Original Article

JHSMR Journal of Health Science and Medical Research

Efficacy of Blood Utilization in Elective Surgery for Non-COVID Patients during COVID-19 Outbreaks

Perinpit Jitmun, R.N., Sunisa Chatmongkolchart, M.D.

Department of Anesthesia, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

Received 2 November 2023 ● Revised 26 December 2023 ● Accepted 31 December 2023 ● Published online 29 April 2024

Abstract:

Objective: This study aimed to evaluate the pattern of blood transfusion requests and utilization in non-coronavirus disease (COVID) patients having undergone elective surgeries during the COVID-19 pandemic.

Material and Methods: The pattern of blood transfusion requests and utilization for elective surgical procedures in six departments of a University Hospital; between January 2020 and December 2021, were retrospectively evaluated. The cross-match-to transfusion (C/T) ratio, transfusion probability (%T), transfusion index (Ti), and maximum surgical blood order schedule (MSBOS) were calculated.

Results: A total of 15,030 patients underwent elective surgery. Among the 14,426 units of blood requested, 12,776 (89%) units were cross-matched preoperatively for 5,799 (39%) patients, and an additional 1,650 (11%) units were requested for 394 (2.6%) patients intraoperatively. Among these, 4,588 (32%) units were transfused to 1,710 (11.4%) patients. The overall C/T ratio, %T, and Ti were 2.78, 29.5%, and 0.79, respectively. Blood utilization indices for each department varied substantially according to the type of surgery, with blood utilization indices being unfavorable for 68 (80%) of the 85 procedures. The MSBOS was 0 for 32 procedures.

Conclusion: Over-ordering of blood units for elective surgical procedures remained common during the COVID-19 pandemic. The blood utilization indices showed substantial variations according to the type of surgical procedures. The MSBOS has been formulated to assist in future decision-making.

Keywords: blood utilization, COVID-19, C/T ratio, MSBOS, pandemic, transfusion

Contact: Sunisa Chatmongkolchart, M.D.
Department of Anesthesia, Faculty of Medicine, Prince of Songkla University,
Hat Yai, Songkhla 90110, Thailand.
E-mail: sunisasherry@gmail.com

J Health Sci Med Res 2025;43(1):e20241058
doi: 10.31584/jhsmr.20241058
www.jhsmr.org

Introduction

The number of units of blood requested preoperatively often exceeds the actual requirement, resulting in insufficient blood circulation, increased costs, wastage of time, and an increase in the workload of the blood bank staff. The American Association of Blood Banks (AABB) guidelines recommend the use of three indicators to ensure appropriate blood use: cross-match to transfusion (C/T) ratio. These are the probability of transfusion (%T), transfusion index (Ti)[1]. A C/T ratio of >2.5, %T of <30%. and Ti of <0.5 indicating inefficient blood utilization[1]. The maximum surgical blood order schedule (MSBOS), an international standard used for the preparation of appropriate amounts of blood in surgery, has been found to reduce excess blood preparation[2-7].

The practice of blood preparation, as well as the pattern of blood transfusion requests and utilization for elective surgery at our hospital, has not met international standards since 2003, with C/T ratios of 6.5 and 3.6 reported in 2003[8] and 2008[7], respectively. Notably, the C/T ratio has only decreased to 2.6, despite the introduction of MSBOS, indicating that the utilization of blood remains inefficient[7].

The COVID-19 pandemic has resulted in a worldwide shortage of blood, owing to the decrease in the number of blood donors[9,10]. It has been hypothesized that the pattern of blood transfusion requests and utilization in elective surgeries for non-coronavirus disease (COVID) patients may become more efficient at our hospital.

Therefore, this study aimed to examine the efficacy of blood transfusions in patients undergoing elective surgery at Songklanagarind Hospital during the COVID-19 pandemic, and to establish MSBOS for elective surgical procedures.

Material and Methods

This retrospective study was approved by the Institutional Review Board and the Human Research Ethics Committee of the Faculty of Medicine, Prince of Songkla University (REC. 65-166-8-7). Patients having undergone elective surgery at a university hospital in southern Thailand; between January 2020 and December 2021, were identified from the electronic medical records of the hospital and anesthetic databases and included in this study. Elective surgeries included: surgeries performed in the Departments of Orthopedics, Obstetrics & Gynecology, Cardiothoracic Surgery, General Surgery, Neurosurgery, and Urology.

The following data were collected from the medical records and databases:

1. Patient characteristics: age, gender, comorbidities, American Society of Anesthesiologists (ASA) physical status classification, and preoperative hematocrit (Hct)
2. Intraoperative data: type of surgery, duration of surgery, and estimated blood loss
3. Details related to blood transfusion requests and utilization: the number of red blood cell (RBC) units cross-matched preoperatively, the number of RBC units cross-matched intraoperatively, and the number of RBC units transfused intraoperatively and up to 24 hours postoperatively.
4. The efficiency of blood utilization expressed as: C/T ratio, %T, and Ti.

The blood utilization indices were calculated using the following formulae:

1. C/T ratio=number of cross-matched units requested preoperatively/number of units transfused (intraoperatively and up to 24 hours postoperatively). A value ≤2.5 indicates effective blood usage.
2. %T=(total number of patients transfused/total number of patients cross-matched)×100. A value ≥30% indicates effective blood usage.
3. Ti=number of units transfused/number of patients who were cross-matched. A value ≥0.5 indicates effective blood usage.
4. MSBOS=1.5×Ti. MSBOS is the estimated amount of blood required for an individual procedure.

In addition, the blood utilization indices were also calculated for each procedure in each department

Statistical analysis

The data were entered into a Microsoft Excel spreadsheet, after ensuring completeness, consistency, and was then analyzed subsequently. Categorical data are expressed as numbers, frequencies, and percentages; whereas, continuous data are presented as mean and standard deviation or median and interquartile range (IQR), as appropriate; according to the data distribution.

Results

A total of 15,030 patients from six surgical departments underwent elective surgery between January 2020 and December 2021. From these, 59% were female, and 64.4% of patients were aged between 15-64 years, more than 60% were ASA class II This was with the exception for those in neurosurgery and cardiothoracic surgery (>65%); wherein, these were ASA class III, 86% of patients had Hct ≥30% with the mean Hct being 37.9± 4.5%, the mean operative time was 205±120 minutes, and the median (IQR) estimated blood loss was 250 (50-500) mL. Table 1 presents the blood utilization indices of each department.

Among the 14,426 units of blood that were cross-matched, 12,776 (88.6%) and 1,650 (11.4%) units were cross-matched preoperatively and intraoperatively, respectively. Only 4,588 (32%) units were transfused, with 9,838 (68%) units being unused.

The overall blood utilization indices were as follows: C/T ratio 2.78; %T 29.5%; and Ti 0.79. The Department of Cardiothoracic Surgery, with a C/T ratio of 1.5, %T of 59.1%, and Ti of 2.1, was the only department that demonstrated effective blood utilization. The Department of Urology had the most unfavorable C/T ratio (5.88). The three indices of the Department of Urology, Obstetrics & Gynecology and Neurology did not reach the target values.

The %T reached the target value in the Departments of Cardiothoracic Surgery and General Surgery. The Department of Obstetrics & Gynecology had the most unfavorable %T (18.3%).

The Departments of Cardiothoracic Surgery, Neurosurgery, and Orthopedics were able to achieve the target Ti value. The Department of Cardiothoracic Surgery had the highest Ti (2.1).

Table 1 Blood requirement and blood utilization indices by departments

Departments	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)
	Case	Unit	Case	Unit	Case	Unit			
Orthopedics	1,572	2,887	94	358	463	1,007	2.87	29.5	0.64
Obstetrics-and gynecology	1,394	2,181	77	338	255	582	3.75	18.3	0.42
Cardiothoracic	866	2,783	89	357	512	1,823	1.53	59.1	2.11
General	841	1,506	57	231	179	388	3.66	33.0	0.46
Neurosurgery	594	2,007	60	298	196	548	3.88	21.3	0.92
Urology	532	1,412	17	68	105	240	5.88	19.7	0.45
Total	**5,799**	**12,776**	**394**	**1,650**	**1,710**	**4,588**	**2.78**	**29.5**	**0.79**

Tables 2–7 present the blood utilization indices according to the procedures for each department. A large difference in blood utilization was observed according to the procedure in each department, with the C/T ratios varying from <1 to >100. The three indices reached the target value in only 17 (20%) of the 85 procedures. The following surgeries had effective C/T ratios: revision of hip replacement (0.97) (Table 2), cesarean hysterectomy (0.8) (Table 3), procedures requiring cardiopulmonary bypass (Table 4), adrenalectomy (1.8) (Table 5), craniotomy for brain tumor removal (2.2) (Table 6), and the revision of nephrectomy with inferior vena cava (IVC) thrombectomy (0.7) (Table 7). The MSBOS was 0 for 32 surgical procedures.

Table 2 The blood utilization indices in orthopedic patients by procedure

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
Revision of hip replacement	15	45	7	24	15	46	1.0	88.0	3.10	4.6
Open reduction internal fixation	506	998	53	204	213	478	2.0	42.0	0.94	1.4
Arthrotomy	10	19	1	2	4	9	2.0	40.0	0.90	1.4
Spine decompression with instrument	53	162	3	16	25	64	2.5	47.1	1.20	1.8
Total hip arthroplasty	88	151	2	20	29	57	2.6	32.9	0.65	0.97
Close reduction internal fixation	28	52	0	0	8	19	2.7	28.5	0.68	1.0
Bipolar hemiarthroplasty	53	95	1	4	20	33	2.8	33.7	0.62	0.93
Tumor resection	191	343	14	59	36	122	2.8	18.8	0.64	0.96
Amputation	32	61	1	3	13	18	3.4	40.0	0.56	0.84
External fixation	20	35	1	3	4	10	3.5	20.0	0.50	0.75
Remove/off implant	80	120	4	7	18	27	4.4	22.5	0.34	0.51
Irrigation debridement and dressing wound	118	185	3	9	27	41	4.5	22.8	0.35	0.52
Spine decompression	173	358	2	4	39	67	5.3	22.5	0.39	0.58
Revision fixator	27	38	1	2	4	7	5.4	14.8	0.26	0.39
Arthroscopy	15	19	0	0	1	2	9.5	6.6	0.13	0.2
Release/repair muscle ligament	38	46	1	1	3	3	15.3	1.8	0.0	0.0
Total knee arthroplasty	69	84	0	0	4	4	21.0	5.7	0.0	0.0
Close reduction	7	9	0	0	0	0	>100.0	0.0	0.0	0.0
Revision of knee replacement	5	10	0	0	0	0	>100.0	0.0	0.0	0.0
Minimally invasive spine surgery	27	36	0	0	0	0	>100.0	0.0	0.0	0.0
Hand microvascular nerve surgery	15	21	0	0	0	0	>100.0	0.0	0.0	0.0
Total	**1,572**	**2,887**	**94**	**358**	**463**	**1,007**	**2.8**	**29.4**	**0.64**	

C/T=cross-match-to transfusion, %T=transfusion probability, Ti=transfusion index, MSBOS=maximum surgical blood order schedule

Table 3 The blood utilization indices in obstetric and gynecologic patients by procedure

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
Cesarean hysterectomy	22	98	8	86	20	112	0.8	90.9	5.10	7.6
Cesarean section with myoma	9	20	3	11	6	15	1.3	66.6	1.67	2.5
Cesarean section with pracenta previa	27	72	1	10	9	23	3.1	33.3	0.85	1.3
Cesarean section	131	175	0	0	10	12	14.5	7.6	0.09	0.1
Myomectomy/debulking tumor	88	142	5	24	23	47	3.0	26.1	0.53	0.8
TAH BS/BSO	496	785	37	129	111	238	3.2	22.3	0.48	0.7
Hysterectomy	74	110	4	16	14	23	4.7	18.9	0.31	0.5
Surgical staging	179	271	8	29	35	57	4.7	19.5	0.32	0.5
Salpingectomy/oophorectomy	102	152	6	17	14	30	5.0	13.7	0.29	0.4
Ovarian cystectomy	28	37	3	9	4	7	5.2	14.2	0.25	0.4
Hysteroscopic surgery	23	35	0	0	1	2	17.5	4.3	0.09	0.1
Laparoscopic surgery	140	177	1	3	6	9	19.6	4.2	0.06	0.1
Omentectomy lysis adhesion	10	17	0	0	0	0	>100.0	0.0	0.0	0.0
Vaginal hysterectomy pelvic floor repair	40	43	0	0	0	0	>100.0	0.0	0.0	0.0
Others*	25	47	1	4	2	7	6.7	8.0	0.28	0.4
Total	**1,394**	**2,181**	**77**	**338**	**255**	**582**	**3.7**	**18.2**	**0.42**	

C/T=cross-match-to transfusion, %T=transfusion probability, Ti=transfusion index, MSBOS=maximum surgical blood order schedule, TAH=transabdominal hysterectomy, BS=bilateral salpingectomy, BSO=bilateral salpingo-oophorectomy

*include endometrial biopsy, fractional curettage, PAP smear, intrauterine device, remove gauze from vagina, ileal conduit

Table 4 The blood utilization indices in cardiothoracic surgical patients by procedure

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
(I) Require CPB										
Other general thoracic surgery	2	8	1	6	2	17	0.5	100.0	8.5	12.8
Bentall's operation	19	86	15	106	19	168	0.5	100.0	8.8	13.2
CABG and valve repair/ replacement	30	122	8	25	28	151	0.8	93.3	5.0	7.5
Valve repair and replacement	164	676	25	112	163	581	1.1	99.3	3.5	5.2
Coronary artery bypass graft	169	677	24	68	166	560	1.2	98.2	3.3	4.9
Correcting congenital cardiac defects	100	387	13	33	95	276	1.4	95.0	2.7	4.1
(II) CPB is not required										
Off pump coronary artery bypass	4	16	0	0	2	4	4.0	50.0	1.0	1.5
Correcting cardiac defects (PDA ligation, BT shunt)	29	69	1	1	9	11	6.2	31.0	0.38	0.6
Thoracotomy	108	239	1	2	15	32	74	13.0	0.30	0.4

Table 4 (continued)

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
Lobectomy	189	391	1	4	13	23	17.0	6.0	0.12	0.2
Transcatheter aortic valve implantation	5	20	0	0	0	0	>100.0	0.0	0.0	0.0
Video-assisted thoracic surgery	44	87	0	0	0	0	>100.0	0.0	0.0	0.0
Other general thoracic surgery*	3	5	0	0	0	0	>100.0	0.0	0.0	0.0
Total	**866**	**2,783**	**89**	**357**	**512**	**1823**	**1.5**	**59.0**	**2.1**	

C/T=cross-match-to transfusion, %T=transfusion probability, Ti=transfusion index, MSBOS=maximum surgical blood order schedule, CPB=cardiopulmonary bypass, CABG=coronary artery bypass graft, PDA=patent ductus arteriosus, BT=Blalock-Taussig
*tracheostomy

Table 5 The blood utilization indices in general surgical patients by procedure

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
Adrenalectomy	4	9	1	4	2	5	1.8	50.0	1.25	1.8
Liver/Hepatofocal resection	109	191	15	65	36	82	2.3	33.0	0.75	1.1
Abdominal exploration	186	374	23	118	53	161	2.3	28.0	0.86	1.3
Amputation	10	23	0	0	4	7	3.2	40.0	0.70	1.0
Whipple procedure	81	152	7	16	22	37	4.1	27.0	0.45	0.6
Hyperthermic intraperitoneal chemotherapy	6	14	0	0	2	3	4.6	33.0	0.50	0.7
Bowel resection	69	123	5	12	13	26	4.7	18.8	0.38	0.5
Irrigation and debridement	35	54	0	0	9	9	6.0	25.7	0.26	0.3
Esophagectomy	24	52	1	3	4	8	6.5	16.6	0.33	0.5
Gastrectomy	20	34	0	0	3	4	6.8	15.0	0.20	0.3
Thyroid/Parathyroidectomy	10	15	0	0	1	2	7.5	10.0	0.20	0.3
Laparoscopic surgery	265	431	5	13	29	43	10.0	10.9	0.16	0.2
Mastectomy	8	16	0	0	1	1	16.0	12.5	0.12	0.1
Others*	14	18	0	0	0	0	>100.0	0.0	0.0	0.0
Total	**841**	**1,506**	**57**	**231**	**179**	**388**	**3.88**	**21.0**	**0.46**	

C/T=cross-match-to transfusion, %T=transfusion probability, Ti=transfusion index, MSBOS=maximum surgical blood order schedule, *includes port A insertion, tenckhoff insertion or removal, radiofrequency ablation of liver tumors, tumor removal at brachial plexus, s tump suturing, percutaneous transluminal angioplasty (PTA), remove graft, split-thickness skin graft (STSG)

Table 6 The blood utilization indices in neurosurgical patients by procedure

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
Craniotomy for brain tumor removal	320	1,224	57	280	197	551	2.2	61.5	1.72	2.6
Microvascular decompression	2	8	0	0	1	2	4.0	50.0	1.0	1.5
Repair dura/meningocele	16	40	0	0	6	7	5.7	37.5	0.44	0.7
STA-MCA bypass	15	58	0	0	4	9	6.4	26.6	0.60	0.9
Aneurysm clipping	10	40	2	8	2	6	6.6	20.0	0.60	0.9
Transsphenoidal surgery for pituitary tumours	52	159	4	10	13	22	7.2	25.0	0.42	0.6
Laminectomy	43	152	0	0	8	14	10.8	18.6	0.33	0.5
Cervical-spine fixation	26	90	0	0	4	5	18.0	15.3	0.19	0.3
Burr hole with varioguide biopsy	29	72	0	0	2	2	36.0	6.8	0.0	0.0
VP shunt/EVD	58	112	0	0	1	1	>100.0	1.7	0.0	0.0
Cranioplasty	7	16	0	0	0	0	>100.0	0.0	0.0	0.0
Tracheostomy	8	15	0	0	0	0	>100.0	0.0	0.0	0.0
Other cranial operations*	8	20	0	0	0	0	>100.0	0.0	0.0	0.0
Total	**594**	**2,007**	**60**	**298**	**196**	**548**	**3.6**	**32.9**	**0.92**	

C/T=cross-match-to transfusion, %T=transfusion probability, Ti=transfusion index, MSBOS=maximum surgical blood order schedule, STA=superficial temporal artery, MCA=middle cerebral artery, VP=ventriculoperitoneal, EVD=external ventricular drain; TSS=Transsphenoidal surgery for pituitary tumors

*includes coiling and flow-diversion stent insertion, syringo-pleural stent, untethering of the spinal cord, subduro-peritoneal drainage

Table 7 The blood utilization indices in urological surgery patients by procedure

Type of operation	Pre-op cross match		Intra-op cross match		Transfused		C/T ratio	Transfusion probability (%T)	Transfusion index (T_i)	MSBOS unit
	Case	Unit	Case	Unit	Case	Unit				
Nephrectomy with IVC thrombectomy	2	10	2	6	2	13	0.7	100.0	6.5	9.8
Cystectomy	65	231	2	9	39	87	2.6	60.0	1.34	2.0
Nephrectomy	52	190	7	32	21	71	2.6	40.0	1.36	2.0
Pyelolithotomy	10	20	0	0	1	2	10.0	10.0	0.20	0.3
Kidney transplant	8	30	0	0	1	3	10.0	12.5	0.38	0.6
Transurethal endoscopic surgery	140	243	2	7	18	23	10.5	12.8	0.16	0.2
Laparotomy	168	495	2	8	16	27	18.3	9.5	0.16	0.2
Percutaneous nephrolithotomy	57	114	0	0	1	1	>100.0	1.7	0.0	0.0
Other urological surgery*	30	75	2	6	6	15	5.0	20.0	0.50	0.8
Total	**532**	**1,412**	**17**	**68**	**105**	**240**	**5.8**	**19.7**	**0.45**	

C/T=cross-match-to transfusion, %T=transfusion probability, Ti=transfusion index, MSBOS=maximum surgical blood order schedule, IVC=inferior vena cava, PCNL percutaneous nephrolithotomy

*including groin node dissection, penectomy, orchiectomy, testicular tumor removal, vesicostomy repair, incision and drainage

Discussion

This study evaluated the efficacy of blood utilization for elective surgery for non-COVID patients during the COVID-19 pandemic. It found that over-ordering of blood remains common, and 68% of the cross-matched blood was not used. Preoperative typing and screening, rather than crossmatching, should be performed, as indicated by MSBOS being equal to zero, in 32 surgical procedures. The results of this study align with those of studies conducted before the COVID outbreak[2,11-15].

The most efficient use of blood was observed in cardiothoracic surgery in this present study, and the most effective procedure was surgery requiring cardiopulmonary bypass. Cardiac surgeries are associated with a risk of severe bleeding and require large amounts of blood, owing to the surgical method and patient factors. The findings of this present study are consistent with those of the study by Mangwana et al, which reported a C/T ratio of 1.34, %T of 83%, and Ti of 1.22[16]. However, unlike this present study, which only included elective surgeries, their study included both emergency and elective surgeries. The most effective C/T ratio was observed for CABG with valve repair (1.4) and CABG (2.22); the corresponding values in this study were 0.8 and 1.2, respectively. Both procedures required additional cross-matching intraoperatively.

Several neurosurgical procedures, ranging from intracranial procedures (brain tumor, spinal surgery) to minor procedures (burr hole, biopsy, external ventricular drainage) were included in this present study. Hence, the overall utilization indices do not meet international standards. Craniotomy for tumor removal was the only procedure showing effective blood utilization. Several factors, including age, gender, and extension of the surgery, affected the transfusion probability for neurosurgical procedures[14]. Although a high risk for intraoperative blood transfusion is associated with brain tumor, the C/T ratio was 5.0–8.7; indicating excessive preoperative blood preparation[3,17]. In contrast, craniotomy with tumor removal had a C/T ratio of 2.2, %T of 61%, and Ti of 1.7 in this present study.

Although MSBOS was derived for each neurosurgical procedure, a wide variation in blood preparation and utilization was observed for each procedure. For instance, among the 320 patients that underwent craniotomy with tumor removal, 57 (18%) required additional cross-matched blood intraoperatively. Thus, blood reservations must be considered individually in the future. Tunthanathip et al.[18]. used machine learning to guide blood preparation for craniotomy with tumor removal, and reported that this method was more specific and cost-effective. This model included nine factors: tumor classification, tumor size, type of operation, preoperative seizures, hypertension, hemoglobin level, gender, body mass index, and ASA classification.

Urological and obstetric & gynecological procedures showed the least effective blood utilization in this present study, which is consistent with the findings of a study conducted in Ethiopia[11,12]. General surgery and orthopedics procedures had a considerable number of non-transfused blood in this present study, and this is comparable with the findings of studies conducted in India and Pakistan[2,13]. However, previous studies collected data over a period of 2–6 months; wherein, this present study collected data over 2 years. Moreover, a significant number of surgeries for each type were included in this present study.

Several blood conservation policies have been formulated to reduce unnecessary cross-matching of blood; such as the surgical blood ordering equation[19,20], patient-specific blood ordering system[21], and MSBOS[2-6,22-24]. However, MSBOS remains the most widely implemented strategy[2-6,22-24]. MSBOS was introduced in the 1970s[25,26], and was found to reduce unnecessary cross-matching, enhance patient safety and be cost-effective[3,27]. Although, several strategies can be used to calculate MSBOS[3,5,24,28]. MSBOS was calculated using Mead's criteria in this present study (MSBOS=1.5xTi)[29].

MSBOS was first introduced at our institution in 2005 and revised in 2008[7,8]. However, blood requests remain a routine practice owing to a lack of regular action, continuous follow-up and feedback. Blood requests remained a routine practice during the COVID-19 pandemic[18] and did not meet international standards.

The MSBOS recommendations in this current study differed significantly from the recommendations in the study conducted at our institution in 2008[8]; such as hepatectomy, esophagectomy, and pancreaticoduodenectomy (Table 8). This was owing to the increase in the number of minimally invasive surgeries and advances in modern surgical techniques leading to reduced blood loss[30]. This finding is consistent with the findings of the study by Hassan et al.[2], that reported a difference in MSBOS recommendations in studies conducted at the same institution 14 years apart. Hence, it is necessary to update MSBOS regularly, as recommended by Kim et al.[6] They conducted a study that included 77,639 elective surgeries of between 2016 and 2021, which evaluated the average number blood units transfused and the decrease in the average annual %T over time[6].

Healthcare professionals acknowledged the difficulty of cross-matching during the COVID-19 pandemic[31]. Nevertheless, preoperative blood requests remain a routine practice. The practice of preparing blood products before commencing surgery, combined with the acknowledgment of blood shortages, maybe the cause for the tendency to request cross-matching of blood for elective procedures during COVID-19 outbreaks. Surgeons and anesthesiologists may prefer preparing excess blood products preoperatively. The findings of this present study are consistent with those of a study conducted in Ethiopia[22]; however, they are in contrast with those of a study conducted in Northern India[32]. These studies collected data on blood reservations during the COVID-19 outbreaks. The C/T ratio was 4.6 in the study from Ethiopia, and 77.7% of cross-matched blood units were not transfused[22]. The study from Northern India, which collected data between November 2019 and November 2020, reported a C/T ratio of 1.1, indicating remarkable effectiveness. However, 83.3% of the donors were replacement donors in their study[32], which is in contrast to blood donation practices in Thailand during the COVID outbreaks. Most donors donate blood voluntarily

Table 8 Comparing the recommended MSBOS

Type of operation	Study in 2008[8] (before using MSBOS)	Study in 2008[8] (following MSBOS)	Current study (Recommended MSBOS)
Hepatectomy	4	3	1.1
Esophagectomy	4	4	0.5
Gastrectomy	2	2	0.3
Thyroidectomy	T/S	T/S	0.3
Pancreaticoduodenectomy	4	3	0.6
Mastectomy	T/S	0	0.1
Lung resection	2	T/S	0.2
TUR-P	T/S	T/S	0.2
Nephrectomy	2	T/S	2.0
Cystectomy	4	4	2.0
Craniotomy with tumor removal	6	2	2.6
Craniotomy with aneurysm clipping	4	2	0.9

MSBOS=maximum surgical blood order schedule, TUR-P=transurethral resection of the prostate, T/S=type and screen and are not remunerated: replacement donors accounted for approximately 13% of cases[33].

Global blood donations decreased by 40-60% during the COVID-19 pandemic[34], and a decline was also observed in Thailand[1]. However, our institution is the main referral center in Southern Thailand so whilst most community hospitals were unable to provide services during some stages of the pandemic, the number of patients who underwent surgery at our institution did not decrease significantly during outbreaks. Compared with the pre-pandemic era, the overall number of elective surgeries performed at our institution decreased by approximately 8.5%. The findings of this present study showed that 88.6% of blood requests were made preoperatively, and an additional 11.4% were required urgently intraoperatively. Therefore, blood banks must always be prepared to meet urgent blood requirements, and change their blood donation policy or allocate blood from another center if necessary. Notably, it could not be verified as to whether the 9,838 units of unused blood were ultimately used or discarded.

Although MSBOS has proven to be an effective tool for reducing unnecessary cross-matching, it is affected by many factors[14,29,35]. Every single patient undergoing surgery has different risks for bleeding and transfusion. Therefore, tools must be developed to predict the risk of blood transfusions more accurately. As the data has become larger and more complex, machine learning has recently been used to predict individual blood transfusion risk in neurosurgery[18], orthopedic surgery[36] and cardiothoracic surgery[39].

The findings of this present study are the foundational steps towards developing effective and actionable tools. Several changes may be required to implement new routines[40]. Additionally, preparing for a new pandemic will require several steps, including identifying obstacles, utilizing tools and continuous monitoring with a multidisciplinary team.

Strengths of this study

This study captures the pattern of blood preparation for elective surgery over a 2-year period during the COVID-19 pandemic. The data covers a wide range of surgeries and includes a significant number of patients undergoing each surgery. In addition to intraoperative cross-matching, blood transfusions were observed until 24 hours postoperatively. Thus, the surgeries or patients unexpectedly requiring blood were recorded.

Limitations of the study

This study has certain limitations. First, the generalizability of this study is limited, owing to it being conducted in a single center, and its retrospective study design. Second, comparative data were not collected during the pre-COVID period. Third, no standardized transfusion criteria have been established. Thus, the decision to perform a blood transfusion was made by the anesthesiologist or primary physician. Fourth, patients with preoperative anemia and those receiving preoperative blood transfusions were not excluded. Lastly, patient-specific conditions; such as preoperative hemoglobin levels, comorbidities and use of anticoagulants, were not considered while calculating the MSBOS. These factors should be evaluated in future studies.

Conclusion

In summary, the COVID-19 pandemic did not alter the pattern of preoperative blood cross-matched for elective surgeries within our institution. Preoperative over-ordering of blood remains common, The blood utilization indices varied greatly according to the surgical procedure. Hence, the evaluation of individual risks is important for blood management, and tools that can accurately predict the risk of transfusion must be developed and implemented appropriately until they become a new routine.

Ethics approval of research

The study was approved by the Institutional Review Board and the Human Research Ethics Committee of the Faculty of Medicine, Prince of Songkla University (REC. 65-166-8-7).

Authors contributions

All authors made important contributions to the work reported: conception, study design, data acquisition, analysis and interpretation, drafting, revising, editing, and critically reviewing content and approving the final version of the manuscript.

Acknowledgement

The authors gratefully acknowledge the blood bank staff for their advice, cooperation, and assistance. We are grateful to Dr. Arinda Sontarapornpol for advice on data acquisition.

Conflict of interest

The authors have no conflicts of interest to disclose.

References

1. Carson JL, Guyatt G, Heddle NM, Grossman BJ, Cohn CS, Fung MK, et al. Clinical practice guidelines from the AABB: red blood cell transfusion thresholds and storage. JAMA 2016;316:2025-35. doi: 10.1001/jama.2016.9185.
2. Hasan O, Khan EK, Ali M, Sheikh S, Fatima A, Rashid HU. “It's a precious gift, not to waste”: is routine cross matching necessary in orthopedics surgery? Retrospective study of 699 patients in 9 different procedures. BMC Health Serv Res 2018;18:804.
3. Saringcarinkul A, Chuasuwan S. Maximum surgical blood order schedule for elective neurosurgery in a university teaching hospital in northern Thailand. Asian J Neurosurg 2018;13:329–35.
4. Tan PP, Abdul RJ, Mat NS, Mohd YI, Mohd NS. Implementation of maximum surgical blood ordering schedule in a tertiary hospital in Malaysia during COVID-19 pandemic. Transfus Apher Sci 2021;60:103280. doi: 10.1016/j.transci.2021.103280.
5. Woodrum CL, Wisniewski M, Triulzi DJ, Waters JH, Alarcon LH, Yazer MH. The effects of a data driven maximum surgical blood ordering schedule on preoperative blood ordering practices. Hematology 2017;22:571-7.
6. Kim J, Kim H, Shin K, Kim HH, Lee H. Necessity for regular updates of the maximum surgical blood order schedule (MSBOS). Korean J Blood Transfus 2022;33:97-106.
7. Mahattanobon S, Sunpaweravong S. Blood order guideline for elective surgery: Impact of a guideline. Songkla Med J 2008; 26:491-500.
8. Wanasuwannakul T, Vasinanukorn M, Lim A. Appropriate blood order for elective surgical procedures in Songklanagarind Hospital: analyzed from the types of operation, patients, baseline hematocrit and underlying diseases. Thai J Anesthesiol 2005;31:271-80.
9. Lertpaisankul, S Phomsila R, Thipsuwankul W, Phetsree N, Rodwihok T, Tadsomboon S. Model of blood recruitment and impact of blood management of the six lower-northern provinces during the COVID-19 pandemic in 2020. J Hematol Transfus Med 2021;31:35-45.
10. Kandasamy D, Shastry S, Chenna D, Mohan G. COVID-19 pandemic and blood transfusion services: the impact, response and preparedness experience of a tertiary care blood center in southern Karnataka, India. Hematol Transfus Cell Ther 2022; 44:17-25.
11. Zewdie K, Genetu A, Mekonnen Y, Worku T, Sahlu A, Gulilalt D. Efficiency of blood utilization in elective surgical patients. BMC Health Serv Res 2019;19:804.
12. Belayneh T, Messele G, Abdissa Z, Tegene B. Blood requisition and utilization practice in surgical patients at university of Gondar Hospital, northwest Ethiopia. J Blood Transfus 2013; 2013:758910. doi: 10.1155/2013/758910.
13. Shaikh OH, Bhattarai S, Shankar VG, Basavarajegowda A. Blood ordering and utilization in patients undergoing elective general surgery procedures in a tertiary care hospital: a prospective audit. Natl Med J India 2022;35:68-73.
14. Barth M, Weiss C, Schmieder K. Red blood cell transfusion probability and associated costs in neurosurgical procedures. Acta Neurochir 2018;160:1483-9. doi: 1007/s00701-018-3516-x.
15. Raghuwanshi B, Pehlajani NK, Sinha MK, Tripathy S. A retrospective study of transfusion practices in a tertiary care institute. Indian J Anaesth 2017;61:24-8.

16. Mangwana S, Bedi N, Yadav P, Chugh R. Optimization of blood transfusion services: analysis of blood requisition and utilization practices in cardiac surgical patients in a tertiary care hospital, India. Glob J Transfus Med AATM 2017;2:47-51.
17. Chotisukarat H, Akavipat P, Sookplung P, Damrongbul K. Effectiveness index of preoperative blood preparation for elective neurosurgery at Prasat Neurological Institute. Thai J Anesthesiol 2017;43:232–40.
18. Tunthanathip T, Sae-Heng S, Oearsakul T, Kaewborisutsakul A, Taweesomboonyat C. Economic impact of a machine learning-based strategy for preparation of blood products in brain tumor surgery. PLOS ONE 2022;17:0270916. doi: 10.1371/journal.pone.0270916.
19. Nuttall GA, Santrach PJ, Oliver WC Jr, Ereth MH, Horlocker TT, Cabanela ME, et al. A prospective randomized trial of the surgical blood order equation for ordering red cells for total hip arthroplasty patients. Transfusion 1998;38:828-33.
20. Kajja I, Bimenya GS, Eindhoven GB, Duis HJ, Sibinga CT. Surgical blood order equation in femoral fracture surgery. Transfus Med 2011;21:7-12.
21. Palmer T, Wahr JA, O'Reilly M, Greenfield ML. Reducing unnecessary cross-matching: a patient-specific blood ordering system is more accurate in predicting who will receive a blood transfusion than the maximum blood ordering system. Anesth Analg 2003;96:369-75.
22. Misganaw A, Simegn GD, Bayable SD, Aschale A, Beyable AA, Ashebir YG, et al. The practice of blood cross-match request and transfusion in surgical patients at Debre Markos comprehensive Specialized Hospital, Debre Markos, Ethiopia 2021/2022: a prospective study. Ann Med Surg 2022;80:104145. doi: 10.1016/j.amsu.2022.104145.
23. Guzman JPS, Resurreccion LL, Gepte MBP. Use of maximum surgical order schedule (MSBOS) among pediatric patients to optimize blood utilization. Ann Pediatr Surg 2019;15:4.
24. Loong TY. Guidelines on blood and blood components transfusion: maximum surgical blood order schedule (MSBOS) for elective surgery [monograph on the Internet]. Cheras, Kuala Lumpur: UKM Medical Center; 2019 [cited 2023 Oct 8]. Available from: https://hctm.ukm.my/makmal/wp-content/uploads/2020/10/2-MSBOS-ed.5.pdf
25. Friedman BA, Oberman HA, Chadwick AR, Kingdon KI. The maximum surgical blood order schedule and surgical blood use in the United States. Transfusion 1976;16:380-7.
26. Friedman BA. An analysis of surgical blood use in United States hospitals with application to the maximum surgical blood order schedule. Transfusion 1979;19:268-78.
27. Hall TC, Pattenden C, Hollobone C, Pollard C, Dennison AR. Blood transfusion policies in elective general surgery: how to optimise cross-match-to-transfusion ratios. Transfus Med Hemother 2013;40:27-31.
28. Stanworth SJ, New HV, Apelseth TO, Brunskill S, Cardigan R, Doree C, et al. Effects of the COVID-19 pandemic on supply and use of blood for transfusion. Lancet Haematol 2020;7:756–64.
29. Mead JH, Anthony CD, Sattler M. Hemotherapy in elective surgery: an incidence report, review of the literature, and alternatives for guideline appraisal. Am J Clin Pathol 1980;74:223-7.
30. Kerr RS. Surgery in the 2020s: implications of advancing technology for patients and the workforce. Future Healthc J 2020;7:46-9.
31. Miskeen E, Omer Yahia AI, Eljack TB, Karar HK. The impact of COVID-19 pandemic on blood transfusion services: a perspective from health professionals and donors. J Multidiscip Healthc 2021;14:3063-71.
32. Yasmeen I, Ahmed I, Bashir S. Efficiency of blood utilization and characteristics of patients receiving blood transfusion at an associated hospital in North India. Int J Res Med Sci 2021;9:1056-59.
33. Sripara P, Boonmawongsa N, Benjangkaprasert B. Impact of COVID-19 pandemic on blood donation in blood transfusion center, Faculty of Medicine, Khon Kaen University. Srinagarind Med J 2023;38:104-111.
34. Kaur P, Bedi RK, Mittal K, Sood T. Exploring the unseen effect of COVID 19 pandemic on blood transfusion services in a tertiary care centre. Transfus Apher Sci 2023;62:103569. doi: 10.1016/j.transci.2022.103569.
35. Moghaddamahmadi M, Khoshrang H, Khatami SS, Hooshmand MA, Ghovvati CH, Mehrkhah S. Survey of maximum blood ordering for surgery (MSBOS) in elective general surgery, neurosurgery and orthopedic surgery at the Poursina Hospital in Rasht, Iran, 2017. Hematol Transfus Cell Ther 2021;43:482-8.
36. Jo C, Ko S, Shin WC, Han HS, Lee MC, Ko T, et al. Transfusion after total knee arthroplasty can be predicted using the machine learning algorithm. Knee Surg Sports Traumatol Arthrosc 2020;28:1757-64.
37. Chen Y, Cai X, Cao Z, Lin J, Huang W, Zhuang Y, et al.

Prediction of red blood cell transfusion after orthopedic surgery using an interpretable machine learning framework. Front Surg 2023;10:1047558. doi:10.3389/fsurg.2023.1047558.

38. Wang Z, Zhe S, Zimmerman J, Morrisey C, Tonna JE, Sharma V, et al. Development and validation of a machine learning method to predict intraoperative red blood cell transfusions in cardiothoracic surgery. Sci Rep 2022;12:1355. doi: 10.1038/s41598-022-05445-y.

39. Lou SS, Liu H, Lu C, Wildes TS, Hall BL, Kannampallil T. Personalized surgical transfusion risk prediction using machine learning to guide preoperative type and screen orders. Anesthesiology 2022;137:55-66.

40. Rubin R. It takes an average of 17 years for evidence to change practice-the burgeoning field of implementation science seeks to speed things up. JAMA 2023;329:1333-6.