Original Article

Evaluation of Risk Scores in Predicting Perioperative Blood Transfusions in Adult Cardiac Surgery

Abstract

Objective: Allogeneic blood product transfusions are associated with an increased morbidity and mortality risk in cardiac surgery. At present, a few transfusion risk scores have been proposed for cardiac surgery patients. The present study is aimed to develop a new score and to compare with preexisting scores – Transfusion Risk and Clinical Knowledge (TRACK) and Transfusion Risk Understanding Scoring Tool (TRUST) score. **Methodology:** A total of 1014 adult patients undergoing cardiac surgery were enrolled in the retrospective study. Independent predictors of allogeneic blood transfusions were selected from TRACK and TRUST scores. A predictive score was developed from six variables using logistic regression analysis, and new score was compared to the other existing scores – TRACK and TRUST. **Results:** The new score had following predictors: age >58 years, weight <63 kg for males and <49 kg for females, gender (female), complex surgery, hemoglobin <13.5 g/dl, and creatinine >1.36 mg/dl. Validation of new score demonstrated an acceptable predictive power (area under the curve [AUC] 0.749) and a good calibration at the Hosmer–Lemeshow test. New score was comparable with TRACK score with $P = 0.578$ (AUC of TRACK 0.756 and AUC of new score 0.749). There was a significant difference between new score and TRUST score, $P = 0.01$ (AUC of TRUST 0.72 and AUC of new score 0.749). **Conclusion:** New score is a simple risk model based on six predictors having a similar accuracy and calibration in predicting the transfusion rate in cardiac surgery as compared to TRACK score.

Keywords: *Red blood cell transfusions, scoring system, coronary artery bypass grafting, cardiopulmonary bypass*

NR Madhu Krishna, PS Nagaraja, Naveen G Singh, SN Nanjappa, Karthik Narendra Kumar, V Prabhakar, N Manjunatha

Department of Cardiac Anaesthesiology, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bengaluru, Karnataka, India

Introduction

Bleeding in cardiac surgery is the most common manifestation leading to an increased risk of transfusion.[1] Cardiac surgical patients are more prone to bleeding due to the fact that they need continuous anticoagulation, and they are exposed to extracorporeal circuit, which activates the coagulation cascade. Furthermore, as the surgical procedure *per se* necessitates the manipulation of great vessels, inadvertent injury would risk these patients for a torrential bleed.

Literature review has shown that anemia in cardiac surgical patients is more prevalent than in general population and also a strong association with increased morbidity and mortality resulting in increased costs. The prevalence was 19% in women and 14% in men as per European audit. Due to the limited cardiac reserve, high incidence of bleeding, and hemodilution due to cardiopulmonary bypass (CPB), patients undergoing cardiac surgery are more susceptible to the consequences of perioperative anemia. Correcting perioperative anemia is of utmost importance in cardiac surgery as it is directly associated with oxygen supply and delivery; however, it is still debated to use hemoglobin (Hb) percentage as the transfusion trigger. Red blood cell (RBC) transfusion usage has to be tailored carefully since RBC transfusion is not without complications. It is independently associated with higher morbidity and mortality.[2]

Cardiac surgery has an estimated 20% of the total blood transfusions[2] of which 11% of the transfusions were utilized in patients undergoing coronary artery bypass grafting (CABG).

Transfusion risk in cardiac surgery is as high as 20%–60% and at times can reach up to 80% depending on the institutional practices. Transfusion volume as low as

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Address for correspondence: *Dr. Naveen G Singh, Department of Cardiac Anaesthesia, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bengaluru - 560 069, Karnataka, India. E-mail: naveengsingh@hotmail.com*

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one unit has also been shown to impact the morbidity and mortality.[3]

Allogeneic blood transfusion is known to cause multiple adverse effects which can be broadly classified as hemolytic and nonhemolytic. In cardiac surgery, it is found to cause increase in postoperative ventilator hours, sepsis, acute respiratory distress syndrome (ARDS), postoperative sternal wound infection, renal failure, and death.[4]

There are various strategies which have been employed to reduce transfusion in the perioperative period. The strategies are aimed at maximizing the reserve by preoperative identification of anemia and optimizing the red cell mass with erythropoietin therapy and/or preoperative blood donation.

Identification and treatment of coagulopathy including cessation of antiplatelets, appropriate surgical hemostasis, minimizing CPB prime and time, intraoperative cell salvage, antifibrinolytic therapy, and adequacy of heparin reversal are the measures taken to minimize intraoperative blood loss. Early intervention for surgical bleeding, algorithm-based transfusion, and postoperative cell salvage have shown to decrease the need for transfusion.

Pre- or perioperative autologous blood donation and use of cell salvage techniques have been widely investigated to decrease the transfusion requirement.[3]

Few measures can be simple while other techniques might necessitate use of costlier equipment such as cell salvage techniques to decrease the transfusion requirement.[2]

Hence, preoperative patient risk stratification might help to better manage patients, by detecting high-risk patients who might require aggressive blood management strategies ranging from correction of preoperative anemia to use of cell salvage techniques ultimately to improve patient outcomes.[3]

Multiple studies have been developed to predict the transfusion risk preoperatively in cardiac surgery patients. These range from studies which predict single variable[5-7] in determining transfusion risk to scoring system which combine multiple factors to determine the transfusion risk.[3,2]

Scoring system by considering multiple factors which are most important in predicting transfusion is simple, well calibrated and has a better discriminating power; hence, scoring system usage will be more useful than single predictors.[3]

Ranucci *et al*.[8] developed and externally validated Transfusion Risk and Clinical Knowledge (TRACK) score to assess transfusion risk in adult patients undergoing cardiac surgery. The TRACK score used the following five preoperative variables: age, weight, sex, complex surgery, and preoperative hematocrit level to determine the transfusion risk.

This was a simple and better score compared to other scores[1,2,9,10] which had multiple parameters used to predict transfusion risk preoperatively.

For patients posted for CABG, Magovern *et al*.[9] and Litmathe *et al*.[10] developed predictive scores to determine transfusion risk. Alghamdi *et al*.[2] had developed Transfusion Risk Understanding Scoring Tool (TRUST) to stratify cardiac surgery patients according to their blood transfusion needs.

Although TRACK score and various other scores have shown to be effective in transfusion risk prediction preoperatively, its routine usage as a part and parcel of cardiac preoperative evaluation is not widely investigated.[3]

This could be due to the limited studies using TRACK score other than the parent institution in determining preoperative score and the paucity of data in using this transfusion risk score in the management of patient and final patient outcome.[3]

However, starting to widely use preoperative transfusion risk scoring system such as the TRACK score, would be the first step to better design goal directed management protocol with these scores in future. These scores were validated in the western population. There is paucity of literature in predicting transfusion rate in Asians.

Hence, this study was undertaken to design a scoring system for predicting transfusion rate which could cater the Asian population and to compare with the available TRACK and TRUST scoring system.

Methodology

After approval from the institutional ethical board, this retrospective study was designed. Since this was a retrospective study, the need to obtain informed consent was exempted.

Retrospective data of 1014 cases from the hospital database were collected over a period of 1 year from February 2016 to January 2017. Of the total 1014 cases retrospectively interrogated, spectrum of cases included Off-pump coronary artery bypass grafting (OPCAB) (488), Atrial septal defect (ASD) (124), aortic valve replacement (132), mitral valve replacement (123), double valve replacement (54), Bentalls (7), on-pump CABG (56), CABG + valve replacement (18), redo surgeries (6), left atrial myxoma (4), and ruptured sinus of Valsalva repair (2). All adult patients undergoing cardiac surgery irrespective of use of bypass were included in the study. Patients receiving acute normovolemic hemodilution preoperatively, age <18 years, emergency surgeries, and transplant surgeries were excluded from the study.

All variables required for the generation of TRACK and TRUST score were collected. These included age, weight, gender, preoperative hematocrit, preoperative Hb, preoperative creatinine, and complex surgery. Coronary revascularization + valve surgery, redo surgeries, and ascending aorta operation were termed as complex surgery.

TRACK score and TRUST score were calculated from the data collected.

Although multiple intraoperative factors could affect the transfusion independently, these were not collected since the aim was to assess the preoperative score and its utility in determining transfusion risk in the study population. Patients requiring transfusion were recorded.

Clinical management

Cardiac surgeries were conducted with general anesthesia with positive pressure ventilation with elective postoperative ventilation as per the institutional protocol. Patients requiring bypass would undergo CPB under systemic heparinization with the maintenance of activated clotting time (ACT) >480 s. Roller pumps were utilized in all patients; priming was with crystalloid solutions at variable volume. Temperature management was dependent on the case performed. Crystalloid cardioplegia was employed to arrest the heart. During bypass time, pericardial blood was collected into a reservoir and reinfused to the patient; however, other salvage techniques were not used postoperatively. After weaning from bypass, protamine was used to reverse heparin aiming at an ACT <120 s. Antifibrinolytics were used pre- and postoperatively if required. Extubation was done in the postoperative Intensive Care Unit after satisfying extubation criteria. Any excessive postoperative drainage was managed according to the institutional protocol for bleeding management. Thromboelastogram was not available always to guide fresh-frozen plasma and platelet transfusion. Re-exploration was performed if necessitated.

Since transfusion is still guided by individual treating anesthesiologist or surgeon, there was no specific transfusion trigger practiced at the institute; however, Hb of 8 gm% was used as the transfusion trigger unlike in conditions such as massive bleeding, unstable hemodynamics, low cardiac output, and signs of organ ischemia would necessitate transfusion at higher Hb.

On CPB, Hb <6–7 g% was considered as transfusion trigger.

OPCAB were performed through midline sternotomy and revascularization was conducted post systemic heparinisation aiming ACT >350 s. If required procedure was converted into on pump surgery .On completion of anastomoses, heparin activity was neutralized with protamine to achieve an ACT of around 140 s.

Predictors used in TRACK and TRUST score which can potentially assess the risk of transfusion were first tested in the present study, to determine the association of dependent variable using univariate analysis. Statistical tests included a Student's *t*-test for unpaired data (continuous variables) and a Pearson's Chi-square test (categorical variables).

From these, factors associated with RBC transfusion at a $P < 0.1$ were selected and used to perform stepwise forward multivariable logistic regression analysis after which variables which had independent risk associated with transfusion with a $P < 0.05$ (logistic model) were selected and utilized to device new score for preoperative risk assessment of transfusion.

To assess the calibration of this new score, Hosmer–Lemeshow goodness-of-fit test was done and was found to have acceptable calibration.

For the continuous variables, adequate cutoff points were obtained by plotting them against the transfusion rate based on locally weighted scatterplot smoothing technique (LOWESS). LOWESS is a method based on iterative weighted least squares applied to nonlinear regressions.

A logistic regression model was created using the predictor values. Each predictor was given a score of 1 or 0 and total of which was used as a new score for risk of transfusion determination.

Effectiveness of the new score designed was analyzed by Hosmer–Lemeshow test and receiver operating characteristic analysis using measurement of the area under the curve (AUC).

The new score designed was compared with existing tools in cardiac surgery, that is, TRACK and TRUST score.

The characteristics of these scoring systems are reported in Table 1.

Statistical calculations were performed using a computerized statistical program (SPSS 12·0, Chicago, IL, USA).

Results

In a retrospective analysis of 1 year, 1014 patients data were analyzed and 773 (76.2%) patients received RBC transfusion.

Developmental score which included six independent variables, i.e., age, weight, gender, complicated surgery, Hb, and creatinine was found to be associated with perioperative

Table 1: Details of existing transfusion scoring systems

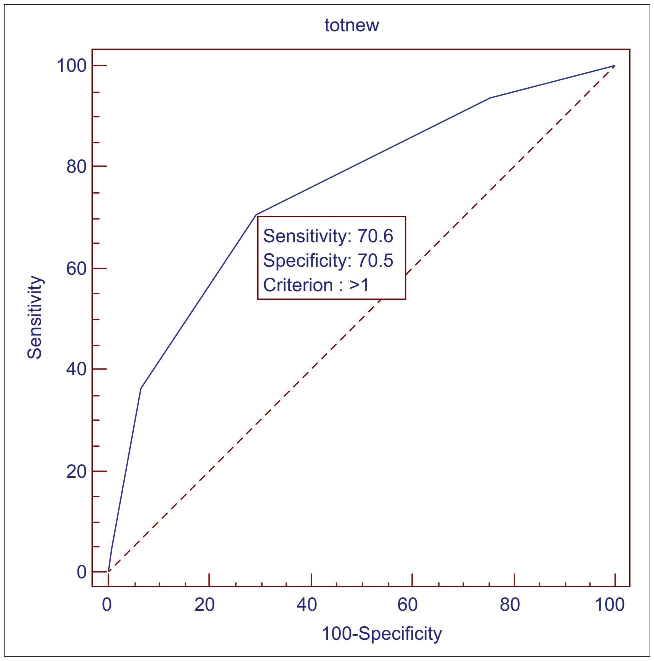
Trust score	Score	Track score	Score
Hb <13.5 g/dl	1	Age >67 years	6
Weight <77 kg	1	Weight <60 kg (female) or <85 kg (male)	2
Female sex	1	Gender-female	4
Age >65 years	1	Complex surgery	7
Nonelective surgery	1	Hematocrit (continuous)	1 point per each value (%) below 40%
Creatinine >1.36 mg/dl	1		
Previous cardiac surgery	1		
Nonisolated operation	1		

Hb: Hemoglobin

Table 2: New score and all its variables

	Co-efficient β	SE	*P*	Exp(β)	95% CI for Exp (B)		Score
					Lower	Upper	
Age >58 years	0.015	0.006	0.016	1.015	1.003	1.028	1
Weight males ≤63 kg, female ≤49	−0.023	0.007	0.002	0.977	0.963	0.991	1
Sex (female)	0.946	0.238	0.000*	0.388	0.244	0.619	1
Complex surgery (yes)	1.686	0.484	0.000	0.185	0.072	0.478	1
Hb <13.5 g/dl	−1.209	0.173	0.000	0.299	0.213	0.419	1
Creatinine >1.36 mg/dl	0.977	0.504	0.053	0.377	0.140	1.011	1
Constant	5.728	0.836	0.000	307.404			Total score=6

*P <0.0001. SE: Standard error, Hb: Hemoglobin, CI: Confidence interval



Graph 1: Receiver operating characteristics of new score (totnew = new score)

RBC transfusion using univariate analysis. These variables determined transfusion risk in a multivariable stepwise forward logistic regression analysis. Continuous variables (age, weight, Hb, and creatinine) were explored for categorization and dichotomization, by separately plotting them against the transfusion rate, and LOWESS technique was used to get adequate cutoff for these values which are as follows: age >58 years and weight (males <63 kg and females <49 kg).

These six independent variables were entered into multivariable logistic regression to predict the risk of transfusion.

A score of 1 was assigned if age >58 years, weight <63 kg for males and <49 kg for female, gender (female), complex surgery, Hb <13.5 g/dl, and creatinine >1.36 mg/dl. Total score was 6.

The new score is an additive score, distribution ranging from 0 to 6 [Table 2].

The transfusion rate is defined by the equation: $P = e^{-0.390 + (0.987 * \text{total score})}/1 + e^{-0.390 + (0.987 * \text{total score})}$

Calibration of the model was good, with $P > 0.5$ at the Hosmer–Lemeshow test. The discriminative properties were acceptable with an AUC value of 0.749 [Table 3 and Graph 1].

The observed transfusion rate in the present study was 76.2%. The expected mean transfusion rate according to new score was 80%, TRUST score was 79%, and TRACK was 81%.

The new score was comparable with TRACK score with $P = 0.578$ (AUC of TRACK 0.756 and AUC of new score 0.749).

There was a significant difference between new score and TRUST score, $P = 0.01$ (AUC of TRUST 0.72 and AUC of new score 0.749). The new score had a better predictive value than TRUST score. There was a significant difference between TRACK and TRUST score, $P = 0.01$ (AUC of TRACK 0.756 and AUC of TRUST score 0.72) which signifies TRACK score better than TRUST score [Table 4 and Graph 2].

Discussion

RBC transfusion in cardiac surgery is a major determinant which can increase the morbidity and mortality of cardiac surgery,[2] but the beneficial effect of treating perioperative anemia can never be neglected.

RBC transfusion alone can increase the morbidity such as atrial fibrillation, renal dysfunction, ARDS, and low cardiac output syndrome.

The increased demand of RBC availability for cardiac surgery is also a major economic burden.[8]

Usage of preoperative transfusion risk assessment scores can provide quality information which when used to stratify high- and low-risk patients can help in better outcome and can decrease the economic burden. This can be achieved by streamlining expensive strategies such as cell saver technique in high-risk groups.[2]

Patients screened as high risk for transfusion can be managed more aggressively starting from preoperative correction of anemia, early usage of point-of-care tests for coagulation assessment and rapid correction of coagulopathy.[3]

Considering these advantages, multiple scoring systems[1-4,8,9] have been developed to predict preoperatively risk of RBC transfusion in perioperative period.

Ranucci *et al.*[8] developed TRACK score which was simpler and easier score compared to other scores which had multiple variables making the scoring complicated. TRACK score has shown better results and can keep the risk assessments simple making the scoring easy. TRACK score has been used in Jehovah's witness patients undergoing cardiac surgery and was found to predict postoperative clinical outcomes which was comparable to EuroSCORE II.[11]

Table 3: New score and its validation

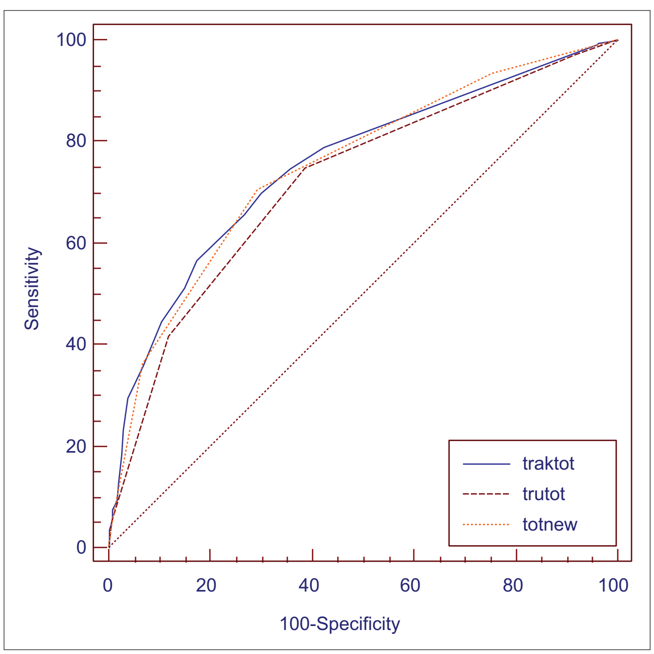
	β	SE	Significant	Exp(β)	95% CI for Exp(β)	
					Lower	Upper
New score	0.987	0.088	0.000	2.684	2.257	3.192
Constant	−0.390	0.145	0.007	0.677		

Hosmer-Lemeshow test χ^2: -1.9678, P=0.3739.
CI: Confidence interval, SE: Standard error

Table 4: Comparison between new score versus Transfusion Risk and Clinical Knowledge score versus Transfusion Risk Understanding Scoring Tool score

	AUC	Sensitivity (%)	Specificity (%)	Criterion
New score	0.749 (0.722-0.776)	70.6	70.5	>1
TRACK score	0.756 (0.729-0.782)	70.9	71.3	>4
TRUST score	0.720 (0.692-0.748)	74.9	61.4	>1

TRACK: Transfusion Risk and Clinical Knowledge, TRUST: Transfusion Risk Understanding Scoring Tool, AUC: Area under the curve



Graph 2: Receiver operating characteristic comparison between new score versus Transfusion Risk and Clinical Knowledge score versus Transfusion Risk Understanding Scoring Tool score. (Traktot – Transfusion Risk and Clinical Knowledge score, trutot – Transfusion Risk Understanding Scoring Tool score, totnew - new score)

Hence, in this study, TRACK score as preoperative risk assessment tool and its effectiveness in predicting postoperative RBC transfusion risk was studied. In the present study, new score AUC was comparable with AUC of TRACK score (AUC of TRACK 0.756 and AUC of new score 0.749) with similar sensitivity and specificity.

Well *et al.*[12] concluded that less is more in multivariate analysis, that is, instead of including many variables which might be statistically significant, analysis can be more effective if few variables are selected. TRUST score had eight variables and TRACK score had five variables; both these scores performed better than complex scoring system.

Ranucci *et al.*[8] concluded saying simple score such as TRACK score performed well in validation series as compared to TRUST score. In the present study, the new score performed better than TRUST score (AUC of TRUST 0.72 and AUC of new score 0.749) with a better sensitivity and specificity.

Bartoszko and Karkouti[3] developed score ACTA-PORT which showed an AUC of 0.76; however, they have suggested to use these scoring system into clinical practice if its use can change clinical behavior and patient management and result in a positive impact on hospitals and patients. In our present, new score had an AUC of 0.749, and hence, the new score can be a promising tool in the Asian population determining transfusion requirement.

To introduce a scoring system into clinical practice, the new score should demonstrate better or equal performance to the existing models and should be user-friendly. The TRACK being a simple score was comparable to the present new score. The clinical usefulness of the new score can identify patients with higher risk for receiving transfusion and to apply possible specific strategies to decrease this risk.

Limitation of the present study was as follows: first, it addressed only allogeneic RBC transfusion without discriminating between patients receiving one or more RBC units. Second, the authors did not report the rate of fresh-frozen plasma and platelet transfusion which would have affected postoperative outcome.

Conclusion

The scoring system derived from the present study is simple and easier to predict transfusion risk which is comparable to the TRACK score which can guide in better blood transfusion management.

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Conflicts of interest

There are no conflicts of interest.

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