Autologous Blood Donation in Cardiac Surgery: Reduction of Allogeneic Blood Transfusion and Cost-Effectiveness

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Objective: **The purpose of this study was to assess transfusion requirements in patients undergoing cardiac surgery with and without autologous blood donation and to calculate the costs of predonation from the hospital perspective.**

Design: **Observational study.**

Setting: **Single university hospital.**

Participants: **Four thousand three hundred twenty-five patients undergoing elective cardiac surgery with and without autologous blood donation.**

Interventions: **Eight hundred forty-nine patients (20%) underwent autologous blood donation, whereas 3,476 (80%) did not. Perioperative allogeneic blood transfusion was recorded as the primary endpoint. To avoid selection bias, patients were stratified according to their preoperative risk score. A decision model was derived from acquired data for the optimization of autologous blood donation.**

Measurements and Main Results: **Allogeneic blood transfusion rate was 13% in patients with predonation versus 48% without predonation ($p < 0.05$). This difference remained statistically significant even after risk stratification. The predonation of 1, 2, or 3 units reduced the probability of receiving allogeneic blood to 24%, 14%, and 9%, respectively. An efficient program of predonation within the department of anesthesiology allowed keeping the costs of predonation low. Decision-tree analysis revealed that predonation of 2 autologous units of blood saved the most allogeneic blood for the smallest increase in costs. Incremental cost for male patients predonating 2 units was $33 (US), whereas for females predonation could be done at no extra cost in comparison to patients without predonation.**

Conclusion: **Autologous blood donation significantly reduces allogeneic blood requirement in cardiac surgery. If adjusted for diagnosis and gender, autologous blood donation is a cost-effective alternative to reduce allogeneic blood consumption.**

KEY WORDS: cardiac surgery, blood transfusion, autologous blood, predonation, blood saving, decision analysis, cost-effectiveness, blood saving

AUTOLOGOUS BLOOD DONATION before elective cardiac surgery has proved to be an effective measure to reduce the exposure of patients to allogeneic blood.[1-3] However, other studies did not completely agree with these results.[4] There are studies examining the cost-effectiveness of autologous blood donation, defined as quality-adjusted years of life saved by the avoidance of transfusion-transmitted viral infections like human immunodeficiency virus, hepatitis, or human T-lymphotropic virus. The extremely low per unit probability of these infections[5] resulted in cost-effectiveness values ranging from $235,000 (US) up to $1,190,000 per quality-adjusted year of life saved for autologous blood donation in elective cardiac surgery.[6,7] From these results, it has been concluded that autologous blood donation is not cost-effective.[8]

The calculation of high traceable costs of autologous predonation in these studies is mainly the result of high personnel costs and a considerable number of unnecessary predonations resulting in discarding predonated blood units. Personnel costs can be reduced by optimal organization of the predonation unit. Tailoring the predonation program to the specific needs of a particular hospital, a defined patient population and/or a certain type of surgery can lower the discard rate. A prerequisite for this management is thorough information about the actual transfusion practice within the respective hospital.

The cost-effectiveness model of autologous blood donation based solely on the avoidance of viral infections excludes several aspects from consideration. Potential risks associated with allogeneic transfusion like posttransfusion infections[9-13] or long-term mortality[14] could change the estimates of cost-effectiveness substantially. For example, a recent cardiac surgical study showed a significantly reduced long-term survival in patients with allogeneic blood transfusion in comparison to patients without transfusion but with an equal risk profile.[14] Other studies also reported an unfavorable effect of allogeneic blood-product transfusion.[15-18] Furthermore, the emergence of new diseases is likely to add considerable extra cost to allogeneic transfusion by the implementation of new testing or inactivation strategies.[19,20] Neither patient's preferences nor quality of life related to transfusion practices are weighed against the cost of autologous blood donation. Finally, there are repeated serious shortages of blood supply, drawing increased attention to the development of blood-conservation strategies. The objective of the present study was to assess transfusion practice and costs of transfusion in cardiac surgery with and without autologous blood donation and to develop a diagnosis- and gender-based decision model for the optimization of autologous blood donation.

MATERIAL AND METHODS

This study is a retrospective analysis based on data prospectively collected from 4,878 adult patients consecutively enrolled between 1995 and 2000 at the German Heart Center Munich undergoing elective cardiac surgery for coronary artery bypass graft (CABG) surgery, coronary artery bypass grafting with aortic or mitral valve replacement (combined procedures), aortic valve replacement (AVR), mitral valve repair/replacement (MVR), double valve replacement (DVR), closure of atrial septal defects (ASD), or other types of operations. All patients were evaluated for preoperative autologous blood donation. Inclusion criteria for autologous blood donation were the willingness of the patient to participate and the absence of exclusion criteria. Exclusion criteria were the unwillingness of the patient to predonate, the combination of coronary artery disease and severe aortic stenosis defined as mean systolic pressure gradient >80 mmHg or a history of syncope, unstable angina, a preoperative hemoglobin concentration lower than

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1053-0770/05/1905-0005$30.00/0

doi:10.1053/j.jvca.2005.04.017

11 g/dL, acute infection, tooth extraction within the last 3 days, and a time interval less than 5 days before the operation.

Autologous blood donation (ABD) was carried out on an outpatient basis in the German Heart Center Munich by an anesthesiologist experienced in blood donation and the respective surgical intervention. There was at least 1 session and a maximum of 3 sessions depending on diagnosis, gender, and available time before the operation. To use the capacity of the staff effectively, at least 4 patients donated blood in parallel when possible. Within each session, 6 to 8 mL/kg of whole blood were taken per patient and processed to 1 unit of packed red cells and 1 unit of fresh frozen plasma. The removed blood volume was simultaneously replaced by crystalloids

The maximum storage time of packed cells is 42 days. To avoid the transfusion of very old packed cells or to conflict with the expiration date, predonation was started not earlier than 35 days before the scheduled time of operation. Predonation was usually started 14 to 20 days before the scheduled operation date with a second donation 1 week before operation. The last session of ABD was carried out no later than 5 days before admission to the hospital for surgery.

Demographic and clinical data were documented prospectively according to a standardized database. The preoperative cardiovascular state of patients was assessed according to the New York Heart Association (NYHA) classification. Additionally, the preoperative risk was evaluated with the Cleveland Clinic risk score.[21] Perioperative transfusion was indicated if the hematocrit was less than 21% in female and less than 24 % in male patients or less than 18% during cardiopulmonary bypass. Intravenous anesthesia with sufentanil, midazolam, and pancuronium was used in all patients. The membrane oxygenator was primed with 1,800 mL of crystalloid solution. A high-dose aprotinin regimen (approximately 6 million KIU per patient) was part of the routine protocol. Blood loss was recorded at 6, 12, and 24 hours postoperatively.

A decision model was developed to estimate the number of autologous blood donations necessary to avoid the transfusion of 1 unit of allogeneic blood. Calculation basis was a decision tree. Software for decision tree analysis was Data 3.5 for Windows (Tree Age Software, Williamstown, MA). Decision-tree analysis was conducted for the whole population and for CABG and AVR patients and separately for male and female patients. Decision-tree analysis was not conducted separately for patients of the other diagnosis groups because these groups were too small for sufficient analysis with the underlying decision tree model. Patients who were classified NYHA IV or had a Cleveland Clinic risk score >11 were excluded because most of them were not eligible for ABD. To avoid selection bias, patients were stratified according to their preoperative risk calculated by the Cleveland Clinic risk score.[21]

Costs were calculated from the hospital perspective. Acquisition costs for allogeneic blood units and laboratory material were obtained from the hospital price lists, while costs for staff, investments, and maintenance were obtained from the hospital departments. Because the discarding of autologous units donated but not transfused recently proved to be a main cost driver in autologous blood donation,[5,22] the costs of predonated autologous units were taken into account regardless of whether transfused or not. Furthermore, the cost for the predonation of one autologous unit always included 1 autologous fresh frozen plasma. For every patient not undergoing ABD, 2 units of allogeneic blood were procured before surgery. The resulting costs of procurement were taken into account regardless of an actual transfusion because the costs of allocation were incurred anyway.

A sensitivity analysis was conducted to evaluate whether plausible changes in the value of the main variables affected the results of the analysis. Because a wide variation of acquisition costs for allogeneic blood and operating costs for ABD (eg, staff costs dependent on the number of patients predonating simultaneously per day) can occur, a range of ±20% of the costs for allogeneic and autologous blood was taken to test the robustness of the results.

Statistical analysis was carried out with StatView for Windows (Abacus Concepts, Inc, Berkeley, CA, 1996). Groups were compared using the unpaired Student t test for continuous variables or Mann-Whitney U test, if appropriate. The chi-square test was used to analyze discrete variables. Data are presented as mean ± standard deviation. A p value of less than 0.05 was considered significant.

RESULTS

Analysis was based on a total of 4,325 patients, including 2,742 CABG, 60 combined procedures, 717 AVR, 369 MVR, 82 DVR, 94 ASD, and 261 patients undergoing other procedures. Out of the 4,878 originally documented patients, 13 were excluded from decision-tree analysis because of invalid data sets and 540 patients because they were classified NYHA IV or had a preoperative Cleveland Clinic risk score >11. Only six of the patients classified NYHA IV underwent autologous blood donation. Patient characteristics and clinical data are shown in Table 1.

The proportion of patients participating in the ABD program was 20% (849/4,325) in the entire study population, 16% (437/2,742) in the CABG group, and 26% (184/717) in the AVR group. No adverse events because of blood donation were observed. Thirteen percent of patients undergoing ABD received allogeneic blood during their hospital stay, whereas 48% of the patients without predonation received allogeneic transfusion (CABG, 15% v 46 %; AVR, 12% v 50%, $p < 0.05$ each) (Fig 1). Patients without predonation received 1.68 ± 3.35 (mean ± SD) allogeneic packed cell units, whereas patients in the autologous group got 0.42 ± 1.76 units ($p < 0.05$) (CABG patients, 1.53 ± 2.88 v 0.50 ± 1.88; AVR patients, 1.45 ± 2.32 v 0.25 ± 0.80 U, respectively; all $p < 0.05$) (Fig 2). Patients with predonation received a higher total number of any transfusion (autologous and allogeneic) compared with patients without predonation (2.38 v 1.68 U, $p < 0.05$). This difference was statistically significant only for male patients but not for female patients (Table 2). In the ASD closure group, 57% of patients underwent ABD, none of them receiving allogeneic blood.

The preoperative hemoglobin concentration was significantly lower in patients with predonation, yet still within the physiologic range. However, hemoglobin concentration at discharge from the intensive care unit was significantly higher in these patients. Twenty-nine percent of the autologous packed cells were not transfused and discarded. The discard rate was higher in male (32%) compared with female patients (19%) ($p < 0.05$). After stratification of patients according to the Cleveland Clinic risk score, differences in transfusion events still were significant (Fig 1). Transfusion-related data stratified for male and female patients are shown in Table 2.

Data from the decision-tree model are depicted in Figure 2 and Table 3. Generally, the probability of patients with predonation to receive allogeneic blood decreased with an increasing number of predonated autologous blood units. However, the additional reduction in donor exposure rate decreased with an increasing number of predonated autologous units.

Female patients, regardless of whether undergoing ABD or not, were transfused more frequently and to a higher extent

Table 1. Demographic and Clinical Data

	All Patients		CABG		AVR		ASD	
	ABD	NABD	ABD	NABD	ABD	NABD	ABD	NABD
Number of patients (%)	849 (20)	3476 (80)	437 (16)	2305 (84)	184 (26)	533 (74)	54 (57)	40 (43)
Female/male (%)	27/73	33/67	14/86	25/75	32/68	42/58	28/26	27/13
Age (y)	59 ± 13*	64 ± 12	63 ± 8*	66 ± 10	57 ± 13*	66 ± 13	42 ± 14	42 ± 18
Weight, female (kg)	66 ± 10	66 ± 12	69 ± 11	68 ± 11	67 ± 11	65 ± 11	65 ± 9	61 ± 9
Weight, male (kg)	82 ± 11*	79 ± 12	82 ± 11*	80 ± 12	83 ± 11*	78 ± 11	79 ± 11	79 ± 21
Previous heart surgery (%)	10	11	6	6	9	14	6	5
ECC (min)	96 ± 40*	101 ± 53	96 ± 41	98 ± 53	92 ± 23	94 ± 29	59 ± 30	49 ± 27
Hb preop, male (g/dL)	133 ± 12*	140 ± 17	132 ± 11*	141 ± 15	133 ± 10*	139 ± 19	144 ± 11	140 ± 20
Hb discharge ICU, male (g/dL)	117 ± 13*	111 ± 13	116 ± 13*	111 ± 13	121 ± 14*	112 ± 13	132 ± 41*	112 ± 14
Hb preop, female (g/dL)	122 ± 13*	129 ± 16	121 ± 9*	129 ± 14	120 ± 11*	128 ± 15	127 ± 12*	137 ± 10
Hb discharge ICU, female (g/dL)	113 ± 12*	110 ± 13	112 ± 10	110 ± 13	115 ± 12	111 ± 14	111 ± 10	114 ± 12
Total blood loss, male (mL)	772 ± 536	802 ± 636	802 ± 470	799 ± 568	687 ± 579	659 ± 556	564 ± 299	404 ± 264
Total blood loss, female (mL)	559 ± 508	632 ± 474	713 ± 741	676 ± 437	416 ± 271	501 ± 419	424 ± 332	595 ± 669

NOTE. Only patients classified NYHA I to NYHA III and/or Cleveland Clinic risk score <11 are taken into consideration. If not otherwise depicted, values are given in mean ± SD. After risk adjustment according to the Cleveland Clinic risk score the differences in weight and ECC time were no longer statistically significant.

Abbreviations: ABD, autologous blood donation; NABD, no autologous blood donation; Hb, hemoglobin concentration; ECC, extracorporeal circulation.

*$p < 0.05$.

compared with male patients (Table 2). Accordingly, the residual probability of receiving allogeneic blood could not be reduced to the same degree in female compared with male patients. Because of the lower discard rate (ie, the lower number of unnecessarily predonated units), costs for female patients predonating 2 units were equal or even lower than for female patients without predonation.

The cost structure of autologous and allogeneic blood is

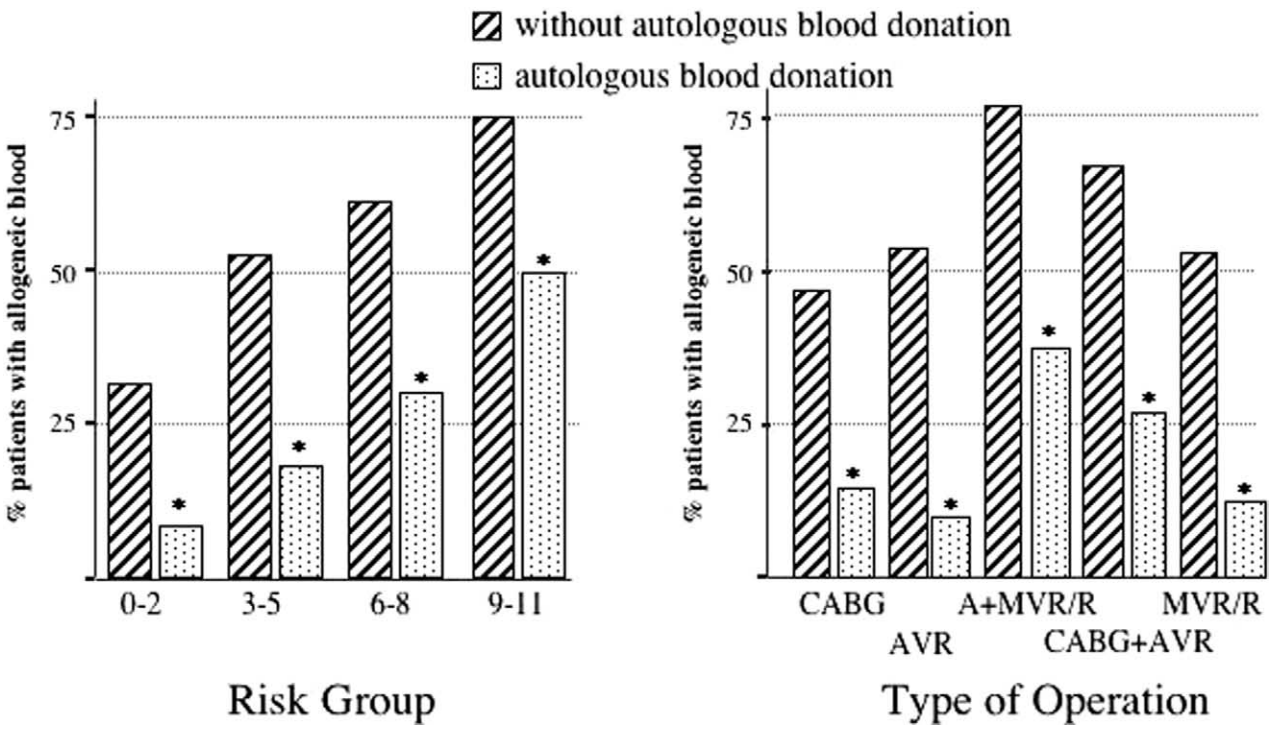

Fig 1. The left panel shows the percentage of patients receiving allogeneic blood stratified according to their preoperative Cleveland Clinic risk score. Patients with a risk score >11 are excluded from this figure because these were all high-risk patients. The right panel shows the percentage of patients receiving allogeneic blood according to the type of operation. The differences between patients with and without predonation were statistically significant at all points. MVR/R, mitral valve repair/replacement.

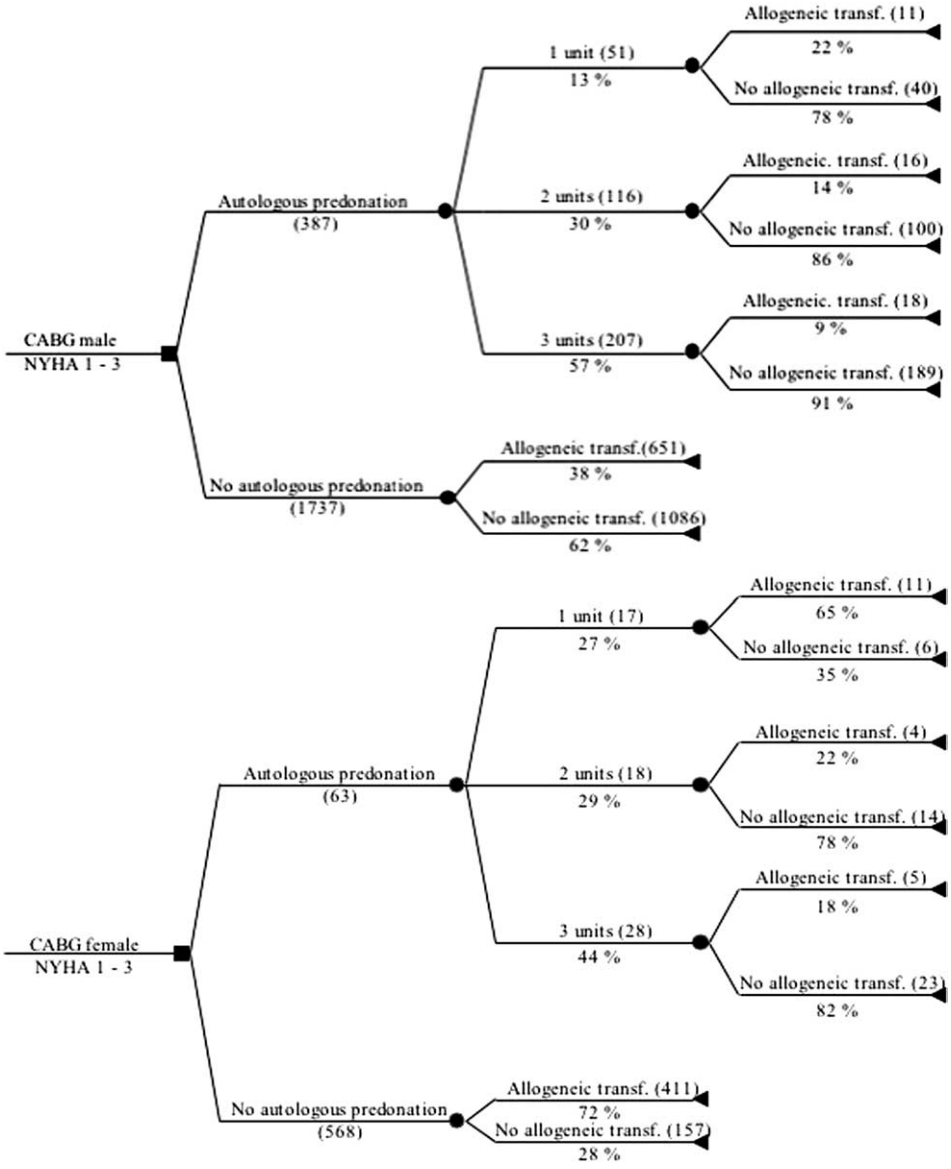

Fig 2. Two examples of the decision-tree analysis. The top panel shows the allocation of male CABG patients to the predonation and nonpredonation group and depicts the percentage of patients with allogeneic transfusion (%) according to the number of predonated autologous units. The bottom panel gives the same information for female patients.

shown in Tables 4 and 5. The personnel costs were calculated under the assumption of 6 patients per predonation session using 4 donation chairs simultaneously. In this model, the physician's working time for 6 donations is 90 minutes, and the total personnel cost per autologous unit amounts to $31. Costs for the procuring of 2 allogeneic units, even if not transfused, amount to $29.

Sensitivity analysis did not alter the results in a substantial way (Table 6). However, taking into account another 20% cost reduction for 1 autologous unit, transfusion costs for a male patient predonating 2 autologous units converged toward those for a male patient without predonation ($159 for autologous predonation *v* $158 for no predonation).

DISCUSSION

This study shows that the predonation of autologous blood is an effective practice in order to reduce allogeneic blood transfusion with an acceptable cost in cardiac surgery. The decision model shows that the predonation of 2 autologous units before CABG or AVR surgery keeps the best balance between the reduction of the risk probability of receiving allogeneic transfusion and associated costs, whereas the predonation of 3 units increases the respective expenses substantially (Fig 2). The reduction of allogeneic donor exposure from 48% to 13% in the entire study population was similar or even superior compared with other blood conservation strategies. For example, the preoperative administration of recombinant erythropoietin did not influence the residual probability of receiving allogeneic blood in cardiac surgery,[23] or reduced it from 67% to 11%, depending on population, blood loss, and the respective study protocol.[24] Acute normovolemic hemodilution seems to be only effective with high initial hematocrit, low target hematocrit after acute normovolemic hemodilution, and high surgical blood loss.[25] Pharmacologic methods of blood conservation

Table 2. Transfusion-Related Data Separated by Type of Operation and Gender

			Allogeneic (%)	Allogeneic (Units)	Total (Units)
All patients	Female	ABD (27%)	21	0.57 ± 1.98*	2.55 ± 2.16
		NABD (33%)	68	2.30 ± 3.30	2.30 ± 3.30
	Male	ABD (73%)	10	0.36 ± 1.67*	2.31 ± 1.95*
		NABD (67%)	38	1.38 ± 3.33	1.38 ± 3.33
CABG	Female	ABD (14%)	31	0.98 ± 2.40*	2.98 ± 2.41
		NABD (25%)	72	2.41 ± 3.20	2.41 ± 3.20
	Male	ABD (86%)	12	0.41 ± 1.77*	2.44 ± 1.99*
		NABD (75%)	37	1.25 ± 2.70	1.25 ± 2.70
AVR	Female	ABD (32%)	20	0.34 ± 0.78*	2.41 ± 1.10
		NABD (42%)	71	1.93 ± 2.27	1.93 ± 2.27
	Male	ABD (68%)	8	0.21 ± 0.81*	2.09 ± 1.32*
		NABD (58%)	35	1.10 ± 2.29	1.10 ± 2.29

NOTE. The percentage of male and female patients within the groups with and without predonation is presented.

Abbreviations: Allogeneic (%), percentage of patients receiving allogeneic transfusion; Allogeneic (units), number of allogeneic units transfused; Total, allogeneic and autologous blood transfused; ABD, autologous blood donation; NABD, no autologous blood donation.

*$p < 0.05$, patients with predonation versus patients without predonation.

such as high-dose aprotinin also reduce blood requirement by approximately 50%,[26] showing good cost-effectiveness.[27] In contrast to the CABG and AVR groups, predonation in patients undergoing ASD closure, which is a simple procedure almost never requiring allogeneic blood transfusion, turned out to be costly and without relevant blood savings in the present study. Therefore, it is concluded, that predonation of autologous blood is neither medically nor economically indicated in ASD closure procedures. Based on the present data, the authors eliminated predonation for ASD closure almost totally in this institution.

Costs were calculated from the hospital perspective considering hospital purchase prices. The costs for 1 autologous unit ($80) in this study amounted to 77% of that for 1 allogeneic unit ($103). The lower costs of 1 autologous unit are the result of low collection costs resulting from predonation at the same institution where surgery takes place. In a department specializing in autologous predonation personnel costs can be cut dramatically by simultaneous donation of several patients. The amount of $80 agrees closely with studies also performing ABD and surgery at the same institution.[22] In contrast, cost studies calculating very high cost-effectiveness values for autologous predonation were based on autologous unit costs 30% above the per unit costs for allogeneic blood.[5,6] The purchase of autologous blood from a commercial donor center is more expensive compared with a predonation department within the hospital. Personnel costs are the pivotal point for cost calculation of autologous predonation; the more effective the working time is used, the lower the costs of 1 autologous unit. The authors based the cost calculation on 6 patients per predonation session and 4 patients predonating simultaneously on 4 chairs. One physician can perform this work within 1 or 1.5 hours. This organization renders the program cost-effective.

Table 3. Results of the Decision-Tree Analysis

	Patients (n)	Allogeneic Blood (%)	Units (Mean)	Cost (USD)
Male				
ABD, 1 unit	78	18	1.6	170
ABD, 2 units	206	11	1.9	191
ABD, 3 units	337	8	2.8	276
NABD	2,341	38	1.4	158
Female				
ABD, 1 unit	49	35	2.3	145
ABD, 2 units	78	22	2.5	212
ABD, 3 units	101	13	3.1	303
NABD	1,135	68	2.3	244

Abbreviations: ABD, autologous blood donation; NABD, patients without predonation; Allogeneic Blood (%), percent of patients with allogeneic blood transfusion; Units, total blood volume transfused (autologous and allogeneic); Costs, transfusion-related costs for 1 patient of the respective group; USD, US dollars.

Table 4. Cost Structure of 1 Autologous Blood Unit

	Cost (USD)
Variable costs	
Blood bag	13
Serologic material	12
Other materials	5
Preparation blood bank	5
Infusion	3
Fixed costs	
Investments	10
Repairs/maintenance/rate of interest	1
Staff costs	
Physicians	12
Nurses	13
Secretary	6
Total costs for 1 autologous PRC/FFP	80

NOTE. Other materials include syringes, swabs, and others. Investments include among others the costs of 4 donation chairs, a centrifuge, and a refrigerator and are calculated to amount to $60,000. An amortization per 10 years is used. Costs for repairs, maintenance, and rate of interest are calculated with 13% of investments. Working time of physicians, nurses, and secretary is estimated at 15, 30, and 15 minutes per patient, respectively, under the assumption of 6 predonations per day.

Abbreviations: PRC, packed red cells, FFP, fresh frozen plasma; USD, US dollars.

Table 5. Cost Structure of 1 Allogeneic Blood Unit

	Cost (USD)
Variable costs	
Price of 1 unit PRC	69
Cross-matching	0.5
Screening for antibodies	2
Transfusion set/bedside test card	2
Other materials	1
Transport costs	1
Additional charges for nights/holidays	2
Fixed costs	
Investments	2
Repair/maintenance/rate of interest	0.20
Staff costs	
Blood bank/MTA	23
Total costs	103

NOTE. Other materials include syringes, swabs, and others. Investments are calculated to amount to $188,000. An amortization per 10 years is used. Costs for repair, maintenance, and rate of interest are calculated with 13% of investments. Personnel costs are estimated on the basis of a total working time of 60 minutes total per unit.

Abbreviations: PRC, packed red cells; MTA, medical technical assistant; USD, US dollars.

Discarding unnecessarily predonated units increases the cost of autologous predonation. The discard rate of 32% in male and 19% in female patients appears fairly high at first sight. However, the respective control group without predonation had a transfusion rate of roughly 50%. Therefore, the discard rate is within the expected range.

In accordance with other studies, autologous predonation patients received a higher number of any transfusion (autologous and allogeneic) than patients without predonation, supporting previous findings that autologous blood donors are more likely than nondonors to receive any transfusion.[1,28] Despite the fact that predonating patients had a lower preoperative hematocrit compared with controls, their hematocrit at discharge was found to be higher compared with controls. This fact must be interpreted as "overtransfusion" or a more liberal transfusion indication for autologous compared with allogeneic units. However, a more restrictive transfusion regimen alone would not alter cost estimates in this model because expenses of predonated autologous units were taken into account regardless of whether transfused or not.

A further reduction of the costs for 1 autologous unit of 20% or a 20% increase of the per unit costs for allogeneic blood would almost equalize the costs of a male ABD patient predonating 2 units to the costs of a male patient without predonation. Whereas a further reduction of the costs for 1 autologous unit would only be practicable by a high turnover of patients reducing per unit staff and fixed expenses, an increase in the costs for 1 allogeneic unit of 10% to 20% by the implementation of a new testing or inactivation strategy is quite realistic.[20]

The numbers of predonated autologous units necessary to avoid 1 allogeneic unit were chosen as an endpoint in order to express the potential of autologous predonation to save allogeneic blood. Overall, the donation of 1.5 autologous units saved 1 allogeneic unit for additional expenses of $19. At the same time, the residual risk of receiving allogeneic blood is reduced from 48% to 13%. This suggests a good relationship between traceable costs and clinical benefit. This relationship is especially pronounced in female predonating patients who actually saved money compared with controls. This finding is mainly because of the high transfusion rate in female patients, leading to a low discard rate and indicated that autologous predonation is more effective in operations with a higher transfusion probability. On the other hand, in male patients with an overall transfusion rate less than 50%, the discard rate of autologous units is higher. Derived from the decision analysis, the authors usually take only 2 units of autologous blood from male patients, whereas an attempt is made to get 3 units from female patients for most operations, when permitted by the preoperative schedule. However, higher per patient costs of up to $51 (CABG male) still seem economically reasonable if compared with other blood-conservation strategies like intraoperative salvage with expenses of about $300 per patient[29] or preoper-

Table 6. Sensitivity Analysis

	Entire Study Population Costs	Allog. −20%	Allog. +20%	Autol. −20%	Autol. +20%	CABG Costs	Allog. −20%	Allog. +20%	Autol. −20%	Autol. +20%	AVR Costs	Allog. −20%	Allog. +20%	Autol. −20%	Autol. +20%
Male															
ABD, 1 unit	170	138	166	137	169	164	146	179	146	179	132	121	142	116	148
ABD, 2 units	191	185	197	159	224	197	190	205	165	230	181	177	184	148	213
ABD, 3 units	276	269	283	228	325	277	270	284	228	325	263	259	267	214	311
NABD	158	131	187	158	158	148	119	171	148	148	131	108	153	131	131
Female															
ABD, 1 unit	145	132	158	129	161	220	191	246	202	235	93	91	96	77	109
ABD, 2 units	212	202	223	180	245	251	234	270	220	284	283	258	307	250	315
ABD, 3 units	303	290	315	254	351	329	312	347	281	378	266	262	271	218	315
NABD	244	197	290	244	244	255	204	302	255	255	205	165	244	205	205

NOTE. Sensitivity analysis of the transfusion-related costs as given in Table 3.

Abbreviations: Costs, transfusion costs in US dollars for 1 patient of the respective group as derived from decision-tree analysis without variation of price; Allog., 1-way sensitivity analysis resulting from a 20% variation of the costs for an allogeneic unit; Autol., 1-way sensitivity analysis resulting from a 20% variation of the costs for an autologous unit.

ative treatment with erythropoietin costing more than $1,000 per patient.[30]

This study is subject to several limitations. First, the data of the cost calculations are only applicable for the given organization in this department and cost structure of this country. Furthermore, because the authors applied the cost structure during the study period, the costs calculated are low compared with the current costs of transfusion. Because of new technology, the costs of allogeneic and autologous blood increased considerably during recent years.[20] Goodnough et al[20] calculated only the testing costs at between $40 and $50 per blood donation. However, the present study intended to give an impression of the cost relationship rather than to provide the current costs.

Second, patients undergoing ABD were younger, more likely to be male, and in favorable NYHA status as compared with patients without predonation. Therefore, patients with autologous predonation may have been less likely to receive allogeneic transfusion, contributing to lower per patient transfusion costs. To compensate for this potential selection bias, the patients were stratified for their preoperative risk. As shown in Figure 1, the difference in transfusion requirement was statistically different regardless of the risk groups.

Third, this study covers a period of 5 years. Within this period, patient population, risk stratification of patients, surgical techniques, waiting time before operation, and transfusion medicine changed.[31-33] At the present time, cardiac surgical patients have a higher risk profile and the transfusion trigger may be more restrictive. On the other hand, with many years of experience, the indication for ABD has expanded. Therefore, the present study gives a reliable overview over the clinical practice of autologous blood donation. A shorter observation period would not allow the collection of a sufficient number of patients.

In conclusion, the higher the probability of transfusion the better efficacy and cost-effectiveness of autologous predonation. Because cardiac surgery still remains a high-transfusion area,[34,35] it offers ideal conditions for autologous blood donation. The fact that compared with other blood conservation strategies, lower costs are generated for saving 1 allogeneic unit shows that ABD remains a promising and cost-effective alternative in the attempt to reduce allogeneic blood transfusion in elective cardiac surgery.

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