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Can Maximum Surgical Blood Order Schedule Be Used as a Predictor of Successful Completion of Bloodless Surgery?

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Background: The Soonchunhyang University Hospital Bloodless Center was established in 2000, and more than 2,000 bloodless surgeries have been performed there since. In this study, the lowest postoperative Hb/preoperative Hb ($Hb_{low/pre}$) ratio and mortality rates of patients who underwent bloodless surgery were analyzed for each maximum surgical blood order schedule (MSBOS) category to assess whether MSBOS can be used as a predictor of successful completion of bloodless surgery.

Methods: A total of 971 patients were included. MSBOS was defined as the average number of units of RBCs transfused during each elective surgery. We used the $Hb_{low/pre}$ ratio as an alternative to intraoperative blood loss. Frequency of $Hb_{low/pre}$ ratios ≤0.5, use of transfusion alternatives, and mortality rates were compared across MSBOS categories.

Results: Out of the 971 patients, 701 (72.2%) were categorized as type and screen (T&S), 184 (18.9%) as MSBOS 1, 64 (6.6%) as MSBOS 2, and 22 (2.3%) as MSBOS 4. Transfusion alternatives were used by 397 (40.9%) patients. The frequency of the use of simultaneous erythropoietin and iron, hemostatics, acute normovolemic hemodilution, and Cell Saver (Haemonetics corp., USA) was higher in patients in the higher MSBOS categories. Six (0.6%) patients died within 30 days of surgery. $Hb_{low/pre}$ ratios tended to be lower as the level of MSBOS category increased.

Conclusions: Surgeries in the higher MSBOS categories tended to be associated with high blood loss and mortality. Active use of transfusion alternatives is recommended in patients in high MSBOS categories who are scheduled to undergo bloodless surgery.

Key Words: Bloodless surgery, MSBOS, $Hb_{low/pre}$ ratio, Mortality

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INTRODUCTION

Minimizing and avoiding unnecessary allogeneic transfusions appears to be beneficial for most patients. Invaluable experience has been gained from caring for severely anemic or bleeding patients who refuse blood transfusions for religious or other personal or medical reasons. In particular, patients who belong to the Jehovah's Witness faith should be treated with a more constructive approach that improves outcomes for these patients without violating their religious convictions [1-4].

The Soonchunhyang University Hospital (SCH) Bloodless Center was established in 2000 to provide the highest quality care for patients who wish to avoid blood transfusions; 2,000 bloodless surgeries have been performed since its establishment. We have previously reported on these cases [5], and have noted the influence of the lowest postoperative Hb/preoperative Hb ($Hb_{low/}$

$_{pre}$) ratio on successful completion of bloodless surgery.

Given an increasing aging population and rising concern over shortages in blood supply, optimization of blood use has become a very important issue. The introduction of the Maximum Surgical Blood Order Schedule (MSBOS)-the amount of blood to be crossmatched for specific elective operations-has helped rationalize the number of units of blood routinely crossmatched for elective surgical procedures and has concomitantly reduced the unnecessary use of blood [6-8]. In our hospital, we established a MSBOS by analyzing red blood cell (RBC) utilization for elective surgeries; since then we have used the MSBOS to reserve crossmatched blood for immediate use in elective surgery.

In this study, we analyzed the $Hb_{low/pre}$ ratio and mortality rates of patients in each MSBOS category who underwent bloodless surgery between 2003 and 2010 in order to assess whether MSBOS can be used as a predictor of successful completion of bloodless surgery.

METHODS

From January 2003 to December 2010, 1,687 patients who wished to undergo bloodless surgery visited the SCH Bloodless Center. Out of these, 971 consecutive patients whose preoperative and postoperative Hb levels 30 days after surgery could be determined and whose surgery fell into one of our MSBOS categories were included. Some of these patients were reported in our previous study [5], but the patients in this study were selected only if the surgeries they underwent fell into one of our MSBOS categories, whereas in the previous study all patients treated during the specified study period were included. Prior approval for the study was obtained from the SCH's institutional review board (2012-057).

The MSBOS was defined as the average number of units of RBCs transfused for each elective surgery [9]. Our MSBOS was initially established in 2004 for surgeries that were performed more than five times during the period investigated, and it has been modified regularly since then.

We used the $Hb_{low/pre}$ ratio as an indirect indicator of blood loss. We classified our patients according to the $Hb_{low/pre}$ ratio by allocating them to $Hb_{low/pre} \leq 0.5$ and $Hb_{low/pre} > 0.5$ groups [10]. We then compared the number of patients in each group who fell into each MSBOS category. Hb_{low} was the lowest Hb value recorded in the 30 days after surgery, and Hb_{pre} was the last available Hb value prior to surgery.

We also compared the use of transfusion alternatives such as hematinic agents (iron, erythropoietin [EPO]), hemostatics such as aprotinin, tranexamic acid, and hemocoagulase, intraoperative salvage by Cell Saver (Haemonetics corp., Braintree, MA, USA), and acute normovolemic hemodilution (ANH) before surgery for each MSBOS category. Mortality was defined as in-hospital death occurring within 30 days of surgery, and was compared across all MSBOS categories.

1. Statistics

Pearson chi-square test was used to evaluate differences in the use of transfusion alternatives, mortality rates, and the number of patients with a $Hb_{low/pre}$ ratio ≤ 0.5 for each MSBOS category. The distribution of $Hb_{low/pre}$ ratios in each MSBOS category was evaluated using the Kruskal-Wallis test. SPSS version 18.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses, and P values <0.05 were considered significant.

RESULTS

1. MSBOS categories of patients in our study who underwent elective surgery

Of the 971 patients included in our study, 701 (72.2%) were categorized as type and screen (T&S), 184 (18.9%) as MSBOS 1, 64 (6.6%) as MSBOS 2, and 22 (2.3%) as MSBOS 4. No patient was categorized as MSBOS 3 (Table 1). Surgeries are listed in Table 1 in order of frequency for each MSBOS category.

2. Comparison of the use of transfusion alternatives among MSBOS categories

Transfusion alternatives were used for 397 (40.9%) of the 971 patients. There was no statistical difference in the use of EPO and iron across the MSBOS categories. However, the frequency of use of simultaneous EPO and iron, hemostatics, ANH, and Cell Saver was statistically different among MSBOS categories ($P<0.05$, Pearson chi-square test). Patients in the MSBOS 2 and 4 categories tended to use more alternatives than patients in the T&S and MSBOS 1 categories. However, the number of patients who used transfusion alternatives was not exactly correlated with the level of MSBOS category, with the exception of ANH (Table 2).

3. Comparison of mortality rates across MSBOS categories

Six (0.6%) patients died within 30 days of surgery; 2 (0.2%) were categorized as T&S, 2 (1.1%) as MSBOS1, and 2 (9.1%) as MSBOS 4. The mortality rates were statistically different across the MSBOS categories ($P=0.000$, Pearson chi-square test) and tended to be higher in the higher level MSBOS categories.

Table 1. The MSBOS of elective surgeries included in this study

MSBOS category	Type of surgery	N of patients
T&S	Hysterectomy*	140
(N=701)	C-section	108
	Thyroidectomy*	56
	Partial dissectomy	45
	Mastectomy*	37
	Cholecystectomy*	30
	Appendectomy*	27
	Open reduction of fracture and internal fixation	22
	Removal of fixation device	21
	Excision and biopsy	19
	Ovarian cystectomy*	19
	Myolysis†	15
	Arthroscopy (knee)	13
	Closed reduction of fracture and internal fixation	12
	Salpingo-oophorectomy*	11
	Low anterior resection, laparoscopic	9
	Exploratory laparotomy	8
	Laparoscopic hemicolectomy	6
	Arthroscopy (shoulder)	6
	Gastrectomy, total	6
	Herniorrhaphy	6
	Partial resection of small intestine	4
	Transurethral resection of bladder or prostate	4
	Hemorrhoidectomy	3
	Other	74
1	Myomectomy	47
(N=184)	Bipolar hemiarthroplasty	35
	Total knee replacement arthroplasty	35
	Gastrectomy, subtotal	24
	Whipple's operation	13
	Hemicolectomy	6
	Clipping of aneurysm (brain)	6
	Lobectomy of lung	5
	Superficial temporal artery-middle cerebral artery anastomosis	3
	Miles' operation	3
	Other	7
2	Removal of brain tumor	29
(N=64)	Total hip replacement arthroplasty	25
	Liver segmentectomy	6
	Exploration and decompression of spinal cord	4
4	Hepatectomy, lobectomy	11
(N=22)	Craniotomy for evacuation of hematoma	5
	Craniectomy	3
	Revision arthroplasty	3
Total		971

*Include endoscopic, laparoscopic or pelviscopic operations; †Laparoscopic coagulation of myoma or transvaginal ultrasound-guided radiofrequency myolysis for uterine myoma

Abbreviations: MSBOS, maximum surgical blood order schedule; T&S, type and screen.

4. Distribution of $Hb_{low/pre}$ ratios according to MSBOS category

The mean, SD, and range of $Hb_{low/pre}$ ratios for each MSBOS category are shown in Table 3. Each of these parameters was statistically different across the MSBOS categories, and tended to be lower as the level of the MSBOS category increased (Kruskal-Wallis test, $P=0.000$). On the other hand, 14 (2.0%), 6 (3.3%), 2 (3.1%), and 2 (9.1%) patients in the T&S and MSBOS 1, 2, and 4 categories, respectively, had $Hb_{low/pre}$ ratios ≤ 0.5. However, there was no statistical difference in the distribution of $Hb_{low/pre}$ ratios across the MSBOS categories ($P=0.155$, Pearson chi-square test).

DISCUSSION

Bloodless surgery is a widely accepted concept that includes all available techniques and strategies to avoid exposing a patient to allogeneic blood transfusion. The selection of the most appropriate technique for a given patient requires skilled inpatient evaluation and a great deal of clinical experience [11, 12]. The SCH Bloodless Center receives approximately 630 patient visits per year on average; of these, 94% are from Jehovah's Witnesses. The SCH bloodless medicine team consists of a patient coordinator, a nurse, and hematology, chest surgery, general surgery, and laboratory medicine specialist physicians. All team members actively cooperate in assessing and monitoring patients who wish to receive bloodless treatment [8, 13].

When physicians order more blood than is needed, the blood becomes unavailable to other patients, which may increase the outdate rate. Therefore, providing testing guidelines such as the T&S policy and the MSBOS may be useful for decreasing the amount of blood wasted [14, 15]. The MSBOS is a guideline for appropriate patient care that aids physicians in determining the number of units appropriate for each patient. A T&S order is recommended for procedures that require, on average, <0.5 units of blood per patient per procedure [9].

In this study, we analyzed the $Hb_{low/pre}$ ratio and mortality rates of patients in each MSBOS category who underwent bloodless surgery. The $Hb_{low/pre}$ ratio was used as an alternative to intraoperative blood loss. Wu et al. [16] calculated intraoperative blood loss based on preoperative and postoperative hematocrit levels and units of RBCs transfused intraoperatively. We were unable to directly calculate intraoperative blood loss because we could not obtain consistent postoperative Hb data from the same postoperative day due to the retrospective nature of the study. Karkouti et al. [10] found that a >50% decrease in Hb concentration was independently associated with increased risk of

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Table 2. Comparison of the use of transfusion alternatives across MSBOS categories

Transfusion alternatives	MSBOS				Total	*P* value*
	T&S	1	2	4		
Erythropoietin (EPO)	3 (0.4)†	2 (1.1)	0 (0.0)	0 (0.0)	5 (0.5)	0.632
Iron	63 (9.0)	12 (6.5)	4 (6.3)	3 (13.6)	82 (8.4)	0.510
EPO & iron	98 (14.0)	88 (47.8)	43 (67.2)	12 (54.5)	241 (24.8)	0.000
Hemostatics	19 (2.7)	2 (1.1)	4 (6.3)	2 (9.1)	27 (2.8)	0.045
ANH	67 (9.6)	36 (19.6)	33 (51.6)	12 (54.5)	148 (15.2)	0.000
Cell Saver	46 (6.6)	61 (33.2)	29 (45.3)	7 (31.8)	143 (14.7)	0.000
Any alternatives‡	203 (29.0)	113 (61.4)	62 (96.9)	19 (86.4)	397 (40.9)	0.000

*Pearson chi-square test; †Number (%) of patients; ‡Number (%) of patients treated with any of transfusion alternatives.
Abbreviations: MSBOS, maximum surgical blood order schedule; ANH, acute normovolemic hemodilution.

Table 3. Distribution of $Hb_{low/pre}$ ratios across MSBOS categories

	MSBOS				*P* value*
	T&S	1	2	4	
Mean	0.819	0.750	0.757	0.655	0.000
SD	0.112	0.116	0.113	0.192	0.000
Range	0.330-0.994	0.320-0.987	0.048-0.992	0.184-0.926	0.000

*Kruskal-Wallis test, $P=0.000$.
Abbreviations: $Hb_{low/pre}$, the lowest postoperative Hb/preoperative Hb; MSBOS, maximum surgical blood order schedule; T&S, type and screen; SD, standard deviation.

death, stroke, and kidney failure. In our study, the $Hb_{low/pre}$ ratio tended to be lower as the level of the MSBOS category increased, and the percentage of patients with an $Hb_{low/pre}$ ratio ≤ 0.5 tended to be higher as the level of the MSBOS category increased. Mortality rates also tended to be higher in the higher-level MSBOS categories. These results suggest that surgeries with a high MSBOS classification tend to be associated with high blood loss and mortality. Meanwhile, the frequency of use of simultaneous EPO and iron, hemostatics, ANH, and Cell Saver was higher in patients in the MSBOS 2 and 4 categories compared with the T&S and MSBOS 1 categories who underwent bloodless surgery. Physicians or surgeons can refer to our study when using transfusion alternatives, especially for patients in the higher MSBOS categories who are scheduled to undergo bloodless surgery. In our protocol for bloodless surgery, we usually recommend the use of transfusion alternatives such as intravenous EPO (200 IU/kg, 3 times/week), subcutaneous darbepoetin (240 μg, 1 time/week), or intravenous iron (100 mg, only if the ferritin level is <200 mg/dL) in patients with Hb levels <13 g/dL.

There were several limitations in our study, including the use of a low-risk group of patients and the inability to estimate direct blood loss during surgery or to evaluate postoperative complications within each MSBOS category. In addition, the number of deaths was insufficient to support any relationship between mortality and MSBOS category.

However, this is the first report to evaluate $Hb_{low/pre}$ ratios and mortality rates across MSBOS categories in patients who have undergone bloodless surgery. We previously reported on the characteristics of patients who underwent bloodless surgery and the influences of postoperative Hb_{low} along with the $Hb_{low/pre}$ ratio on successful completion of bloodless surgery [5]. In this study, we especially classified our patients with bloodless surgery according to MSBOS and evaluated $Hb_{low/pre}$ ratios and mortality rates among MSBOS categories. Therefore, we expect that our data will be helpful for predicting successful bloodless surgery according to MSBOS category.

In the future, a prospective multicenter study involving other bloodless centers in Korea and including more high-risk patients is needed to evaluate and compare mortality rates, actual operative blood loss, and postoperative complications across MSBOS categories and to establish evidence-based guidelines for bloodless surgery.

Authors' Disclosures of Potential Conflicts of Interest

No potential conflicts of interest relevant to this article were reported.

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