MATHEWS

Research Article

Mathews Journal of Case Reports

Evaluation of the Effect of Acute Normovolemic Hemodilution on Bleeding Rate and Short-Term Post-Operative Complication of Patient Who Underwent on-Pump Coronary Artery Bypass Graft Surgery

Fatemeh Abdoli[1], Kianoush Saberi[2]*, Ali Abdoli[3], Hossein Saberi[4], Hasti Saberi[5], Shahnaz sharifi[6]

[1]*Tehran University of Medical Sciences, School of Medicine, Tehran, Iran*

[2]*Tehran University of Medical Sciences, Imam Khomeini Hospital complex, Department of Anesthesiology, Tehran, Iran*

[3]*Department of Nursing, Shahid Beheshti University of Medical Sciences, Tehran, Iran*

[4]*Iran University of Medical Sciences, School of Medicine, Tehran, Iran*

[5]*Islamic Azad University, School of Food Industrial Engineering, Tehran, Iran*

[6]*Shahid Beheshti University of Medical Sciences, Tehran, Iran*

ABSTRACT

Background: Efficacy of minimal acute Normovolemic Hemodilution (ANH) in avoiding homologous blood transfusion during cardiovascular surgery remains controversial. Postoperative bleeding and transfusion remain a source of morbidity and cost after open heart operations. To better understand the role of acute normovolemic hemodilution (ANH) in coronary artery bypass grafting (CABG), we compared ANH with standard intraoperative care in a retrospective cohort study. **Methods:** This retrospective cohort study is based on 572 patients who underwent on-pump CABG in the cardiac operating room of Imam Khomeini Hospital from June 2016 till March 2022. 221 patients (38.6%) were in the ANH group and 351 patients (61.4%) were in the control group. This study was based on patients documented information. P<0.05 was significant. **Result:** The prevalence of short-term complications was bleeding (74.96%), AKI (7.38%), CVA (1.92%) and HF (1.05%), respectively. In general, bleeding was more in the ANH group. There was no significant relationship between ANH and days of hospitalization in ICU (P=0.291), CVA (P=0.748), HF (P=1.000), AKI (P=0.411), bleeding rate on the second day (P=0.180), platelet transfusion (p= 0.158) and FFP transfusion (p=0.776). There was a significant relationship between ANH and the reduction of bleeding (P=0.000), the increase in bleeding on the first day (P=0.006), the reduction of mortality (P=0.007), the reduction of transfusion packed cell (p=0.000). **Conclusion:** It seems that ANH leads to a decrease in mortality and bleeding, and as a result, a decrease in the allogenic blood transfusions and an increase in bleeding on the first day, but it have no effect on the days of hospitalization in the ICU, CVA, HF, AKI, platelet and FFP transfusion. Therefore, ANH is an effective technique in reducing mortality and bleeding and the allogenic blood transfusion.

Keyword: coronary artery bypass graft surgery, CABG, Acute

Vol No: 08, Issue: 07

Received Date: May 12, 2023

Published Date: May 26, 2023

***Corresponding Author**

Kianoush Saberi

Imam Khomeini Hospital Complex, Tohid Squre, Tehran, Iran; Tel: +989128984844

Email: saberikn@yahoo.com

Citation: Abdoli F, et al. (2023). Evaluation of the Effect of Acute Normovolemic Hemodilution on Bleeding Rate and Short-Term Post-Operative Complication of Patient Who Underwent on-Pump Coronary Artery Bypass Graft Surgery. Mathews J Case Rep. 8(7):117.

Normovolemic Hemodilution, ANH, bleeding, allogenic blood transfusion, short-term complication, cardiac surgery

INTRODUCTION

Allogeneic blood is a scarce and expensive resource and its use continues to raise concerns, including but not limited to latent viral or transfusion-transmitted infectious disease, for both the patient and physician [1,2]. Allogeneic transfusions are associated with worse short- and long-term outcomes, that are dose-dependent, with patients receiving even 1 unit of red blood cells (RBCs) having a 77% increased adjusted odds of mortality compared with those not receiving transfusions [3]. Mortality in cardiac surgery increases by 0.5% for every unit of blood infused and allogeneic transfusions are also associated with an overall increase in the length of hospital stays [18] [4]. The 2011 National Blood Collection and Utilization Survey Report states that cardiac surgery is still one of the largest users of RBCs and utilize 50% of all platelet use in surgery in the US, accounting for 10–15% of the nation's blood supply [5,6]. Acute normovolemic hemodilution (ANH) could be a viable option to allogeneic blood transfusion. It was introduced in the 1970s and is a method of autologous blood transfusion used mainly in cardiac surgical specialties, but is now being used in other surgical areas [7]. Following anesthesia induction and prior to heparinization, a specific amount of whole blood volume is removed from the patient and stored at the bedside. This is followed by replacement with sufficient volumes of crystalloid or colloid solutions to maintain intravascular (stroke) volume [1,8,9]. The stored autologous blood is then administered either intra- or post-operatively as required [10]. If an adequate volume of blood is removed and there is no profound RBC loss during surgery, it is possible to achieve an acceptable hemoglobin concentration without the administration of allogeneic transfusion [1]. There are many possible beneficial effects of ANH including reduced risk of adverse transfusion-related reactions and infections, lower erythrocyte damage, less negative impact on coagulation, preservation of RBC mass and platelets, as well as improved perfusion during cardiopulmonary bypass (CPB) resulting in increased tissue oxygen delivery [7,10]. The few contraindications to the use of ANH include anemia, sepsis and bacteremia [7]. Despite the possible benefits of ANH, there is little conclusive evidence as to its effectiveness in reducing the number of allogeneic transfusions and decreasing morbidity and mortality. The latest blood management guidelines from the American Society of Anesthesiologists recommend to consider the use of ANH to "reduce allogeneic blood transfusion in patients at high risk for excessive bleeding (e.g., major cardiac, orthopedic, thoracic, or liver surgery), if possible" [11]. However, these guidelines provide no specific methods to ensure a standardized approach to the implementation and performance of ANH, nor do they detail the specific patient populations who will benefit from this technique. Further guidance and clarification are required to enable ANH to be accepted by the wider medical community as a practical tool in Patient Blood Management (PBM). ANH is an under-recognized and under-utilized viable tool in PBM. There is significant heterogeneity, variability in performance and publication bias in the existing literature, making it difficult to reliably interpret results and generate conclusive guidelines [12]. The blood conservation effect and the degree of ANH were still controversial. The purpose is to investigate the allogenic blood transfusion and the mortality and morbidity of ANH compared to previous methods [13]. The benefits of this study include reducing mortality and morbidity, reducing the allogenic blood transfusion in CABG, and reducing complications from allogeneic blood transfusions.

METHODS AND MATERIALS

This retrospective cohort study was on 572 patients who underwent on pump CABG in the cardiac operating room of Imam Khomeini Hospital from June 2016 till March 2022. A simple sampling method has been available. The age, sex, acute normovolemic hemodition (ANH) and pump time were the independent variables, and the dependent variables included short-term postoperative complications (including bleeding, cardiovascular accident (CVA), acute kidney injury (AKI) and heart failure (HF)), bleeding on the first day, bleeding on the second day, total bleeding on the first and second day, days of hospitalization in ICU, hours of intubation and mortality were extracted by referring to the patients' records. After collecting the data, it was entered into SPSS software version 26. Then quantitative data were reported as mean and standard deviation separately for two groups. Also, qualitative data were reported in the form of frequency and percentage separately for two groups. T-test or Mann-Whitney and chi-square tests were used to compare the case and control groups based on the normality test. In this study, we compared the amount of bleeding and short-term complications after on pump CABG in two groups. These complications include bleeding, cardiovascular accident (CVA), acute kidney injury (AKI) and heart failure (HF). Two groups were matched in terms of age and sex. In this study, we considered the KDIGO criteria (kidney disease improving global outcomes) for acute kidney injury (AKI). Our case groups were patients who underwent ANH and the control group was patients who received standard care during surgery and allogeneic blood transfusion.

RESULTS

In this study, 572 patients were included based on the

inclusion criteria, of which 411 (71.9%) were male and 161 (28.1%) were female. The average age of the patients was 59.64 years with a standard deviation of 8.578. 11.9% of patients were ≥70 years old. 88.1% of patients were <70 years old. In this study, 221 patients (38.6%) were in the ANH group and 351 patients (61.4%) were in the control group. 74.96% of the patients suffered bleeding complications. 67.3% of patients received pack cells, 28.7% of patients received FFP, and 38.2% of patients received platelets.

7.38% of patients had AKI. The prevalence of mortality in this study was reported to be 2.8%. Table 1 shows the average bleeding on the first day, the second day, and the sum of the first and second days separately. Table 2 shows the average bleeding on the first day, the second day, and the sum of the first and second days associated with the gender.

Table 3 shows the prevalence of short-term postoperative complications of on pump CABG according to gender.

70.7% of men and 85.5% of women had bleeding. There is a significant relationship between bleeding and gender (chi-square and P=0.000) and bleeding are more common in women.

Table 4 shows the average bleeding of on pump CABG patients in association with short-term postoperative complications.

The average bleeding on the first and second day and the total bleeding on the first and second day were higher in patients who had bleeding and AKI.

Table 5 shows the average postoperative bleeding of on pump CABG patients according to the number of days of hospitalization in ICU.

The average bleeding increased with the increase in the number of days of hospitalization in the ICU.

Table 6 shows the prevalence of short-term postoperative complications of on pump CABG patients according to the number of days of hospitalization in ICU.

Table 1: Assessment of the average bleeding of patients on the first day, the second day and the sum of the first and second day.

	Mean	Mode	Median	Std. Deviation	Confidence Interval	95% Confidence Interval for mean
Bleeding on the first day	410.23	250	350.00	285.322	23.5	386.73 – 433.72
Bleeding on the second day	228.79	150	150.00	141.572	11.66	217.13 – 240.44
sum of the first and second day	639.0158	400.00	550.0000	352.43469	29.02	609.9958 – 668.0358

Table 2: Assessment of the average bleeding on the first day, the second day and the sum of the first and second day associated with the gender.

	Male					Female				
	Mean	Median	Std. Deviation	Confidence Interval	95% Confidence Interval for mean	Mean	Median	Std. Deviation	Confidence Interval	95% Confidence Interval for mean
Bleeding on the first day	456.86	400.00	305.134	29.69	427.17 - 486.56	292.05	250.00	180.448	28.09	263.96 – 320.14
Bleeding on the second day	240.49	150.00	154.857	15.07	225.42 – 255.56	199.13	150.00	94.428	14.7	184.43 – 213.83
sum of the first and second day	697.3529	605.0000	380.50817	37.0318	660.3211 – 734.3848	491.1801	450.0000	204.87917	31.8882	459.2919 – 523.0683

Table 3: Assessment of the prevalence of short-term postoperative complications of on pump CABG according to gender.

	Bleeding yes	Bleeding No	CVA yes	CVA No	HF yes	HF No	AKI yes	AKI No
male	70.7%	29.3%	1.2%	98.8%	1.5%	98.5%	6.6%	93.4%
female	85.5%	14.5%	3.1%	96.9%	0%	100%	9.4%	90.6%

Table 4: Assessment of the average bleeding of on pump CABG patients in association with short-term postoperative complications.

	Bleeding Yes	Bleeding No	CVA Yes	CVA No	HF Yes	HF No	AKI Yes	AKI No
The mean of Bleeding on the first day	448.15	293.46	588.00	406.61	788.33	405.76	446.19	406.90
The mean of Bleeding on the second day	239.46	196.50	298.00	227.57	258.33	228.50	256.67	226.58
The mean of Bleeding on the sum of the first and second day	687.6118	489.9643	886.0000	634.1802	1046.6667	634.2576	702.8571	633.4799

Table 5: Assessment the average postoperative bleeding of on pump CABG patients to the number of days of hospitalization in ICU

	ICU<2	2≤ICU≤4	ICU>4
The mean of Bleeding on the first day	393.17	455.00	492.22
The mean of Bleeding on the second day	222.43	240.14	291.94
The mean of Bleeding on the sum of the first and second day	615.6009	695.1429	784.1667

Table 6: Investigation of the prevalence of short-term postoperative complications of on pump CABG patients according to the number of days in the ICU.

	Bleeding Yes	Bleeding No	CVA Yes	CVA No	HF Yes	HF No	AKI Yes	AKI No
ICU<2	71.8%	28.2%	0.2%	99.8%	0.2%	99.8%	5.9%	94.1%
2≤ICU≤4	84.3%	15.7%	0%	100%	0%	100%	5.7%	94.3%
ICU>4	83.3%	16.7%	8.3%	91.7%	5.6%	94.4%	22.2%	77.8%

Table 7: Investigating the relationship between ANH and early postoperative complications in on pump CABG patients.

	Bleeding yes	Bleeding No	CVA yes	CVA No	HF yes	HF No	AKI yes	AKI No
ANH	66.2%	33.8%	1.4%	98.6%	0.9%	99.1%	8.7%	91.3%
Non ANH	80.2%	19.8%	2%	98%	1.1%	98.9%	6.6%	93.4%

Table 8: Investigating the relationship between ANH and bleeding in on pump CABG patients.

	ANH	Non ANH
The mean of Bleeding on the first day	453.50	382.95
The mean of Bleeding on the second day	238.73	222.31
The mean of Bleeding on the sum of the first and second day	692.2273	605.4728

Table 9: Investigating the effect of ANH on the allogenic blood transfusion.

Platelet	**Platelet**	**FFP**	**FFP**	**Packed cell**	**Packed cell**	**Transfusion**	**Transfusion**	
No	Yes	No	Yes	No	Yes	No	Yes	
58.20%	41.80%	70.50%	29.50%	47.30%	52.70%	33.60%	66.40%	ANH
64.10%	35.90%	71.80%	28.20%	23.60%	76.40%	19.70%	80.30%	Non ANH
61.80%	38.20%	71.30%	28.70%	32.70%	67.30%	25.00%	75.00%	Total

It seems that there is a significant relationship (chi-square and P=0.036) between bleeding and increasing the days of hospitalization in the ICU. It seems that there is a significant relationship (chi-square and P=0.001) between the AKI and the increase in the number of days of hospitalization in the ICU.

Regarding the duration of intubation; 551 patients (98.9%) were intubated for less than one day. 5 patients (0.9%) were intubated for one to two days. One patient (0.2%) was intubated for more than two days. In this study, all patients were connected to a cardiopulmonary pump for less than 180 minutes during surgery, and only one patient was connected to a cardiopulmonary pump for 180 minutes. The average time the patients were connected to the cardiopulmonary pump was 100.16 minutes with a standard deviation of 21.623 minutes. Table 7 shows the relationship between ANH and early postoperative complications of on-pump CABG patients.

66.2% of people in ANH group and 80.2% of non-ANH group had bleeding. It seems that there is a significant relationship (chi-square and P=0.000) between ANH and the reduction of bleeding. Table 8 shows the relationship between ANH and bleeding in on-pump CABG patients.

The average bleeding on the first day in the ANH group was 453.50 ml with a standard deviation of 311.335 and in the Non ANH group was 382.95 ml with a standard deviation of 264.472. It seems that there is a significant relationship (P=0.006) between ANH and the increase in bleeding on the first day.

Mortality is 0.5% in the ANH group and 4.3% in the Non-ANH group. There seems to be a significant relationship (chi-square and P=0.007) between ANH and mortality reduction.

Table 9 shows the effect of ANH on the allogenic blood transfusion (packed cells, FFP and platelets).

In general, 75% of people have received the blood products and 25% have not received the blood products. In the ANH group, 66.4% of people received one, two or all three types of blood products (including packed cells, platelets and fresh frozen plasma) and 33.6% of people did not receive any blood products. In the Non ANH group, 80.3% of people received one, two or all three types of blood products (including packed cells, platelets and fresh frozen plasma) and 19.7% of people did not receive any blood products. This result is statistically significant (p=0.000). There seems to be a significant relationship between ANH and a reduction in the need for transfusion of blood products.

In general, 67.3% of people received packed cells and 32.7% of people did not receive packed cells. In the ANH group, 47.3% of patients did not receive any packed cells, while 52.7% of patients received from one to six units of packed red blood cells. In the Non-ANH group, 23.6% of people did not receive any packed red blood cells, while 76.4% of people received from one to six units of packed red blood cells. This was statistically significant p=0.000

DISCUSSION

In the present study, there was no significant relationship between ANH and days of hospitalization in ICU (Chi-square and P=0.291) [14]. There was a significant relationship (chi-square and P=0.000) between ANH and the reduction of bleeding, and many studies confirm this result [14-22] While in some studies, the total amount of bleeding during and after the operation was not significantly different in the case and control groups [13,23]. In this study, there was no significant relationship (chi-square and P=0.411) between ANH and the increase of AKI [14]. In this study, we found a significant relationship (P=0.006) between ANH and the increase in bleeding on the first day. There was no significant relationship (P=0.180) between ANH and increased bleeding rate on the second day. It seems that there is a significant relationship (P=0.005) between ANH and the increase in total bleeding on the first and second day. While in some studies, the total amount of bleeding during and after the operation was not significantly different in the case and control groups [13,23]. In some studies, the amount of bleeding in the ANH group was lower than the control group [4- 6]. In the present study, there was a significant relationship (chi-square and P=0.007) between ANH and mortality reduction [14]; While in some studies, there was no significant difference in mortality between case and control groups [13,14]. In this study, there seems to be a significant relationship between ANH and reducing the need to transfusion of blood products (p=0.000) [14-22,24,25]. While in some studies, there was no significant difference between the two groups in terms of the transfusion of blood products [13,23,25,26]. In this research, we found a significant relationship between ANH and reducing the need for packed cells transfusion (p=0.000) [14-22,24,25]; While in some studies, there was no significant difference between the two groups in terms of red blood cell transfusion [13,23]. In this study, there seems to be no significant relationship between ANH and reducing the need for fresh frozen plasma transfusion (p=0.776) [14,22]; While in some studies there has been a significant relationship between ANH and the reduction of fresh frozen plasma injection [15,16,21]. In the present study, there was no significant relationship between ANH and the reduction of the need for platelet transfusions (p=0.158) [14,22]; While in some studies, there has been a significant relationship between ANH and the reduction of platelet transfusion[15,16,21,27,31].

CONCLUSION

It seems that ANH leads to a decrease in mortality and bleeding, and as a result, a decrease in the allogenic blood transfusions and an increase in bleeding on the first day, but it have no effect on the days of hospitalization in the ICU, CVA, HF, AKI and platelet and FFP transfusion. Therefore, ANH is an effective technique in reducing mortality and bleeding and the need for allogenic blood transfusion, but it is better to conduct more studies to confirm these results.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

1. Murray D. (2004). Acute normovolemic hemodilution. Eur Spine J. 13: S72-S75.
2. Walunj A, Babb A, Sharpe R. (2006). Autologous blood transfusion. Continuing Education in Anaesthesia, Critical Care and Pain. 6:192-196.
3. Paone G, Likosky DS, Brewer R, Theurer PF, Bell GF, Cogan CM, Prager RL, et al. (2014). Transfusion of 1 and 2 units of red blood cells is associated with increased morbidity and mortality. Ann Thorac Surg. 97: 87-94.
4. Calcaterra D. (2012). Importance of blood conservation in cardiac surgery and impact on patients refusing blood product transfusions. J Blood Disord Transfus. 4: e107.
5. Society of Thoracic Surgeons Blood Conservation Guideline Task Force, Ferraris VA, Brown JR, Despotis GJ, Hammon JW, Reece TB, et al. (2011). 2011 update to the Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists blood conservation clinical practice guidelines. Ann Thorac Surg. 91: 944-982.
6. US Department of Health and Human Services. (2011). 2011 National Blood Collection and Utilization Survey Report.
7. Likosky DS, Dickinson TA, Paugh TA. (2016). Blood conservation - A team sport. J Extra Corpor Technol 48:99-104.
8. Stehling L, Zauder H. (1991). Acute normovolemic hemodilution. Transfusion. 31:857-868.
9. Goldberg J, Paugh TA, Dickinson TA, Fuller J, Paone G, Theurer PF, et al. (2015). Greater volume of acute normovolemic hemodilution may aid in reducing blood transfusions after cardiac surgery. Ann Thorac Surg. 100:1581-1587.
10. Barile L, Fominskiy E, Di Tomasso N, Alpìzar Castro LE, Landoni G, De Luca M, et al. (2016). Acute Normovolemic Hemodilution Reduces Allogeneic Red Blood Cell Transfusion in Cardiac Surgery: A Systematic Review and Meta-analysis of Randomized Trials. Anesth Analg. 124:743-752.
11. American Society of Anesthesiologists Task Force on Perioperative Blood Management. (2014). Practice guidelines for perioperative blood management: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Management*. Anesthesiol. 122:241-275.
12. Zhou X, Zhang C, Wang Y, Yu L, Yan M. (2015). Preoperative acute normovolemic hemodilution for minimizing allogeneic blood transfusion: a meta-analysis. Anesth Analg. 121:1443-1455.
13. Zhou ZF, Jia XP, Sun K, Zhang FJ, Yu LN, Xing T, et al. (2017). Mild volume acute normovolemic hemodilution is associated with lower introperative transfusion and postoperative pulmonary infection in patients undergoing cardiac surgery – a retrospective, propensity matching study. BMC Anesthesiol. 17(1):13.
14. Barile L, Fominskiy E, Di Tomasso N, Alpìzar Castro LE, Landoni G, De Luca M, et al. (2017). Acute normovolemic hemodilution reduces allogenic red blood cell transfusion in cardiac surgery: review and meta-analysis ofrandomised trials. Anesth Analg. 124(3):743-752.
15. Sarin E, Speir A, Henry L, Holmes S, Hunt S, Halpin L, et al. (2012). Acute normovolemic hemodilution decreases blood product use and postoperative mortality and morbidity following cardiac surgery. J Am Coll Cardiol. 59 (13_Supplement):E1843.
16. Mahoori A, Heshmati F, Noroozinia H, Mehdizadeh H, Salehi S, Rohani M. (2009). Intraoperative minimal acute normovolemic hemodilution in patients undergoing coronary artery bypass surgery. Middle East J Anaesthesiol. 20(3):423-429.
17. Höhn L, Schweizer A, Licker M, Morel DR. (2002). Absence of beneficial effect of acute normovolemic hemodilution combined with aprotinin on allogeneic blood transfusion requirements in cardiac surgery. Anesthesiology. 96(2):276-82

18. Casati V, Speziali G, D'Alessandro C, Cianchi C, Antonietta Grasso M, Spagnolo S, et al. (2002). Intraoperative Low-volume Acute Normovolemic Hemodilution in Adult Open-heart Surgery. Anesthesiology. 97:367–373.

19. Li S, Liu Y, Zhu Y. (2020). Effect of acute normovolemic hemodilution on coronary artery bypass grafting: A systematic review and meta-analysis of 22 randomised trials. Int J Surg. 83:131-139.

20. Segal JB, Blasco-Colmenares E, Norris EJ, Guallar E. (2004). Preoperative acute normovolemic hemodilution: a meta-analysis. Transfusion. 44(5):632-644.

21. Licker M, Ellenberger C, Sierra J, Kalangos A, Diaper J, Morel D. (2005). Cardioprotective effects of acute normovolemic hemodilution in patients undergoing coronary artery bypass surgery. Chest. 128(2):838-847.

22. Or TH, Yang MW, Fan WL, Chan KH, Lee TY. (1991). Acute normovolemic hemodilution in coronary artery bypass graft surgery. Ma Zui Xue Za Zhi. 29(2):586-591.

23. Zhou X, Zhang C, Wang Y, Yu L, Yan M. (2015). Preoperative Acute Normovolemic Hemodilution for Minimizing Allogeneic Blood Transfusion: A Meta-Analysis. Anesth Analg. 121(6):1443-1455.

24. Grant MC, Resar LM, Frank SM. (2015). The Efficacy and Utility of Acute Normovolemic Hemodilution. Anesth Analg. 121(6):1412-4.

25. Bryson GL, Laupacis A, Wells GA. (1998). Does acute normovolemic hemodilution reduce perioperative allogeneic transfusion? A meta-analysis. The International Study of Perioperative Transfusion. Anesth Analg. 86(1):9-15.

26. Taketani T, Motomura N, Toyokawa S, Kotsuka Y, Takamoto S. (2005). Beneficial effect of acute normovolemic hemodilution in cardiovascular surgery. Jpn J Thorac Cardiovasc Surg. 53(1):16-21.

27. Engoren MC, Habib RH, Zacharias A, Schwann TA, Riordan CJ, Durham SJ. (2002). Effect of blood transfusion on long-term survival after cardiac operation. Ann Thorac Surg. 74:1180–1186.

28. Paone G, Likosky DS, Brewer R, Theurer PF, Bell GF, Cogan CM, et al. (2014). Membership of the Michigan Society of Thoracic and Cardiovascular Surgeons. Transfusion of 1 and 2 units of red blood cells is associated with increased morbidity and mortality. Ann Thorac Surg. 97:87–93.

29. American Society of Anesthesiologists Task Force on Perioperative Blood Transfusion and Adjuvant Therapies. (2006). Practice guidelines for perioperative blood transfusion and adjuvant therapies: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Transfusion and Adjuvant Therapies. Anesthesiology. 105:198–208.

30. Bennett-Guerrero E, Zhao Y, O'Brien SM, Ferguson TB Jr, Peterson ED, Gammie JS, et al. (2010). Variation in use of blood transfusion in coronary artery bypass graft surgery. JAMA. 304:1568–1575.

31. Stehling L, Zauder HL. (1994). Controversies in transfusion medicine. Perioperative hemodilution: pro. Transfusion. 34:265–268.