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Original Article

Association between frequency of blood tests and mortality rate in patients undergoing massive blood transfusion: a multicenter study in five regions of China

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Abstract: In order to provide Chinese clinicians with guidelines for the management of massive blood loss, we investigated the correlation between the frequency of blood tests and the mortality rate in patients undergoing massive blood transfusion (MBT). The aim of this study is to provide Chinese clinicians with guidelines for the management of massive blood loss. We retrospectively reviewed the medical records of patients who underwent massive blood transfusion (MBT) from 20 tertiary hospitals in 5 regions of China. The frequency of blood tests performed within 24 or 72 hours was compared between patients infused with < 10 and ≥ 10 U of red blood cells (RBC). The correlation between the frequency of blood tests and the mortality rate was determined. A high frequency of blood tests was associated with a low mortality rate in MBT cases. The frequency of all blood tests performed within 24 hours was negatively correlated with the mortality rate in patients infused with ≥ 10 U of RBC, while the frequency of blood coagulation tests performed within 72 hours was negatively correlated with the mortality rate in both patients infused with ≥ 10 and < 10 U of RBC. In conclusions: Measuring the blood indices frequently within the first 24 hours of MBT links to lower mortality rate. Coagulation indices in MBT patients should be closely monitored in the long term to help improve survival.

Keywords: Frequency of blood tests, massive blood transfusion, mortality rate, retrospective analysis, blood coagulation, massive transfusion protocols, transfusion, coagulopathy, acidosis, hypothermia

Introduction

Massive blood transfusion (MBT) is defined as a transfusion of one blood volume over 24 hours [1-4], or the administration of > 10 U of red blood cells (RBC) within 24 hours [4, 5]. Acute clinical situations that warrant the administration of massive transfusion include a 50% blood volume loss within 3 h or a blood loss rate of 150 ml/min [1]. Timely replacement of the blood volume and oxygen carrying capacity in these situations is critical; however, the mortality rate is high among patients who undergo MBT, and those with coagulopathy, acidosis, and hypothermia (lethal triad) exhibit the highest mortality rates. Clinicians who manage patients with massive bleeding follow massive transfusion protocols (MTPs), which have been established to provide healthcare professionals with clear guidance on the management of massive blood loss [1, 4, 5]. Once a patient is in the protocol, the blood bank is able to ensure rapid and timely availability of blood components to facilitate resuscitation. Surgical control of hemorrhage and timely volume resuscitation with fluids and blood components remain the cornerstone of treatment [6]. Emerging evidence suggests that volume resuscitation using a solution containing a 1:1:1 ratio of packed RBC: plasma: platelets improves patient survival [7]. However, while this transfusion ratio may be appropriate for some patients, it may worsen outcomes for other patients [8]. Therefore, early and frequent measurement of blood indices in patients undergoing MBT will provide more convincing data that allow for early recognition of associated hemostatic and metabolic complications [9] and improved outcomes.

We retrospectively reviewed the medical records of 1682 patients who underwent MBT in 20 tertiary hospitals in 5 regions of China to investigate the correlation between the frequency of blood tests and the mortality rate in patients undergoing MBT and to provide guidelines on the management of massive blood loss for Chinese clinicians.

Materials and methods

Equipment and reagents

The following equipment was used in the present study: XE-2100 Automated Hematology System (Sysmex Corporation, Kobe, Japan), Beckman Coulter LH780 Coulter Hematology Analyzer (Beckman Coulter, Inc., CA, USA), HITACHI7170 and 7180 biochemical analyzers (Hitachi, Ltd., Tokyo, Japan), Roche Modular DP automatic biochemical analyzer and Roche Cobas-B123 blood gas analyzer (Roche, CA, USA), OLYMPUS AU640 biochemical analyzer (Olympus Corporation, Tokyo, Japan), and RADIOMETER ABL-77 blood gas analyzer (Radiometer, Copenhagen, Denmark). All reagents and kits used in the blood tests were obtained together with the purchased equipment.

Specimen collection

Two thousand copies of the Massive Transfusion Survey Table (Survey Table, described below) were sent to the members of the National Massive Transfusion Current Status Investigation Coordination Group (Coordination Group) in 20 tertiary hospitals in north, northeast, northwest, south central, and southwest China. A total of 1753 members responded. Data on the case histories of inpatients who underwent MBT in 20 Chinese hospitals from January 2009 to December 2010 were collected. Specimens were collected from June 2010 to January 2011. This study was approved by the ethical committees of the 20 tertiary Chinese hospitals. Written informed consent was obtained prior to commencement of this retrospective study.

Determination of study subjects

The 20 tertiary hospitals were numbered as follows. Hospital 1: the People's Hospital of Guangxi Zhuang Autonomous Region; Hospital 2: First Affiliated Hospital of Kunming Medical University; Hospital 3: Affiliated Hospital of Luzhou Medical College; Hospital 4: Shaanxi Provincial People's Hospital; Hospital 5: Tangdu Hospital, the Fourth Military Medical University; Hospital 6: Xijing Hospital, the Fourth Military Medical University; Hospital 7: the Fourth Clinical Medical College of Hebei Medical University; Hospital 8: Shenzhen People's Hospital; Hospital 9: Southwest Hospital, the Third Military Medical University; Hospital 10: Shengjing Hospital of China Medical University; Hospital 11: Xi'an Hong Hui Hospital; Hospital 12: Xiangya Hospital Central South University; Hospital 13: General Hospital of Chengdu Military Region; Hospital 14: the Second Affiliated Hospital of Medical College of Xi'an Jiaotong University; Hospital 15:Yan'an University Affiliated Hospital; Hospital 16: the First Affiliated Hospital of Shanxi Medical University; Hospital 17: the First Affiliated Hospital of Zhengzhou University; Hospital 18: Xi'an Central Hospital; Hospital 19: Xianyang 215 Hospital; and Hospital 20: Daping Hospital, the Third Military Medical University.

Patients who underwent infusion of $\geq$ 10 U of RBC within 24 hours were included in the observation group, and those who underwent infusion of < 10 U of RBC within 24 hours were included in the control group. Patients who underwent RBC transfusions for trauma, cardiac surgery, obstetric conditions, and other common surgeries (orthopedics, chest, general, urinary, hepatobiliary, and neurological surgery) were included in the study. Patients with coagulation disorders caused by hematological disease, hepatic failure, and bleeding due to coagulation factor deficiencies caused by other medical diseases were excluded from the study. The mortality rate was calculated as the number of inpatients who died during hospitalization divided by the total number of patients hospitalized. The frequency of blood tests performed in patients who underwent MBT was evaluated in two time periods: from the time of the first 1-U RBC transfusion to the end of the 24th hour, and from the first 1-U RBC transfusion to the end of the 72nd hour.

Procedure

The directors of the transfusion departments in the 20 tertiary hospitals designed the Survey Table based on topic discussion, expert consultation, and reference to massive domestic and foreign cases and followed the principles of equality, voluntarieers, and mutual benefit. The meeting to launch the investigation was held on 5 June 2010 in Xi'an and focused on the current national status of MBT. Thirty-five experts in the fields of clinical transfusion, surgery, anesthesia, gynecology and obstetrics, hematological disease, and medical statistics discussed the plan, improved the Survey Table, and trained the investigation staff members.

Survey table

The Survey Table comprised four parts: (1) patients' general information and characteristics (name, sex, age, body weight, blood type, ethnicity, admission number, department, primary diagnosis, secondary diagnosis, pathologic diagnosis, surgery performed, vital signs on admission, etc.); (2) events (operations performed, transfusion within 24 hours, transfusion after 24 hours, total transfusion volume, preoperative assessment results, and intraoperative management); (3) test results (RBT, BCT, liver function, kidney function, and blood gas analysis on kidney function) before initiation of transfusion, test results ≤ 24 hours after initiation of transfusion, and test results > 24 hours after initiation of transfusion; and (4) adverse events (risk factors for requiring MBT).

Quality control

A small preinvestigation was conducted in Shanxi Provincial People's Hospital. The Survey Table was revised and finalized according to the preinvestigation results and experts' comments.

Examination data were obtained from the laboratory examinations performed on surgical inpatients who underwent MBT in the 20 tertiary hospitals. Each laboratory routinely conducts internal quality control and participates in external quality assessments organized by the Clinical Test Center of the Ministry of Health.

Statistical analysis

Statistical analysis was conducted using SAS software (version 8.2; SAS Institute, Inc., Cary, NC, USA). EpiData software (version 3.01; EpiData Association, Odense, Denmark) was used for double data entry verification and database construction. Normally distributed variables are presented as means ± standard deviations, and non-normally distributed variables are presented as medians. The Shapiro-Wilk test, analysis of variance, or the Kruskal-Wallis test was used to compare the means of two groups containing continuous variables with a normal distribution. Categorical variables were analyzed with the chi-squared test. The Cochran-Mantel-Haenszel (CMH) test was used to compare the frequency of blood tests betweentwo groups, adjusting for both multicenter factors and disease factors. A logit model was applied to estimate the association between the frequency of blood tests and thepossible impact factors. Spearman's rank correlation was used to assess the relationship between the mortality rate and frequencyof blood tests performed within 24 and 72 hours in patients who underwent MBT. A P value of < 0.05 was considered to be statistically significant.

Results

General data

In total, 1753 patients who underwent MBT were reported through the Survey Table from the 20 tertiary hospitals. The retrieval rate was 87.65% (1753/2000). After excluding patients with incomplete medical records, the medical records of 1682 patients who underwent MBT were evaluated by statistical processing. Of 1682 patients, 850 were male, 832 were female, the age ranged from 16 to 91 years old (median = 46), and the weight of patients ranged from 46 to 105 kg (median = 59). Shapiro Wilk test determined the ages and weights of patients were not normally distributed. Therefore, these values were presented as medians. In total, 1013 patients were infused with ≥ 10 U of RBC and exhibited a mortality rate of 7.42%, while 669 patients were infused with < 10 U of RBC and exhibited a mortality rate of 7.32%. Categorization according to disease entity revealed that 346 cases involved trauma (mortality rate, 9.84%), 363 involved cardiac surgery (mortality rate, 12.73%), 838 involved general surgery (mortality rate, 5.54%), and 135 involved obstetric conditions (mortality rate, 2.27%). Before MBT performed, the clinical data, such as respiration, pulse, temperature, hemoglobin concentration, hemato-

Table 1. Frequency of RBTs/BCTs performed within 24 hours in patients who underwent MBT

No.	Frequency of RBTs/BCTs within 24 hours (< 10 U RBC)						Frequency of RBTs/BCTs within 24 hours (≥ 10 U RBC)						χ^2	p
	0	1	2	3	≥ 4	Total (%)	0	1	2	3	≥ 4	Total (%)		
RBTs*														
Hospital 1 (n = 101)	3	13	20	7	7	50 (49.5)	8	18	16	5	4	51 (50.5)	20.308	0.000
Hospital 2 (n = 101)	47	0	0	0	0	47 (46.5)	54	0	0	0	0	54 (53.5)	ND	ND
Hospital 3 (n = 147)	21	23	7	1	0	52 (35.4)	42	38	14	0	1	95 (64.6)	ND	ND
Hospital 4 (n = 295)	52	42	21	12	18	145 (49.2)	69	53	14	11	3	150 (50.8)	33.03	0.000
Hospital 5 (n = 99)	15	29	13	2	1	60 (60.6)	10	22	4	3	0	39 (39.4)	ND	ND
Hospital 6 (n = 101)	40	18	1	0	0	59 (58.4)	26	15	1	0	0	42 (41.6)	ND	ND
Hospital 7 (n = 82)	7	8	1	0	0	16 (19.5)	16	33	12	5	0	66 (80.5)	ND	ND
Hospital 8 (n = 105)	15	10	7	7	1	40 (38.1)	16	17	23	7	2	65 (61.9)	ND	ND
Hospital 9 (n = 46)	6	7	4	2	1	20 (43.5)	9	14	3	0	0	26 (56.5)	ND	ND
Hospital 10 (n = 50)	3	6	2	2	1	14 (28.0)	3	14	15	3	1	36 (72.0)	ND	ND
Hospitals 11-20 (n = 555)	115	32	5	7	7	166 (29.9)	281	58	36	9	5	389 (70.1)	11.887	0.018
BCTs**														
Hospital 1 (n = 101)	29	12	5	3	1	50 (49.5)	35	11	5	0	0	51 (50.5)	3.568	0.438
Hospital 2 (n = 101)	47	0	0	0	0	47 (46.5)	54	0	0	0	0	54 (53.5)	ND	ND
Hospital 3 (n = 147)	37	14	1	0	0	52 (35.4)	71	20	3	1	0	95 (64.6)	2.932	0.569
Hospital 4 (n = 295)	110	21	7	2	5	145 (49.2)	120	23	5	0	2	150 (50.8)	2.682	0.613
Hospital 5 (n = 99)	53	6	1	0	0	60 (60.6)	32	5	1	1	0	39 (39.4)	9.031	0.06
Hospital 6 (n = 101)	55	4	0	0	0	59 (58.4)	39	3	0	0	0	42 (41.6)	ND	ND
Hospital 7 (n = 82)	10	4	2	0	0	16 (19.5)	39	20	5	2	0	66 (80.5)	2.73	0.604
Hospital 8 (n = 105)	12	19	5	4	0	40 (38.1)	26	22	11	6	0	65 (61.9)	6.986	0.137
Hospital 9 (n = 46)	13	4	2	0	1	20 (43.5)	19	7	0	0	0	26 (56.5)	ND	ND
Hospital 10 (n = 50)	10	2	1	1	0	14 (28.0)	21	6	6	3	0	36 (72.0)	4.763	0.313
Hospitals 11-20 (n = 555)	139	22	3	1	1	166 (29.9)	344	29	13	2	1	389 (70.1)	47.873	0.000

Notes: RBTs = routine blood tests; BCTs = blood coagulation tests; MBT = massive blood transfusion; RBC = red blood cells; ND = no data. RBTs included RBC, hematocrit, hemoglobin content, and platelet count. BCTs included blood plasma prothrombin time, activated partial thromboplastin time, international standardization ratio, and fibrinogen level. *The Cochran-Mantel-Haenszeltest was conducted with adjustment for multicenter factors; QSMH = 70.2603, P < 0.0001. **The Cochran-Mantel-Haenszeltest was conducted with adjustment for multicenter factors; QSMH = 60.8964, P < 0.0001.

crit, platelet count, prothrombin time, activated partial thromboplastin time, international normalized ratio, fibrinogen concentration, showed no significant differences among patients with these four various disease entities.

Frequency of blood tests performed within 24 hours in patients infused with < 10 and ≥ 10 U of RBC

The CMH test was conducted with adjustment for multicenter factors. In all 20 hospitals, the frequency of blood tests (including both RBTs and BCTs) performed within 24 hours in patients infused with ≥ 10 U of RBC was significantly higher than the frequency of RBTs performed within 24 hours in patients infused with < 10 U of RBC (RBT: QSMH = 70.2603, P < 0.0001; BCT: QSMH = 60.8964, P < 0.0001) (**Table 1**). These results indicate that blood tests were performed more frequently in patients who underwent infusion with ≥ 10 U of RBC.

Statistical analysis of number of MBT patients who did and did not undergo blood tests within 24 hours according to disease group

The CMH test was conducted with adjustment for multicenter factors. As shown in **Table 2**, the ratio of patients who underwent blood tests within 24 hours to the total number of patients in each disease group was significantly different (RBT: QSMH = 8.2867, P = 0.0040;BCT: QSMH = 20.3839, P < 0.0001). Additionally, the frequency of RBTs and BCTs performed in the different disease groups was separately sorted from largest to smallest with the following results: RBT: obstetric disorders > general surgery > trauma > cardiac surgery; BCT:

Table 2. Statistical analysis of number of patients who did and did not undergo RBTs/BCTs within 24 hours of MBT in different disease groups

No.	Trauma			Obstetric conditions			General surgery			Cardiac surgery			χ^2	p
	0	≥ 1	Rate (%)	0	≥ 1	Rate (%)	0	≥ 1	Rate (%)	0	≥ 1	Rate (%)		
RBTs*														
Hospital 1 (n = 51)	0	1	100.00 (1/1)	0	6	100.00 (6/6)	3	21	87.50 (21/24)	5	15	75.00 (15/20)	8.367	0.039
Hospital 2 (n = 54)	13	0	0.00 (0/13)	3	0	0.00 (0/3)	30	0	0.00 (0/30)	8	0	0.00 (0/8)	ND	ND
Hospital 3 (n = 95)	16	23	58.97 (23/39)	6	11	64.71 (11/17)	16	19	54.29 (19/35)	4	0	0.00 (0/4)	5.788	0.122
Hospital 4 (n = 150)	6	9	60.00 (9/15)	1	9	90.00 (9/10)	8	27	77.14(27/35)	54	36	40.00 (36/90)	20.083	0.000
Hospital 5 (n = 39)	4	9	69.23 (9/13)	5	2	28.57 (2/7)	1	18	94.74 (18/19)	0	0	0.00 (0/0)	ND	ND
Hospital 6 (n = 42)	3	2	40.00 (2/5)	1	2	66.67(2/3)	16	12	42.56 (12/28)	6	0	0.00 (0/6)	5.008	0.171
Hospital 7 (n = 66)	1	5	83.33 (5/6)	4	8	66.67(8/12)	9	37	80.43 (37/46)	2	0	0.00 (0/2)	7.525	0.057
Hospital 8 (n = 65)	3	2	40.00 (2/5)	2	8	80.00 (8/10)	8	34	80.95 (34/42)	3	5	62.50 (5/8)	49.059	0.179
Hospital 9 (n = 26)	1	4	80.00 (4/5)	0	1	100.00 (1/1)	6	7	53.85 (7/13)	2	5	71.43(5/7)	1.879	0.598
Hospital 10 (n = 36)	3	10	76.92 (10/13)	0	4	100.00 (4/4)	0	19	100.00 (19/19)	0	0	0.00 (0/0)	ND	ND
Hospitals 11-20 (n = 389)	69	33	32.35(33/102)	8	5	38.46(5/13)	147	53	26.50(53/200)	57	17	22.97(17/74)	2.819	0.42
Total (n = 1013)	119	98	45.16 (98/217)	30	56	65.12 (56/86)	244	247	50.31 (247/491)	141	78	35.62(78/219)	25.122	0.000
BCTs**														
Hospital 1 (n = 51)	0	1	100.00 (1/1)	1	5	83.33 (5/6)	15	9	37.50 (9/24)	19	1	5.00 (1/20)	19.591	0.000
Hospital 2 (n = 54)	13	0	0.00 (0/13)	3	0	0.00 (0/3)	30	0	0.00 (0/30)	8	0	0.00 (0/8)	ND	ND
Hospital 3 (n = 95)	30	9	23.08(9/39)	13	4	23.53 (4/17)	24	11	31.43 (11/35)	4	0	0.00 (0/4)	2.183	0.535
Hospital 4 (n = 150)	9	6	40.00(6/15)	0	10	100.00 (10/10)	28	7	20.00 (7/35)	83	7	7.78 (7/90)	52.153	0.000
Hospital 5 (n = 39)	11	2	15.38 (2/13)	7	0	0.00 (0/7)	14	5	26.32 (5/19)	0	0	0.00 (0/0)	ND	ND
Hospital 6 (n = 42)	4	1	20.00 (1/5)	3	0	0.00 (0/3)	26	2	7.14 (2/28)	6	0	0.00 (0/6)	1.939	0.585
Hospital 7 (n = 66)	2	4	66.67 (4/6)	7	5	41.67 (5/12)	28	18	39.13 (18/46)	2	0	0.00 (0/2)	3.094	0.377
Hospital 8 (n = 65)	2	3	60.00 (3/5)	2	8	80.00 (8/10)	19	23	54.76 (23/42)	3	5	62.50 (5/8)	2.168	0.538
Hospital 9 (n = 26)	3	2	40.00 (2/5)	0	1	100.00 (1/1)	10	3	23.08 (3/13)	6	1	14.29 (1/7)	3.815	0.282
Hospital 10 (n = 36)	8	5	38.46 (5/13)	3	1	25.00 (1/4)	10	9	47.37 (9/19)	0	0	0.00 (0/0)	ND	ND
Hospitals 11-20 (n = 389)	89	13	12.75 (13/102)	7	6	46.15 (6/13)	179	21	10.50 (21/200)	69	5	6.76 (5/74)	17.237	0.001
Total (n = 1013)	171	46	21.20 (46/217)	46	40	46.51 (40/86)	383	108	22.00 (108/491)	200	19	8.68 (19/219)	54.037	0.000

Notes: RBTs = routine blood tests; BCTs = blood coagulation tests; MBT = massive blood transfusion; ND = no data. *The Cochran-Mantel-Haenszeltest was conducted with adjustment for multicenter factors; QSMH = 8.2867, P = 0.0040. **The Cochran-Mantel-Haenszeltest was conducted with adjustment for multicenter factors; QSMH = 20.3839, P < 0.0001.

Table 3. Comparison of frequency of RBTs/BCTs performed on patients infused with ≥ 10 U of RBC and the mortality rate in different disease groups

Frequency		0		1		2		3		≥ 4	
		Survival	Death	Survival	Death	Survival	Death	Survival	Death	Survival	Death
RBTs*	Trauma, n	110	9	52	5	32	1	7	0	1	0
	Obstetric conditions, n	30	0	35	1	16	0	3	0	1	0
	General surgery, n	233	11	134	5	74	3	21	2	5	3
	Cardiac surgery, n	124	17	44	6	11	1	5	5	5	1
BCTs**	Trauma, n	159	12	31	3	7	0	4	0	1	0
	Obstetric conditions, n	46	0	27	1	9	0	3	0	0	0
	General surgery, n	367	16	69	3	23	5	8	0	0	0
	Cardiac surgery, n	173	27	10	2	4	1	0	0	2	0

Notes: RBTs = routine blood tests; BCTs = blood coagulation tests; RBC = red blood cells. *Logit model was applied in the statistical analysis; the maximum likelihood ratio was 5.89, P = 0.435. **Logit model was applied in the statistical analysis; the maximum likelihood ratio was 1.05, P = 0.7886.

obstetric disorders > general surgery > trauma > cardiac surgery.

Frequency of blood tests and mortality rate in patients infused with ≥ 10 U of RBC according to disease group

A logit model was applied in the statistical analysis and fit the data well (RBTs: maximum likelihood ratio = 5.89, P = 0.435; BCTs: maximum likelihood ratio = 1.05, P = 0.7886 [**Table 3**]). As shown in **Table 3**, the frequency of RBTs and BCTs performed in patients infused with ≥ 10 U of RBC was significantly different (RBT: P = 0.0014; BCT: P < 0.0001) among the different disease groups (trauma, cardiac surgery, general surgery, and obstetric conditions). Additionally, the frequency of RBTs and BCTs performed between patients who survived and died was significantly different (RBT: P = 0.0037; BCT: P = 0.0242) among the four disease groups. The mortality rate of patients infused with ≥ 10 U of RBC in the different disease groups was sorted from largest to smallest with the following results: cardiac surgery (13.79%) > trauma (6.91%) > general surgery (4.89%) > obstetric conditions (1.16%) (**Table 3**). Similarly, the mortality rate of patients infused with < 10 U of RBC in the different disease groups was sorted from largest to smallest with the following results: trauma (12.40%) > cardiac surgery (7.64%) > general surgery (5.76%) > obstetric conditions (4.08%).

Correlation between frequency of blood tests performed within 24 hours and mortality rate in patients who underwent MBT

Spearman's rank correlation was employed for the statistical analysis. For patients who underwent MBT with ≥ 10 U of RBC, the frequency of both RBTs and BCTs performed within 24 hours were negatively correlated with the mortality rate (RBT: r = -0.900, P = 0.037; BCT: r = -0.975, P = 0.005). For patients who underwent MBT with < 10 U of RBC, the frequency of blood tests had no correlation with the mortality rate (**Table 4**).

Correlation between frequency of blood tests performed within 72 hours and mortality rate in patients who underwent MBT

Spearman's rank correlation was employed for the statistical analysis. The frequency of RBTs performed within 72 hours showed no correlation with the mortality rate in patients who underwent MBT with both ≥ 10 and < 10 U of RBC. However, the frequency of BCTs performed within 72 hours showed a negative correlation with the mortality rate (< 10 U: r = -0.9747, P = 0.0048; ≥ 10 U: r = -1.0000, P = 0.0000) (**Table 5**).

Discussion

In the present study, we retrospectively reviewed the medical records of 1682 in patients who underwent surgical MBT in 20 tertiary hospitals in 5 regions of China. Our results showed a high frequency of blood tests was associated with a low mortality rate in MBT cases. The frequency of all blood tests performed within 24 hours was negatively correlated with the mortality rate in patients infused with ≥ 10 U of RBC, while the frequency of blood coagulation tests performed within 72 hours was negatively correlated with the mortality rate in both patients infused with ≥ 10 and < 10 U of RBC.

Table 4. Correlation between frequency of blood tests performed within 24 hours and mortality rate of patients who underwent MBT

	Transfusion volume	Status	0	1	2	3	≥ 4	r	p
Frequency of RBTs, n	< 10	Survival	296	178	77	37	32	-0.821	0.089
		Death	28	10	4	3	4		
	≥ 10	Survival	497	265	133	36	12	-0.900	0.037
		Death	37	17	5	7	4		
Frequency of BCTs, n	< 10	Survival	480	96	27	10	7	-0.667	0.219
		Death	35	12	0	1	1		
	≥ 10	Survival	745	137	43	15	3	-0.975	0.005
		Death	55	9	6	0	0		

Notes: MBT = massive blood transfusion; RBTs = routine blood tests; BCTs = blood coagulation tests. Spearman's rank correlation; P < 0.05 was considered statistically significant.

Table 5. Correlation between frequency of blood tests performed within 72 hours and mortality rate of patients who underwent MBT

	Transfusion volume	Status	0	1	2	3	≥ 4	r	p
Frequency of RBTs, n	< 10	Survival	82	108	78	41	63	-0.6323	0.2522
		Death	7	7	1	3	3		
	≥ 10	Survival	265	330	275	181	140	-0.7000	0.1881
		Death	35	26	12	10	15		
Frequency of BCTs, n	< 10	Survival	238	84	34	6	10	-0.9747	0.0048
		Death	12	7	2	0	0		
	≥ 10	Survival	751	270	102	39	29	-1.0000	0.0000
		Death	62	19	10	4	3		

Notes: MBT = massive blood transfusion; RBTs = routine blood tests; BCTs = blood coagulation tests. Spearman's rank correlation; P < 0.05 was cons.

Early recognition of hemostatic and metabolic complications in patients undergoing MBT is essential to improve patient survival. Hemorrhagic shock accounts for 80% of deaths in the operating room and up to 50% of deaths in the first 24 hours after injury [10]. The use of a 1:1:1 ratio of the major transfusion components, namely RBC: plasma: platelets [7], during MBT has been suggested in many hospitals and trauma centers. However, while this transfusion ratio maybe appropriate for some patients, it may put others at risk of worse outcomes and higher delayed mortality [8]. Therefore, more convincing data obtained from blood index monitoring and MBT guidelines are needed for use in the clinical setting. The present study is the first to show that the frequency of performance of both RBTs and BCTs within 24 hours is negatively correlated with the mortality rate in patients undergoing MBT with ≥ 10 U of RBC (**Table 4**). Consistent with our results, previous studies have suggested that patients should be closely observed in the early period of MBT because most adverse reactions occur during the first 15 minutes of the transfusion [11]. Coagulopathy frequently develops in patients undergoing MBT; this contributes to the duration and severity of hemorrhage and is associated with an increased risk of death [12, 13]. Irrespective of the MTP or RBC: plasma ratio of the transfusion, most patients become coagulopathic, and a fibrinogen deficiency is almost always the initial abnormality [14]c. In the present study, the frequency of BCTs performed within 72 hours was negatively correlated with the mortality rate in both patients who underwent MBT with ≥ 10 and < 10 U of RBC. This finding suggests that during MBT, close monitoring of the coagulation indices in the long term may reduce the frequency or severity of coagulopathy and thereby improve survival.

Among the 1682 patients in this study, 1013 were infused with ≥ 10 U of RBC within 24 hours, and the mortality rates in the different disease groups were sorted with the following results: cardiac surgery (13.79%) > trauma (6.91%) > general surgery (4.89%) > obstetric conditions (1.16%) (**Table 3**). The remaining 669 patients were infused with < 10 U of RBC within 24 hours, and the mortality rates in the different disease groups were sorted with the following results: trauma (12.40%) > cardiac surgery (7.64%) > general surgery (5.76%) > obstetric conditions (4.08%) (**Table 3**). According to these results, cardiac surgery and trauma are associated with higher mortality rates than are other disease conditions. Trauma is the leading cause of death in individuals aged 1 to 44 years [10]. Additionally, excessive blood loss during cardiac surgery involving cardiopulmonary bypass requiring MBT is a common complication associated with significant morbidity and mortality [15]. In contrast, obstetric hemorrhage requiring transfusion is a relatively rare event in daily obstetric practice [16]. Therefore, it is quite possible that trauma and cardiac surgery are associated with higher mortality rates than are obstetric conditions and general surgery in Chinese hospitals. However, the frequency of blood tests performed in the different disease groups was arranged as follows: obstetric conditions > general surgery > trauma > cardiac surgery. When we compared the mortality rates in the patients infused with ≥ 10 and < 10 U of RBC with the frequency of blood tests performed in the different disease groups, we found that the disease group with the highest frequency of blood tests had the lowest mortality rate (obstetric conditions), but that the disease groups with the lowest frequencies of blood tests had the highest mortality rates (cardiac surgery and trauma). These results indicate that in China, obstetricians may have a better working knowledge of transfusion practice than do other clinicians. Therefore, Chinese hospitals should underscore the importance of increasing clinicians' knowledge of transfusion practice, and blood indices should be measured early and frequently during MBT as suggested by previously published MTPs [1, 3-5].

Considering that only 20 tertiary hospitals in north, northeast, northwest, south central, and southwest China were included in this study, our results may not comprehensively represent the current MBT status among Chinese hospitals.

In conclusion, this study is the first to explore the association between the frequency of blood tests and the mortality rate in patients undergoing MBT. The results obtained in this study provide a new angle from which clinicians can consider the complications of MBT. Our results show that it is important to measure blood indices early and frequently within the first 24 hours during MBT, especially in patients infused with ≥ 10 U of RBC. Additionally, the coagulation indices of patients undergoing MBT should be closely monitored in the long term to potentially reduce the frequency or severity of coagulopathy and improve survival. Chinese hospitals should underscore the importance of increasing clinicians' knowledge of transfusion practice, and blood indices should be measured early and frequently in patients undergoing MBT.

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Disclosure of conflict of interest

None.

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