Lowering the hemoglobin threshold for transfusion in coronary artery bypass procedures: effect on patient outcome

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BACKGROUND: There is controversy regarding the application of transfusion triggers in cardiac surgery. The goal of this study was to determine if lowering the hemoglobin threshold for red cell (RBC) transfusion to 8 g per dL after coronary artery bypass graft surgery would reduce blood use without adversely affecting patient outcome.

STUDY DESIGN AND METHODS: Consecutive patients (n = 428) undergoing elective primary coronary artery bypass graft surgery were randomly assigned to two groups: study patients (n = 212) received RBC transfusions in the postoperative period if the Hb level was <8 g per dL or if predetermined clinical conditions required RBC support, and control patients (n = 216) were treated according to individual physician's orders (hemoglobin levels <9 g/dL as the institutional guideline). Multiple demographic, procedure-related, transfusion, laboratory, and outcome data were analyzed. Questionnaires were administered for patient self-assessment of fatigue and anemia.

RESULTS: Preoperative and operative clinical characteristics, as well as the intraoperative transfusion rate, were similar for both groups. There was a significant difference between the postoperative RBC transfusion rates in study (0.9 ± 1.5 RBC units) and control (1.4 ± 1.8 RBC units) groups (p = 0.005). There was no difference in clinical outcome, including morbidity and mortality rates, in the two groups; group scores for self-assessment of fatigue and anemia were also similar.

CONCLUSIONS: A lower Hb threshold of 8 g per dL does not adversely affect patient outcome. Moreover, RBC resources can be saved without increased risk to the patient.

Blood for cardiovascular surgery patients accounts for 50 percent of the blood transfused at our institution. Studies of blood use in coronary artery bypass grafting (CABG) procedures indicate that as much as 10 percent of national red cell (RBC) resources may be used for support of these patients.[1] The mean number of units transfused in CABG surgery varies with the institution, ranging from 0.4 to 6.3 units per patient in uncomplicated CABG operations.[1-4]

In a recent analysis, Surgenor et al.[4] reported that institutional transfusion practices contribute significantly to the variation in RBC transfusion decisions in CABG patients. Most transfusion guidelines are based on limited, if any, controlled data.[5-9] The clinical decision for transfusion is often based on hemoglobin (Hb) or hematocrit levels.[10-12] Patients undergoing cardiopulmonary bypass (CPB) are administered intermittent volume expansion, which renders the measured Hb content a relatively inaccurate reflection of RBC mass. Other proposed methods for indicating Hb deficits include the use of an oxygen extraction ratio or blood levels of lactate or other chemical markers.[13-16] However, these measures are invasive and costly, making widespread application unlikely. Thus, measurement of the Hb content

ABBREVIATIONS: CABG = coronary artery bypass grafting; CPB = cardiopulmonary bypass; FACT-An = FACT-Anemia; FACT-F = Functional Assessment of Cancer Therapy-Fatigue; Hb = hemoglobin; ICU = intensive care unit; RBC(s) = red cell(s); THI = Texas Heart Institute.

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of peripheral blood is the most commonly used determinant in evaluating CABG patients for RBC transfusions.

The level of Hb that most accurately predicts the need for RBC transfusion has been debated. The National Institutes of Health Consensus Conference on RBC transfusion requirements disputed the standard perioperative Hb threshold of 10 g per dL.[7] Recent RBC transfusion guidelines from the American College of Anesthesiologists[6] and the College of American Pathologists[9] allow physicians to consider RBC transfusion over a broad range of Hb levels: 6 to 10 g per dL. In a recent study, Weiskopf et al.[17] reported that patients with normal coronary artery anatomy could tolerate acute normovolemic anemia as low as 5 g per dL.

Previous reports have primarily defined the incidence and factors that influence the RBC transfusion rate in CABG surgery.[18,19] Few reports, however, have described the effect of interventions intended to reduce blood use.[20-23] Furthermore, few data are available on outcome when a lower Hb threshold is used for CABG patients. Therefore, the objective of this study was to determine if the use of a lower Hb transfusion threshold could reduce blood use without adversely affecting patient outcome.

MATERIALS AND METHODS

Patients

We enrolled 428 consecutive patients who underwent first-time, elective CABG surgery at the Texas Heart Institute (THI) between February 4, 1997, and November 15, 1997. Patients were randomly assigned to study and control groups on the basis of the last digit of their medical record number. The study group comprised 212 patients who received an RBC transfusion in the postoperative period at a Hb level less than 8 g per dL, unless the patient experienced blood loss >750 mL since the last transfusion, hypovolemia with hemodynamic instability and excessive acute blood loss, acute respiratory failure or inadequate cardiac output and oxygenation, or hemodynamic instability requiring the use of vasopressors. The control group comprised 216 patients who received transfusions on the instructions of their individual physicians, who considered the clinical assessment of the patient and the institutional guidelines, which propose a Hb level <9 g per dL as the postoperative threshold for RBC transfusion.

Patient exclusion criteria included a preoperative Hb level <12 g per dL, history of bleeding diathesis, use of an intraaortic balloon pump, blood loss >2500 mL within 24 hours of operation, and the patient's refusal of blood transfusion for religious reasons.

We analyzed the following patient variables: age; body weight; sex; preoperative exposure to sodium warfarin, heparin, aspirin, or ticlopidine; and preoperative, operative, and postoperative (Days 1-5 and last day before discharge) Hb levels. In addition, we monitored prothrombin time, activated partial thromboplastin time, platelet count, and creatinine levels. Procedure-related variables included the duration of CPB, the number and type of grafts, the lowest core temperature during CPB and the postoperative body temperature upon arrival in the intensive care unit (ICU), estimates of intraoperative blood loss, the volume of chest-tube blood shed after surgery, the volume of returned blood collected in the cell processor during surgery, and the volume of mediastinal shed blood collected in the postoperative period.

Surgical procedure

CABG was performed according to the standard THI technique.[24] Each patient was systemically cooled by means of CPB with moderate hypothermia (28°C), and the heart was arrested with cold blood or crystalloid cardioplegic solution. A membrane oxygenator was used in the CPB circuit, and the heart-lung machine was primed with electrolyte solution. RBCs were added to the pump only if the patient's Hb level was inadequate (<6 g/dL at 30°C). Anesthesia was maintained with thiopental and fentanyl, and pancuronium bromide was used for muscle relaxation and heparin (3 mg/kg) for anticoagulation. At the end of the procedure, protamine sulfate (1.5 mg/100 units of heparin) was administered intravenously to neutralize the heparin. Blood from the bypass circuit was returned to all patients upon completion of the operation.

Outcome measures

We collected data on the location, timing, and volume of blood transfusion; the incidence of RBC transfusions; the mean number of RBC units per patient; and the mean number of RBC units per transfused patient. The outcome measures we analyzed were transfusion incidence, duration of mechanical ventilation, length of stay in the ICU, length of postoperative hospital stay, THI morbidity and mortality data, and patient self-assessment of fatigue and anemia (administered on postoperative Days 3 and 5).

Morbidity data. We analyzed morbidity data from the THI database. We included in our analysis the postoperative occurrence of atrial (supraventricular tachycardia, atrial tachycardia, or atrial fibrillation) or ventricular (premature ventricular contractions, ventricular tachycardia, or ventricular fibrillation) arrhythmias; myocardial infarction; a neurologic event such as a cerebrovascular attack, transient ischemic attack, or paralysis; pulmonary complications, including pneumothorax, pneumonia or tracheobronchitis, pulmonary edema, purulent sputum, O_2 dependence after ICU discharge, and delayed chest tube removal (>48 hours after surgery); renal complications, including renal failure or a creatinine level >2.5 mg per dL (urine output <400 mL in a 24-hour period and/or institution of renal dialysis or ultrafiltration); and serious infections such as culture-proven pneumonia, mediastinitis, wound infection, or septicemia.

Mortality data. Mortality was defined as death during the hospitalization for surgery. These patients were excluded from transfusion analysis because early death precludes observation of transfusion and morbidity rate.

Postoperative health survey questionnaire. We used two instruments, the Functional Assessment of Cancer Therapy-Fatigue (FACT-F) and the Functional Assessment of Cancer Therapy-Anemia (FACT-An), for patient self-assessment of fatigue and anemia. The FACT-F comprises 13 Likert-scaled fatigue items, and the FACT-An comprises 7 nonfatigue items related to anemia. Combined, the questionnaires yield a 20-item scale and a score range of 0 to 60. A high score indicates increased fatigue. Both scales were intended for use with the general version (FACT-G) of the questionnaire. In this study, the FACT-F and FACT-An scales were used without the 28-item general version of the questionnaire (FACT-G). The FACT-F scale has shown strong internal consistency (coefficient alpha range, 0.93-0.95) in cancer patients. The internal consistency of the FACT-An items is lower (alpha range, 0.59-0.70) but acceptable, considering the strong relationship to patient-reported performance status and Hb level. Convergent and discriminate validity testing revealed a positive relationship with other known measures of fatigue. Total scores of both scales differentiated patients by Hb level ($p<0.05$) and patient-reported performance status ($p<0.001$).[25]

Statistical analysis

Statistical evaluations were by protocol (i.e., considering all inclusion and exclusion criteria) and by the intention-to-treat principle, whereby all randomly assigned patients were used.

We used a software system (SAS Institute, Cary, NC) for statistical analyses. A two-tailed, unpaired *t* test was used to compare the mean values of the two groups and a paired *t* test was used to compare repeated measurements in each group. We used chi-square analysis (with Yates's correction for continuity) to compare the groups' discontinued data. If the expected number in any given cell was less than 5, however, Fisher's exact test was used. A comparison of Hb levels was done by using a repeated-measures ANOVA. Relationships between Hb levels and outcome measures were analyzed with a regression method. All tests were two-sided, and no adjustments for multiple comparisons were made. A p value <0.05 was considered significant. Values are presented as the mean ± SD.

RESULTS

Group characteristics

We found no significant differences between the demographics, preoperative status, procedure-related variables, or blood loss in the study and control groups (Table 1). The mean preoperative Hb level in both groups did not differ from data collected from primary CABG patients at our center. Most patients in our study were on a preoperative drug regimen that included aspirin.

Blood conservation

The blood-conservation technique, including return of blood from the bypass circuit, was similarly applied to both groups. From only three patients in each group was blood collected in a semi-automated cell processor for RBC conservation; a mean of 1000 ± 0 mL was returned in each case in the study group and a mean of 1133 ± 97 mL in the control group ($p = 0.774$). Mediastinal shed blood collected in the postoperative period was returned to 21 (10%) study patients (mean vol, 493 ± 235 mL) and 20 (9%) control patients (mean vol, 471 ± 279 mL).

RBC transfusion

The mean number of RBC units transfused per patient during hospitalization was lower in study patients than in control patients (Fig. 1). The transfusion rate in study patients was 2.0 ± 2.2 RBC units, and that in control patients was 2.5 ± 2.6 RBC units ($p = 0.04$); therefore, use of a Hb level of <8 g per dL as an indication for transfusion yielded a 20-percent reduction in RBC use. The total number of RBCs transfused was 426 units in the study group and 538 units in the control group, for a difference of 112 units, or 500 RBC units per 1000 CABG patients. The overall incidence of RBC transfusion was 60 percent in study patients and 64 percent in control patients ($p = 0.312$).

TABLE 1. Intergroup comparisons of patient- and procedure-related variables

Variable	Study group (n = 212)	Control group (n = 216)
Age (years)	61±11	62±11
Body weight (kg)	86±16	84±16
Sex (male/female) (%)	82/18	83/17
Preoperative drug exposure (%)		
Aspirin	71	68
Sodium warfarin	2	2
Heparin	17	16
Ticlopidine	5	5
Preoperative laboratory values		
Hb (g/dL)	14.2 ± 1.2	14.3 ± 1.2
Hematocrit (%)	41.7 ± 3.7	41.9 ± 3.6
Prothrombin time (sec)	11.8 ± 0.7	11.8 ± 0.7
Platelet count (1000/mm^3)	218 ± 59	211 ± 53
Creatinine level (mg/dL)	1.06 ± 0.24	1.03 ± 0.26
Intraoperative data		
Number of grafts per patient	3.4 ± 0.9	3.4 ± 0.9
Patients with IMA* grafts (%)	93	96
Time on CPB (min)	59 ± 26	60 ± 26
Crossclamp time (min)	35 ± 18	36 ± 17
Estimated blood loss (mL)	1116 ± 571	1123 ± 540
Postoperative blood loss† (mL)	1098 ± 553	1158 ± 563

* Internal mammary artery.
† Chest-tube blood shed.

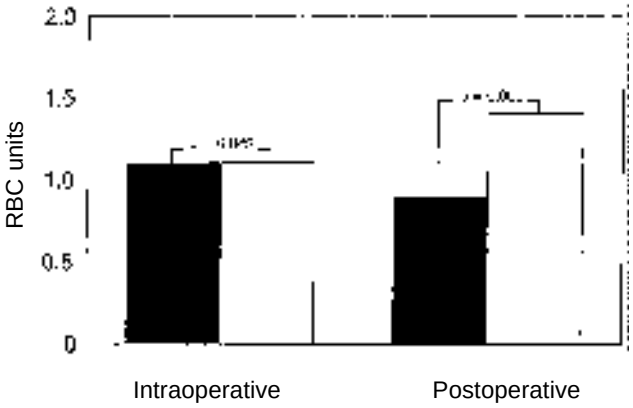

Fig. 1. The RBC transfusion rate (units/patient). Although the intraoperative transfusion rate was similar (p = 0.842), the significant effect of a lower Hb transfusion threshold on blood utilization was demonstrated during the postoperative period (p = 0.005) and affected the overall transfusion rate (p = 0.04). , Study patients; , Control patients.

Analysis of RBC transfusion by hospital site showed that the mean number of RBC units transfused in the operating room was similar: 1.1 ± 1.5 units in the study group and 1.1 ± 1.7 units in the control group. However, in the study patients the number of RBC units transfused in the postoperative period was significantly reduced; the mean number of RBC units transfused postoperatively was 0.9 ± 1.5 in the study group and 1.4 ± 1.8 in the control group (p = 0.005). Although the intraoperative transfusion incidence was similar (41% in study patients vs. 40% in control patients), the postoperative transfusion incidence was significantly lower in study patients (35%) than in control patients (48%) (p = 0.005). The proportion of RBCs transfused intraoperatively in the study group was 55 percent (244/538), whereas control patients received intraoperatively 45 percent (233/426) of all RBCs used in the entire hospital stay (p = 0.004).

We found no evidence to indicate that the study regimen alone delayed the necessity of RBC transfusion. A minority of patients in both groups received an RBC transfusion after the first 24 hours after surgery: 21 percent in the study group and 22 percent in the control group. The number of RBC units transfused to the study patients after 24 hours represents 22 percent of RBC units transfused in the entire hospital stay, while in control patients, the number represents 20 percent. The mean number of RBCs administered after the first 24 hours was 0.44 ± 0.9 in the study group and 0.49 ± 1.1 in controls.

Relationship of Hb to RBC transfusion

We sorted patients by the lowest Hb levels. The postoperative Hb level never fell below 10 g per dL in 20 percent of all patients. Of the 38 patients in the study group with postoperative Hb >10 g per dL, none received RBCs, whereas 6 (14%) of 42 patients in the control group with Hb >10 g per dL received a transfusion. Furthermore, 46 percent of enrolled patients never had a postoperative Hb <9 g per dL. In this subgroup, 5 percent (5/98) of patients in the study group received RBCs, whereas 18 percent (18/98) of control patients underwent RBC transfusion (p = 0.004) (Fig. 2).

In the 71 study patients and the 78 control patients with a lowest postoperative Hb level between 8 and 9 g per dL, we found no significant differences in patient and procedure-related variables. However, the transfusion rates were significantly different: 38 percent of study patients received RBC transfusions versus 56 percent of control patients (p = 0.025) (Fig. 2). In this subset of patients, the mean number of RBC units transfused in the postoperative period was 0.8 ± 1.2 in study patients and 1.4 ± 1.4 in control patients (p = 0.01).

Most patients with a lowest Hb less than 8 g per dL in the postoperative period received transfusions (Fig. 2). All patients in the study (n = 10) and control (n = 12) groups with a Hb level less than 7 g per dL received a transfusion.

Effect of protocol on Hb content

Despite using a lower Hb threshold for transfusion, we found no significant differences in the lowest Hb level in the study and control groups during the preoperative or operative periods, upon ICU admission, on Days 1 to 5, or at discharge (Fig. 3). The mean net reduction in Hb from admission to discharge was 4.2 ± 1.7 g per dL in study patients and 4.2 ± 1.9 g per dL in control patients (p = 0.866).

In the subset of patients with lowest Hb levels of 8 to 9 g per dL during the entire postoperative period, patients in the study group (n = 71) had significantly lower Hb levels than control patients (n = 78) on postoperative Day 2 (9.4 ±

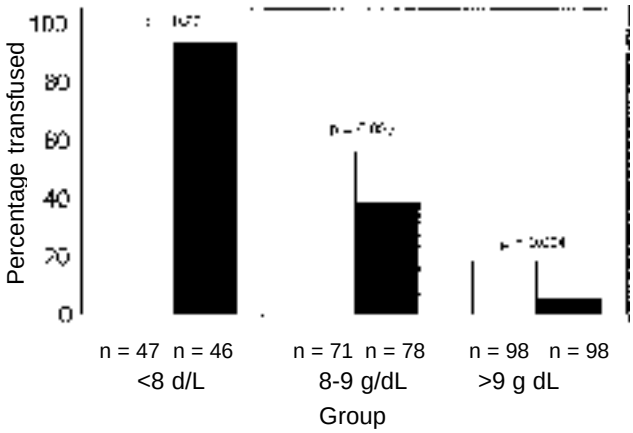

Fig. 2. Transfusion incidence in subgroups of patients by lowest Hb during the postoperative period. Significant differences between study ( ) and control ( ) patients were reached for subgroups with lowest Hb levels >8 g per dL.

0.9 vs. 9.9 ± 1.0; p = 0.019), on postoperative Day 5 (9.1 ± 0.9 vs. 9.7 ± 1.1; p = 0.022), and at the last Hb check before discharge (9.4 ± 0.9 vs. 9.7 ± 1.1; p = 0.033) (Fig. 4). Among these same patients, the mean net reduction in Hb from ICU admission to postoperative Day 5 was 1.8 ± 2.0 g per dL in study patients and 0.6 ± 2.2 g per dL in control patients (p = 0.03).

Patient outcome

Mechanical ventilation. The duration of mechanical ventilation did not differ significantly in study and control patients. However, in the subset of patients with lowest postoperative Hb levels of 8 to 9 g per dL, study patients spent significantly less time on mechanical ventilation than did control patients (8.6 ± 4.5 hours vs. 10.8 ± 5.1 hours, p = 0.008). In addition, we analyzed ventilation time in the subgroup of patients with a lowest Hb of 8 to 10 g per dL during the time from ICU admission to postoperative Day 1, which is the period when most patients were on mechanical ventilation; study patients (n = 65) were extubated more than 2 hours earlier than control patients (n = 62) (p = 0.006). Of the 65 study patients in this subgroup, 37 (57%) were extubated within 8 hours, as compared with 24 (39%) of the 62 control patients (p = 0.04). Preoperative and operative characteristics were similar for these two subgroups, except for the lower incidence of transfusions in the study subgroup during that period (42% vs. 69% in the control subgroup, p = 0.002).

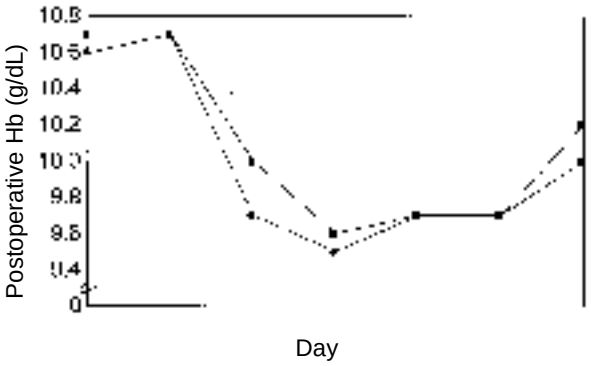

Fig. 3. Postoperative Hb levels for study (—□—) and control (—○—) patients. No significant differences were found between the two groups during the postoperative period.

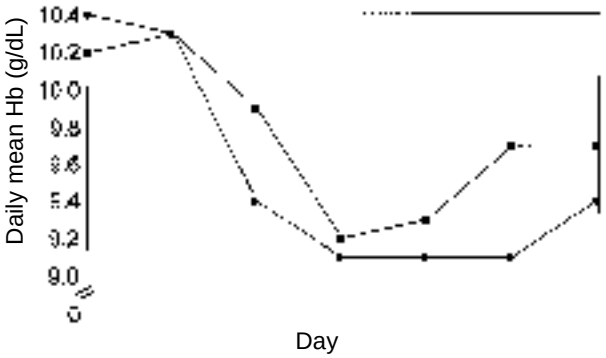

Fig. 4. The daily mean Hb levels in subgroups of patients with lowest postoperative Hb between 8 and 9 g per dL. Significant differences* were found for postoperative Days 2 (p = 0.019) and 5 (p = 0.022) and for the last measured Hb level before discharge (p = 0.033). Study patients, —□—; control patients, —○—.

Hospital stay. We found no significant differences between the two groups in the length of stay in the ICU. Moreover, the total number of days spent in the hospital after surgery was similar for the two groups: 7.5 ± 2.9 days for study patients and 7.9 ± 4.9 days for control patients.

Morbidity and mortality. No significant differences were noted between the two groups in any complication monitored in the study (Table 2). Regression analysis of the relationship between the incidence of complications and lowest Hb levels in all 428 patients showed no significant correlation. On univariate regression analysis, neurologic complications (p = 0.018) and atrial ($p \leq 0.0001$) and ventricular (p = 0.026) arrhythmias correlated with the patients' age. On multivariate regression analysis, age was the only significant predictor of postoperative complications (p = 0.014).

Analysis of all the enrollees, including patients excluded for transfusion assessment, showed that the mortality rate was similar for study and control patients. Death occurred in 3 (1.4%) of 215 study patients and 6 (2.7%) of the 222 control patients (p = 0.321). Review of these deaths show that none could be attributed to a reduction in transfusion trigger or to low Hb levels.

Postoperative health survey questionnaire. The FACT-F and FACT-An instruments were completed by 328 (90%) of 365 patients (155/175 study patients, 89%; and 173/190 control patients, 91%). The use of these questionnaires was discontinued late in the study, after statistical analysis. We found no significant differences in patient-related data, procedure characteristics, or Hb levels in study and control patients who completed the questionnaire. Patient self-as-

TABLE 2. Outcome measures in 212 study patients and 216 control patients

Complication	Study group	(%)	Control group	(%)
Atrial arrhythmia	30	(14)	40	(19)
Ventricular arrhythmia	13	(6)	9	(4)
Myocardial infarction	1	(0.5)	0	(0)
Neurologic deficit	11	(5)	9	(4)
Pulmonary complications	57	(27)	64	(30)
Renal failure	8	(4)	5	(2)
Infection	5	(2)	3	(1)

sessment scores were similar for both groups on postoperative Days 3 and 5.

When analyzed by Hb content, FACT-F and FACT-An scores were significantly different on postoperative Day 5, when patients with a Hb <9 g per dL were compared with patients with a Hb level >10 g per dL ($p = 0.004$). However, the same groups had similar survey scores on postoperative Day 3. Because the goal of our study was to maintain Hb content at >8 g per dL, we reanalyzed the subgroup and excluded patients with lowest Hb <8 g per dL. Then, survey scores did not differ significantly between low and high Hb groups (33.7 ± 13.9 in study patients vs. 29.6 ± 13.3 in control patients, $p = 0.073$).

DISCUSSION

In this study, by lowering the postoperative Hb threshold for RBC transfusion to 8 g per dL, we reduced RBC requirements by 20 percent. Moreover, lowering the threshold did not adversely affect patient outcome, as measured by traditional variables or by patient self-assessment. Although the reduction in RBC use does not seem dramatic, the net RBC savings, when applied to the large number of CABG surgeries performed at our facility, are substantial. We perform 1600 CABG procedures each year; therefore, the projected annual savings are 800 RBC units, which would reduce expenses by more than $150,000.

The potential for undertransfusing patients because of stringent transfusion practices is a growing concern for physicians interested in transfusion medicine.[26] In studies assessing new transfusion guidelines, showing only that surgical procedures can be done with fewer transfusions is not sufficient. Studies proposing reduced transfusion support should provide data indicating that patient outcome is not adversely affected by such restrictions. In our study, traditional outcome measures such as length of stay, duration of mechanical ventilation, and ICU stay were similar for patients receiving a restricted number of transfusions and for those receiving the standard number of transfusions.

A previous study showed that increased rates of postoperative transfusion may be correlated with late extubation.[27] We also noted a shorter duration of mechanical ventilation in a subset of study patients with the lowest postoperative Hb between 8 and 9 g per dL. Although this finding could relate to the fact that patients with a postoperative Hb between 8 and 9 g per dL were sicker, our data on patient comparability suggest that transfusion can be a major determinant of late extubation.

In our study, the mortality rate and the incidence of complications such as myocardial infarction, arrhythmias, and neurologic events were comparable to those reported in other studies.[27,31-35] We found no statistical correlation with morbidity and postoperative Hb levels or decreased transfusion rates. However, because such morbidity occurs infrequently in CABG surgery, a larger study would be necessary to achieve the higher analytic power needed for definitive assessment of these risks. In a large retrospective study of Hb effect on clinical outcome, Carson et al.[28] showed that outcome was independent of Hb content for patients with moderate anemia (Hb >8 g/dL). Our results indicated that age was the main factor associated with complications, which supports findings from previous studies.

Extreme anemia is a predictor of increased morbidity and mortality.[29,30] Fang et al.[29] reported that intraoperative Hct values less than 14 percent were associated with a threefold rise in mortality in CABG patients. Data obtained from patients who refused transfusions for religious reasons suggest that severe complications occur with an acute drop of Hb to less than 5 g per dL.[30] However, the effect of coronary atherosclerosis on the ability of these patients to tolerate anemia is unknown. Larger prospective studies are necessary to determine the degree of anemia that can be safely allowed in the postoperative period in patients at risk for coronary artery disease.

Caution is urged in applying these results to all patients undergoing CABG surgery. Our study group was restricted to low-risk patients without excessive bleeding, and the protocol was not designed to prompt a rigid response based solely on Hb level. Clinical judgment rather than strict adherence to a given Hb threshold is required for managing bleeding or unstable CABG patients. Patients undergoing CABG surgery require special consideration regarding the degree of allowable anemia, because compensatory tachycardia in response to decreased oxygen-carrying capacity may cause a critical increase in myocardial oxygen demand.[31]

In cardiac rehabilitation programs, surgical patients undergo rapid mobilization to reduce the risk of postoperative complications and to minimize the hospital stay. Many clinicians are concerned about the patient's ability to meet the energy demands associated with aggressive rehabilitation activities after restricted Hb support. Johnson et al.[20] found no difference in exercise endurance in liberally transfused CABG patients and those who had been conservatively managed. We applied a self-assessment tool to determine if patients on our restricted transfusion protocol (study patients) felt fatigued and therefore less willing to undergo rehabilitation. Our survey found no difference in vigor in the two groups.

The similarity of FACT-F and FACT-An scores for the groups in our study may be attributed to similarity in one outcome measure, lowest Hb, when the groups were compared as a whole. When we compared the survey scores in subgroups with blood Hb content <9 g per dL to those with Hb content >10 g per dL, we found the expected difference in response. However, when patients with very low Hb levels (<8 g/dL) were eliminated from analysis, the differences

in survey scores were eliminated. Patients with moderately low and average Hb levels appear unable to discern a difference in energy level during postoperative recovery. In a study of a more heterogeneous group of ICU patients, Babineau et al.[11] failed to find clinical differences between patients treated to maintain blood Hb at 10 g per dL and those treated to maintain Hb at 9 g per dL.

Our finding that Hb levels were only modestly affected, despite a significant reduction in RBC support, shows the inaccuracy of Hb levels as an indicator for RBC transfusion. Shifts in blood volume that accompany CABG surgery and other factors such as RBC regeneration may play a role in minimizing the intergroup differences. RBC regeneration, which would probably not affect early postoperative Hb levels, could be expected to ameliorate any late complications associated with restricted RBC transfusion. The patients most affected by the study protocol were those with Hb levels between 8 and 9 g per dL; these patients had significant reductions in Hb on postoperative Days 2 and 5 and at the last Hb check before discharge.

Despite its limitations in predicting blood need, the Hb level, when applied to appropriate groups of patients undergoing CABG surgery, could prevent unnecessary RBC transfusions. Our data indicate that transfusion requirements for cardiovascular and other surgical patients should be more extensively evaluated.

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