off-label use of recombinant activated factor VII in pediatric cardiac surgery patients. Anesth Analg 2012;115(2):364–378. doi:10.1213/ANE.0b013e31825aff10.
24. Gautam S, John RM, Stevenson WG, Jain R, Epstein LM, Tedrow U, et al. Effect of therapeutic INR on activated clotting times, Heparin dosage, and bleeding risk during ablation of atrial fibrillation. J Cardiovasc Electrophysiol 2011;22:248–254, doi: 10.1111/j.1540-8167.2010.01894.x.
25. Ashworth A, Klein AA. Cell salvage as part of a blood conservation strategy in anaesthesia. Br J Anaesth 2010;105(4):401–16. doi: 10.1093/bja/aeq244.
26. Cholette JM, Willems A, Valentine SL, Bateman ST, Schwartz SM; (TAXI); (BloodNet), (PALISI) Network. Recommendations on RBC transfusion in infants and children with acquired and congenital heart disease from the pediatric critical care transfusion and anemia expertise initiative. Pediatr Crit Care Med 2018;19(9S Suppl 1):S137-S148. doi: 10.1097/PCC.0000000000001603.