The Value of Body Surface Area Used in Postpartum Hemorrhage Define Postpartum Hemorrhage

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Research article

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Abstract

Background: Blood loss as a percentage of total blood volume for redefining PPH may be more appropriate compared to the 500ml cutoff for every pregnant woman. This study is to investigate the value of body surface area in redefining PPH.

Methods: In our prospective clinical observational study, we calculated the total blood volume using body surface area and measured blood loss at delivery using gravimetric and volumetric methods for all pregnant women included in our cohort (n=1715). For the five different body surface area groups, we determined different percentages of blood loss in total blood volume among 1201 participants. Furthermore, we compared the prediction values in blood transfusion based on the quantification of bleeding or proportion of blood loss in total blood volume at different quintiles among 514 severe PPH cases.

Results: The median total blood volume and body surface area were 4639ml and 1.73 m^2, respectively. The median total blood volume increased with increasing body surface area, and the different proportions of total blood volume increased accordingly. The median blood loss was 380ml and represented 8.28% of total blood volume. The median measured 24h blood loss across quintile 1 to 5 was 363ml, 360ml, 390ml, 380ml, 440ml, respectively. Using the definition with blood loss of 500 ml and 13% percentage of total blood volume, the incidence of PPH was 30% and 19%. However, the changes of the circulatory system secondary to obstetric hemorrhage was not significantly different at each quintile. Additionally, use of blood loss or the percentage of blood loss in total blood volume has high specificity and sensitivity as the indicators to predict blood transfusion.

Conclusions: Our results suggest that blood loss exceeds 13% of total blood volume as a definition of postpartum hemorrhage. Blood loss above 30% of total blood volume may be recommended for blood transfusion.

Background

Postpartum hemorrhage (PPH) is a continued significant health challenge globally in modern obstetrics [1,2,3]. In developing countries, PPH is the primary cause of maternal mortality, and accounts for over one in four direct maternal deaths [4].

The worldwide traditional definition of PPH is blood loss of over 500 ml, but inaccurate blood loss quantification can affect the diagnosis of PPH. There is now a general consensus that underestimation of blood loss during pregnancy occurs frequently [5]. Additionally, different individuals vary widely from tolerance of blood loss [6]. Hence, the traditional definition has been increasingly questioned by professional organizations and experts in recent years [6-9]. It is generally accepted that a prompt intervention on account of accurate recognition can reduce the serious complications of PPH [10,11].

Both an underestimation and lack of consensus can result in a delay of diagnosis and treatment of PPH. Many obstetricians developed different definitions with more clinical significance compared to the traditional definition. However, there is still not a general agreement. Seeking another more universal clinically relevant definition to reduce maternal morbidity and mortality leading to obstetric hemorrhage is very important. Each pregnant woman differs greatly from body dimension, which reflects the different total blood volume. Similar to trauma surgery, blood loss as a proportion of a pregnant individual's total blood volume is more appropriate compared to an absolute universal cutoff value [12]. One retrospective study indicated a statistically significant increase in estimated blood loss as the body surface area in quintile increased [12]. However, the study did not show that women with a higher body surface area (BSA) and subsequent total blood volume can tolerate a more absolute obstetric blood loss.

In order to further elaborate this problem, we conducted a prospective observational clinical study. This study was undertaken to identify average blood loss based on BSA. We compared this to the standard definition in order to evaluate BSA as a new criterion in PPH.

Methods

Study design and patients

Next, we conducted a prospective observational study that was registered with the clinical trial registry (ChiCTR-TRC-17010828http://www.chictr.org/en/). Between May 2017 and May 2020, all vaginal deliveries were enrolled in the Nanjing Drum Tower Hospital, a tertiary hospital. Inclusion criteria included a singleton delivery with gestational age range of 24 0/7 to 41 6/7 weeks. Women with gestational age of less than 24 weeks or more than 42 weeks were excluded.

Data collection

After admission, we obtained a detailed medical history, including maternal height and weight, using a unified weight scale and height gauge. The amount of postpartum blood loss was measured precisely using weight and volume. Every maternal staff underwent training of gravimetric and volumetric measurement of blood loss. All soaked gauzes and pads that were used in labor or after labor were included in the gravimetric protocol. If blood spilt on the floor, we wiped it using dry gauzes, which were then weighed. The dry weight of all commonly used gauzes and pads were recorded using the baby weight scale in advance. Blood that was collected in the blood container was directly measured. The amniotic fluid was excluded first when we measured all soiled materials. In the process of measuring blood loss through the use of a blood collected bag, we opened a blood bag seal after the amniotic fluid was adequately drained. Prophylactic oxytocin was routinely used in the management of the third stage of labor across all individuals. In total, 24 hours postpartum blood loss was extracted from various case records. The blood pressure and heart rate of each participant were obtained at 30, 60 and 120 minutes after fetus delivery in the supine position. Blood routine examinations were done at admission and 48 hours post-delivery.

Total blood volume has been shown to associated with body surface area, and their relationship is linear [13]. The formula used to calculate blood volume (2.68L/m^2) in this study was adopted from the published study by Baker *et al.*[13]. While many formulas are used to calculate body surface area, the Dubois formula (0.007184*weight^0.425*height^0.725) is the most suitable for pregnant individuals [14]. The formula was adopted in our study to calculate body surface area. According to the delivery record, we calculated median postpartum blood loss at 24 hours and median total blood volume. The different percentages (10%, 13% and 15% blood loss in total blood volume) were also calculated and compared to the standard definition. We categorized patients into different subgroups according to their body surface area. Patients were then assigned into quintiles by body surface area. The previously described data were analyzed across all these subgroups. The relationships between the blood loss and alteration in blood pressure, heart rate and hemoglobin were also investigated. Timely and correct blood transfusion can lead to a decrease in complications of severe PPH. We compared quantification and percentages in predicting blood transfusion when blood loss above 1000 ml.

Statistical analysis

Statistical analysis was performed using SPSS19.0 software. Normally distributed data were presented as mean ± standard deviation (SD). The skewed distributed data were presented as median with interquartile range (IQR) and range. Comparison between groups was done through a T test. We reported categorical variables as frequencies and proportions and compared them to the Chi-square and Fisher's exact test, as appropriate. We evaluated area under the curve (AUC) and associated 95% confidence interval for two predictors at each quintile with blood transfusion using non-parametric receiver-operating curve (ROC) analysis. The P-value of statistical significance was defined to be less than 0.05.

Results

Patients

In the first three months of our clinical observational study, 1715 pregnant women delivered vaginally. Overall, there were 601 primiparas and 600 multiparas in the whole population. The median gestational age was 39 weeks, the median body surface area was 1,73 m^2 and the median BMI was 26.22 kg/m^2 (Table 1). From May 2017 to May 2020, 514 patients experience hemorrhage exceeding 1000 ml.

Different blood loss and percentages of total blood volume in different body surface quintile groups

All patients were classified into different quintiles according to the body surface area (Table 2). From quintiles 1 to 5, the body surface area was 1.40-1.64 m^2, 1.65-1.70 m^2, 1.71-1.77 m^2, 1.78-1.84 m^2 and 1.85-2.83 m^2, respectively. Overall, the median total blood volume was 4639 ml (interquartile range 4445-4866 ml). Hence, 10% of total blood volume is 464 ml and 15% of total blood volume is 696 ml. We found that the median total blood volume increased with increasing body surface area, and different proportions of total blood volume increased accordingly. The median 24h blood loss for the whole population was 385 ml (interquartile range 245-565 ml). For each quintile of body surface area, the median 24h blood loss was 363 ml, 360 ml, 390 ml, 380 ml, and 440 ml, respectively (Figure 1). The median blood loss at 24h postpartum in quintile 5 was significantly higher than in quintile 1 ($P<0.05$), but the percentage of median 24h blood loss in total blood volume between the two groups was identical ($P>0.05$).

The incidences at each quintile across different groups

The prevalence of PPH at each quintile was 27.5%, 28.3%, 30.3%, 25.7% and 37.9%, respectively using the universal definition of PPH (cutoff value of 500 ml). The occurrence of PPH at quintile 5 was significantly higher compared to other quintiles. At quintile 1, we divided 174 patients with blood loss of less than 500ml into two different groups. Blood loss of total blood volume in Group 1 is less than 10%, while blood loss of TBV in Group 2 is more than 10%. The alterations in blood hemoglobin and hemocrit were significantly different ($p<0.05$). At quintile 5, we divided all 91 patients with blood loss more than 500 ml into two different groups. Blood loss of total blood volume in Group 1 was more than 10%, while blood loss of TBV in Group 2 is less than 10%. The alterations in cardiovascular system and blood routine examination were not significantly different.

Furthermore, we compared the consequent dynamics and laboratory changes according to the amount of blood loss or different percentages of total blood volume. Our study indicated that blood loss as a percentage of total blood volume was significantly correlated to changes in diastolic blood pressure, heart rate, hemoglobin and hematocrit.

We found that prevalence of PPH at each quintile was approximately 30% using the universal definition of PPH. When we altered the volume of blood loss to 700 ml or redefined blood loss at 10%, 13% or 15% in total blood volume as definition, the changes in blood pressure, heart rate and blood routine results were not significant different. The incidences of PPH at each quintile was 11.3%, 11.3%, 10.2%, 13.5%, and 20% when we used blood loss of 700 ml as definition. On the other hand, when we used 13% proportion of total blood volume as a new merit to define PPH, the occurrence for each quintile were 22.1%, 16.7%, 18%, 17.3%, and 21.3%, respectively. Additionally, the incidences of PPH at each quintile were 16.3%, 12.1%, 10.7%, 11%, and 17.5% when we used blood loss of 15% in total blood volume. There were no significant differences at each quintile when we used proportion of blood loss in TBA as definition, but there was significant difference at each quintile when we used the amount of blood loss as definition (Table 3).

Blood loss or blood loss in TBV ratio in predicting blood transfusion.

Considering the low incidence of bleeding over 1000 ml, we identified a total of 514 patients with blood loss over 1000 ml in three years. We investigated the value of either blood loss or blood loss in total blood volume in predicting blood transfusion using blood transfusion as the outcome variable. In the meantime, we grouped them by surface area and compared amount of blood loss or blood loss in total blood volume by forecasting blood transfusion at each group. Use of blood loss or blood loss in total blood volume has high specificity and sensitivity as the indicators to predict blood transfusion. However, cutoff values of blood loss predicted by different body surface area groups were significantly different, while the blood loss in total volume ratio was relatively stable (Table 4 and figure 2). The results were a good explanation for a high blood transfusion rate in the group with small body surface area, with a low blood transfusion rate in the group with large body surface area. As the same amount of blood loss in the group with small surface area takes up a larger proportion of blood volume, and is more likely to cause changes in blood pressure and heart rate, clinicians are more likely to administer blood transfusion.

Discussion

The traditional definition of postpartum hemorrhage (PPH) was initially derived from an informal meeting of WHO experts in 1989 [15]. The cutoff value for primary PPH was defined as genital bleeding after delivery of the baby equal to or more than 500ml. This widely used definition has been argued in recent years due to several limitations [16,17]. One of the limitations is accurate estimation of blood loss, while the other one is each individual patient's tolerance of bleeding [18].

Previous studies have shown that the blood loss volume was underestimated approximately 50% of clinical obstetricians' visual estimation [19]. Many studies pointed out most maternal deaths due to PPH involve a delayed diagnosis and management of blood loss [20,21]. Actually, the average blood loss was found to be 300-550ml after vaginal delivery, using photometric or radioactive chromium-tagged red blood cells methods [22,23]. In our study, we used our especially-designed under buttocks blood collected bag that was accompanied with weighing gauzes, absorbent pads, and sanitary towers to directly measure blood loss. Our average blood loss was 241-540 ml after vaginal delivery. It has been demonstrated that our objective measurement was accurate. The low-cost plastic bags were proven to be useful tools to measure blood loss in various studies [24]. Compared to data before the study, the occurrence of PPH in our maternal unit was higher (30% vs 18%), which revealed that we previously underestimated blood loss. The occurrence was higher after our objective blood loss measurement, which indicated additional utero-tonics and sources were recommended to be used to reduce risk of severe morbidity after hemorrhage. We would waste many resources using the traditional definition. Hence, it is urgent to pursue a proper definition of PPH that can be used to identify PPH early and decrease waste of resources as much as possible.

Obstetrical clinicians want to promptly identify abnormal hemorrhage for early intervention. If we define abnormal blood loss as 500 ml, there are more than 30% of patients who needed to be intervened. Among these patients, only 11.7% (42/360) have blood loss above 1000 ml. Obviously, the traditional cutoff value of 500ml was not suitable for direct clinical treatment due to an overload of medical resources. In order to manage postpartum hemorrhage and reduce waste of medical resources, our study demonstrated that blood loss equal to 13% of total blood volume as a new postpartum hemorrhage definition was recommended.

We found that occurrence of PPH was approximately 20% using 13% of total blood volume, which is more appropriate. The total blood volume rises with increasing body surface area, but blood loss as a percentage of total blood volume remains the same, despite elevated bleeding at a large BSA group (Table 2). According to a trauma surgery study, individual's reaction to bleeding was related to the percentage of total blood volume [25]. The results shown that any fixed universal value to PPH does not reflect individual tolerance. We compared consequent dynamics and laboratory changes according to the amount of blood loss or different percentages of total blood volume. Our study showed that bleeding quantification and blood loss as a percentage of total blood volume were significantly correlated to changes in diastolic blood pressure, heart rate, hemoglobin and hematocrit. With increasing amount or percentage, the diastolic blood pressure and heart rate were elevated, but the level of hemoglobin and hematocrit were decreased. We also demonstrated the consequent dynamics and laboratory changes at each quintile, which indicated no significant differences when blood loss was above 700ml and blood loss percentage was above 15%. If we chose the value of 700ml as a new definition, despite the incidence being decreased, the incidence at quintile 5 was higher than other groups. At the same time, the blood loss percentage in total blood volume at quintile 5 was lower than other groups, which was less than 15%. If we chose blood loss of 15% of total blood volume as a new definition, we found significant differences of blood loss at each quintile (631 ml, 690 ml, 705 ml, 732 ml, 800ml), which demonstrated that blood loss as PPH definition was unsuitable.

Conclusions

In conclusion, we recommend blood loss as 13% of total blood volume to define PPH in order to direct first-line treatment. Body surface area as an individual indicator when calculating total blood volume is a simple and suitable method. Blood transfusion is one of the most important management methods for severe obstetric hemorrhage. Our study demonstrated that 30% blood loss in total blood volume is predicted to lead to blood transfusion. There are still some limitations to our study. We need data from other ethnic groups to validate this metric. Additionally, we need to perform a prospective control clinical study to further prove effectiveness of the index.

Abbreviations

PPH: Postpartum hemorrhage; BSA: body surface area; SD: standard deviation; IQR: interquartile range; AUC: area under the curve; ROC: receiver-operating curve.

Declarations

Ethics approval and consent to participate

The study protocol was conducted according to the Declaration of Helsinki and was granted approval by the institutional review board of Nanjing Drum Tower Hospital (Protocol number: 201702001). Informed written consent was acquired from each participant in the study.

Consent for publication

Not applicable.

Availability of data and materials

The material of the current study is be available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest to disclose.

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Authors' contributions

All authors have made relevant contributions to this manuscript. Drafting the work or revising it critically for important intellectual content: YD, XL, TL, YZ, LQ. Final approval of the manuscript submitted: YD, XL. All authors approved the final version of the paper.

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Tables

Table 1. Demographics, Obstetric history, and Procedural factors (n=1715)

	Value
Age (y)	29.0±2.39
Gravidity, n (%)	
1	601(50.0)
2	331(27.6)
3 or more	269 (22.4)
Parity, n (%)	
0	810 (67.4)
1	363 (30.2)
2 or more	28 (2.3)
Induced labor condition	
GDM	9.8% (168/1715)
PE	6.0% (102/1715)
PROM	30.4% (521/1715)
Term/preterm delivery	
Term delivery (≥37 weeks)	94.8% (1625/1715)
Preterm delivery (<37 weeks)	5.2% (90/1715)
BSA, m2, M (Q1~Q3)	1.73 (1.66-1.82)
BMI, kg/m2, M (Q1~Q3)	26.17 (24.34-28.34)
Gestational age, wk, M (Q1~Q3)	39 (39-40)

BSA, body surface area; BMI, body mass index; GDM, gestational diabetes mellitus; PE, preeclampsia; PROM, premature rupture of fetal membranes.

Data are n (%), mean ± standard deviation, or median (interquartile range)

Table 2. Different blood loss and percentages of total blood volume in different body surface quintile groups.

	n	TBV	10%TBV	15%TBV	24h BL	2h BL	24h BL/TBV
Overall	1201	4639 (4445-4866)	464 (445-487)	696 (667-730)	380 (241-540)	340 (205-490)	8.10 (5.30-11.54)
BSA quintile 1 (1.40-1.64)	240	4269 (4160-4347)	427 (416-435)	640 (624-652)	370 (246-509)	330 (210-480)	8.79 (5.81-12.37)
BSA quintile 2 (1.65-1.70)	240	4485 (4445-4517)	449 (445-452)	673 (667-678)	365 (226-514)	330 (190-470)	8.25 (5.06-11.39)
BSA quintile 3 (1.71-1.77)	244	4630 (4599-4683)	463 (460-468)	695 (690-702)	380 (255-540)	340 (220-490)	8.15 (5.46-11.49)
BSA quintile 4 (1.78-1.84)	237	4809 (4767-4860)	481 (477-486)	721 (715-729)	362 (235-519)	330 (200-465)	7.56 (4.92-10.70)
BSA quintile 5 (1.85-2.83)	240	5067 (5003-5204)	508 (500-520)	761 (750-781)	415 (255-589)	365 (220-560)	8.00 (5.01-11.68)
p value		0.000	0.000	0.000	0.047	0.049	0.071

TBV, total blood volume; IQR, interquartile range; BSA, body surface area.

Table 3. The incidences at each quintile across different groups.

	Quintile 1	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**	c2	*p* value
BL<500 ml	66 (27.5)	68 (28.3)	74 (30.3)	61 (25.7)	91 (37.9)	10.26	**0.036***
BL ≥500 ml	174 (72.5)	172 (71.7)	170 (69.7)	176 (74.3)	149 (62.1)		
BL<700 ml	27 (11.3)	27 (11.3)	25 (10.2)	32 (13.5)	48 (20.0)	13.12	**0.011**
BL≥700 ml	213 (88.7)	213 (88.7)	219 (89.8)	205 (86.5)	192 (80.0)		
BL/TBV<10%	95 (39.6)	86 (35.8)	92 (37.7)	65 (27.4)	87 (36.3)	9.09	0.059
BL/TBV≥ 10%	145 (60.4)	154 (64.2)	152 (62.3)	172 (72.6)	153 (63.7)		
BL/TBV<13%	53 (22.1)	40 (16.7)	44 (18.0)	41 (17.3)	51 (21.3)	3.70	0.448
BL/TBV≥ 13%	187 (77.9)	200 (83.3)	200 (82.0)	196 (82.7)	189 (78.7)		
BL/TBV<15%	39 (16.3)	29 (12.1)	26 (10.7)	26 (11.0)	42 (17.5)	8.25	0.083
BL/TBV≥ 15%	201 (83.7)	211 (87.9)	218 (89.3)	211 (89.0)	198 (72.5)		

BL, blood loss; TBV, total blood volume; significant difference, **p* value<0.05.

Table 4. Blood loss or blood loss in TBV ratio in predicting blood transfusion.

Groups	Indicators	n	Blood transfusion, n (%)	AUC	Sensitivity	Specificity	Cut-off value
Total	BL	514	110 (21.4%)	0.858 (0.813-0.903)	0.8	0.81	1436
	BL/TBV	514	110 (21.4%)	0.867 (0.823-0.912)	0.76	0.88	0.32
Quintile 1	BL	103	32 (31.1%)	0.880 (0.802-0.959)	0.88	0.75	1280
	BL/TBV	103	32 (31.1%)	0.894 (0.826-0.963)	0.81	0.83	0.32
Quintile 2	BL	106	23 (21.7%)	0.865 (0.757-0.973)	0.83	0.88	1459
	BL/TBV	106	23 (21.7%)	0.867 (0.757-0.977)	0.78	0.93	0.34
Quintile 3	BL	99	16 (16.2%)	0.932 (0.88-0.984)	0.94	0.81	1439
	BL/TBV	99	16 (16.2%)	0.932 (0.879-0.985)	0.94	0.81	0.30
Quintile 4	BL	104	22 (21.2%)	0.846 (0.727-0.965)	0.73	0.94	1635
	BL/TBV	104	22 (21.2%)	0.847 (0.731-0.963)	0.68	0.96	0.34
Quintile 5	BL	102	17 (16.7%)	0.788 (0.661-0.915)	0.77	0.98	1485
	BL/TBV	102	17 (16.7%)	0.787 (0.659-0.915)	0.71	0.81	0.28
			0.069 (c28.706)				

Figures

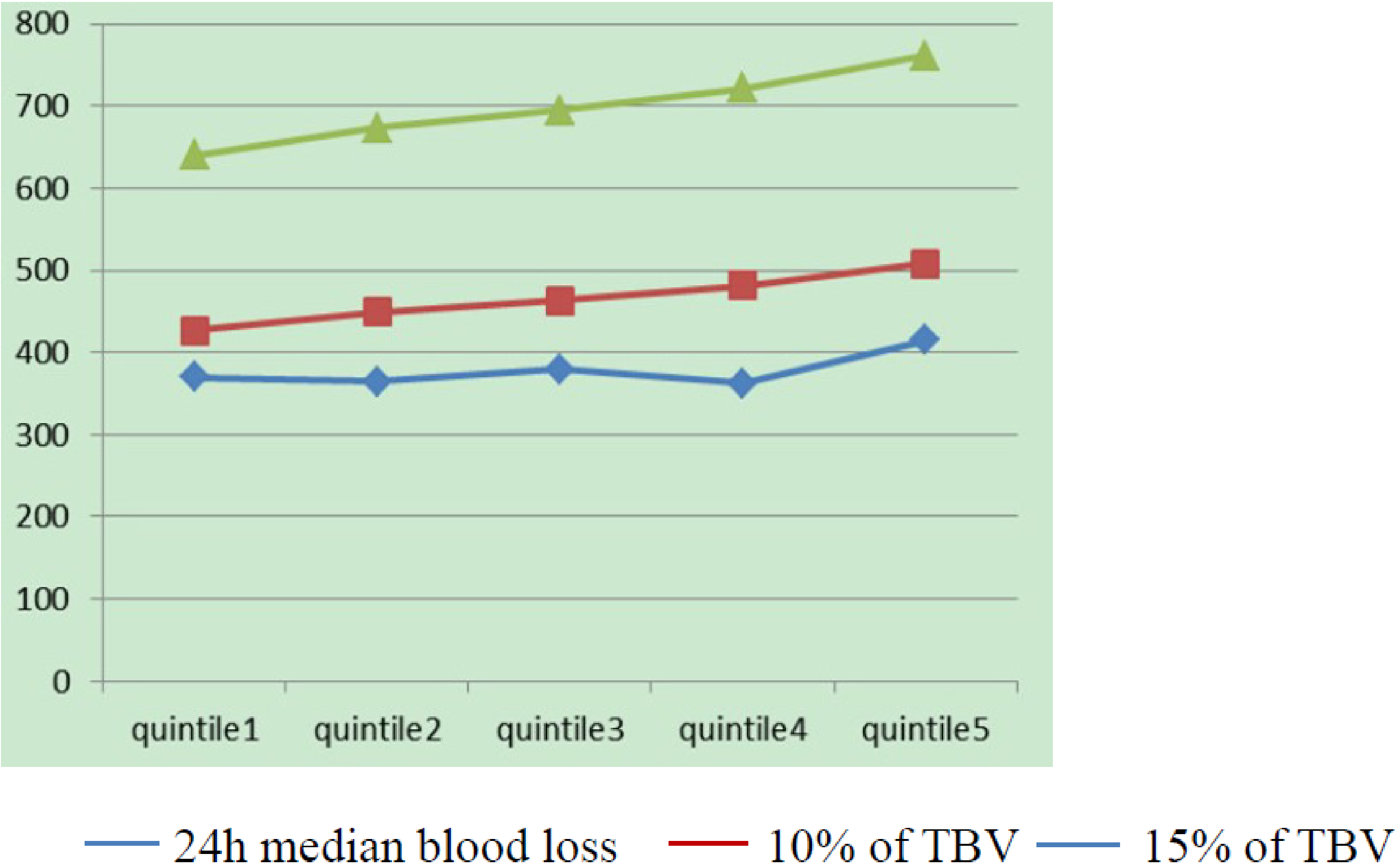

Figure 1

Median 24h estimated blood loss at each quintile, 10% and 15% of the total blood volume

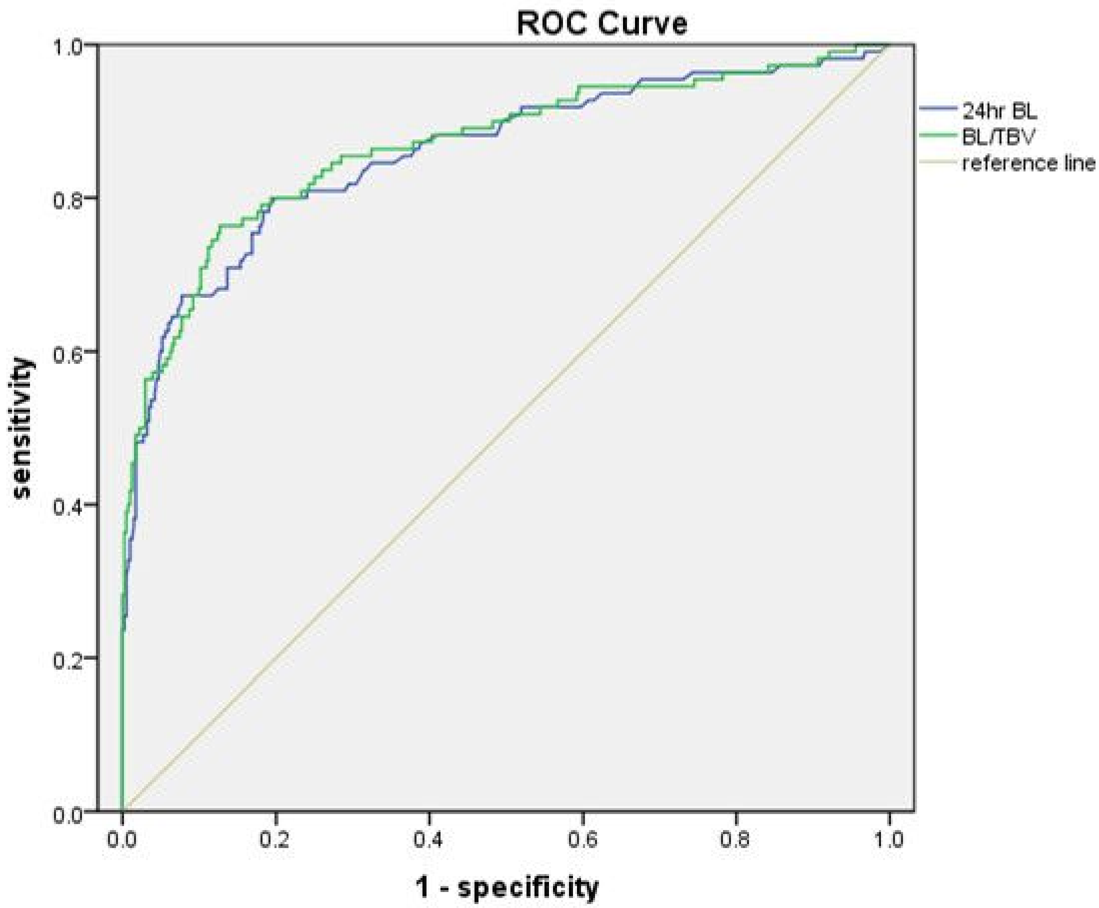

Figure 2

Roc curves of predicted blood loss and BL/TBV in 514 cases

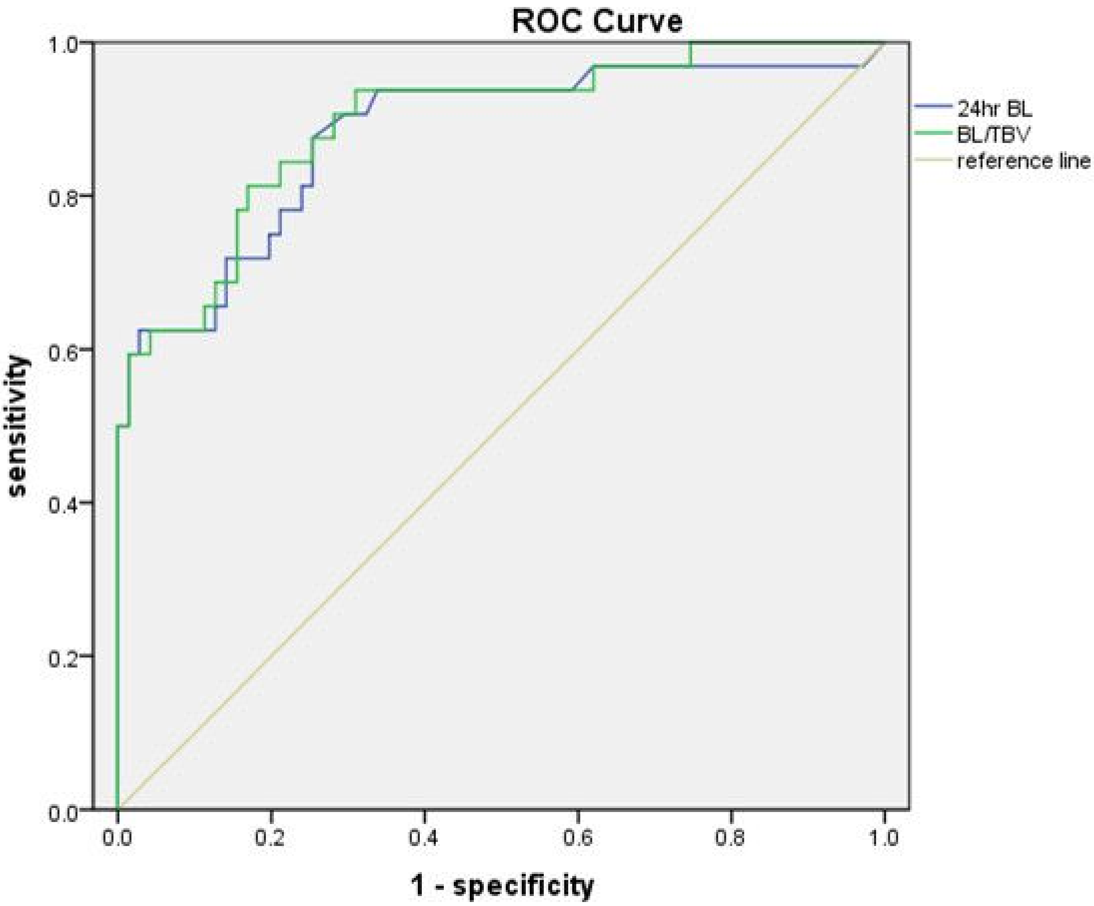

Figure 3

Roc curves of the prediction with blood loss and BL/TBV at quintile 1

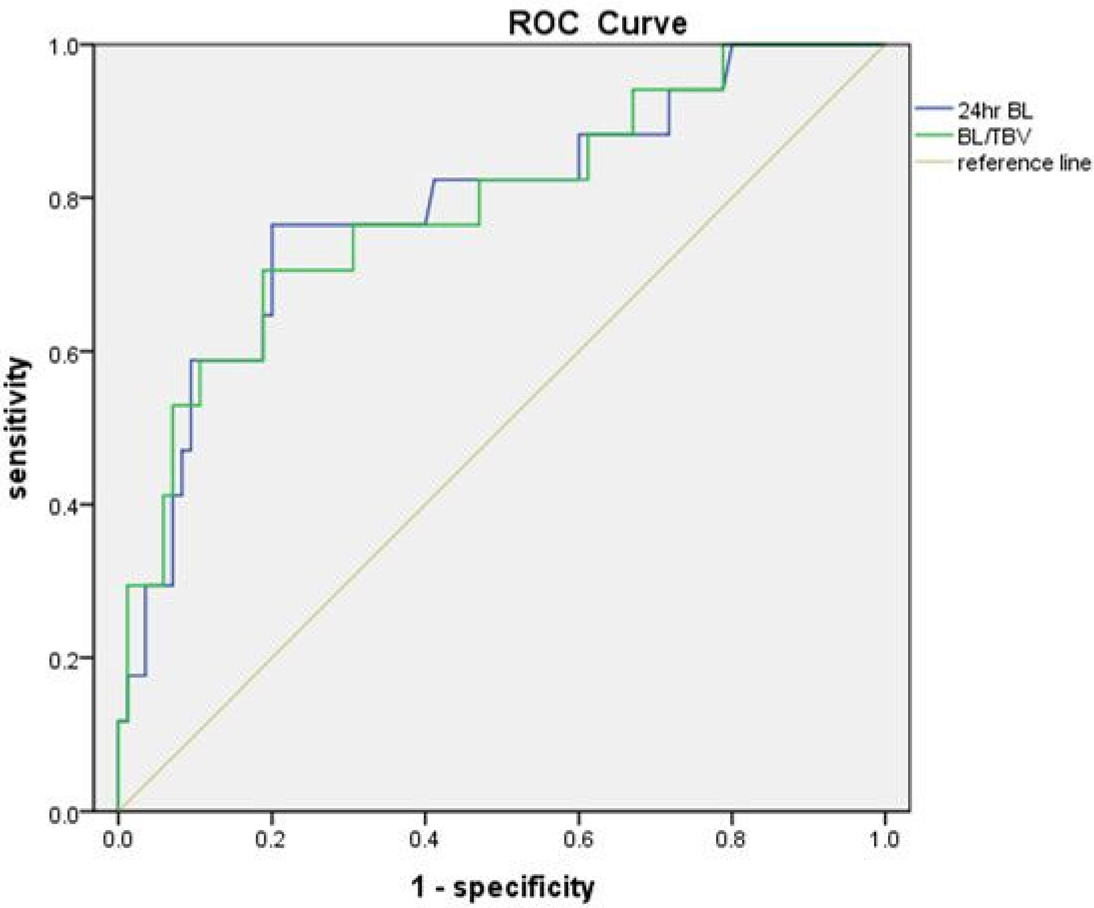

Figure 4

Roc curves of the prediction with blood loss and BL/TBV at quintile 5