Article published online: 2022-09-14

Maximum Surgical Blood Order Schedule for Elective Neurosurgery in a University Teaching Hospital in Northern Thailand

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Abstract

Context: Preoperative blood bank testing should optimize the trade-off between intraoperative transfusion delay and blood wastage. **Aims:** This study aims to develop a maximal surgical blood order schedule (MSBOS) for elective neurosurgery. **Settings and Design:** Prospective data in University Teaching Hospital, Northern Thailand. **Subjects and Methods:** Blood transfusion data were collected on all adult patients satisfying inclusion/exclusion criteria in 2015. Patients were assigned to ten procedure groups (G): vascular: (1) Aneurysm/arteriovenous malformation, (2) Cerebrovascular bypass; tumor resection: (3) Meningioma, (4) Other, (5) Cerebellopontine angle, (6) Pituitary/craniopharyngioma, (7) Endoscopic pituitary; and miscellaneous: (8) Cranioplasty, (9) Spine, (10) Other. The crossmatch-transfusion ratio (**C**/T), transfusion probability (**%**T), and transfusion index (Ti) were calculated. MSBOS was generated by applying published criteria, subjected to clinical neurosurgical judgment. **Statistical Analysis Used:** Statistical Package for the Social Sciences, Vision 20. **Results:** Of 377 patients, 95% underwent preoperative cross-and-match (C and M) testing for 1422 red blood cell (RBC) units, while 3% had no type and screen (T and S) nor C and M, and 2% had T and S only. Overall C/T was 6.6, with range from 4 for G3-53 for G8. Intraoperative %T was 27%. Intraoperative Ti was 0.6. Our MSBOS recommended T and S only for G2, G7, G8, G9, G10; C and M of 2 RBC units for G1, G4, G5, G6; and C and M 2-to-4 for G3. If this were followed in 2015, intraoperative blood needs would have been satisfied for ≥82% of patients, and substantial reductions achieved in blood banking fees. **Conclusions:** Our MSBOS may help optimize blood ordering and serve as an example for similar efforts for other surgical specialties.

Keywords: *Blood transfusion, crossmatch-transfusion ratio, elective neurosurgery, maximal surgical blood order schedule, transfusion index, transfusion probability*

Introduction

In preparing for elective neurosurgery, there are various blood banking-related decisions and procedures that a surgeon might order before surgery. The type and screen (T and S) procedure assays patient blood for its ABO-Rh groups and uncommon antibodies that might be incompatible with donor blood.[1] However, T and S does not reserve any specific donor red blood cell (RBC) units for potential use in the patient. In the cross-and-match (C and M) procedure (sometimes referred to as "type and crossmatch", T and C), in addition to the assays of the T and S, samples of patient and donor blood are mixed to detect incompatibility of donor RBCs and recipient serum. If no incompatibility is found, the donor unit is set aside specifically for the patient for immediate use during surgery, making it temporarily unavailable to other patients who may need it.[2] This may result in the unit's expiration before its release for use in other patients and thus represents undesirable wastage.

No T and S at all for some procedures, or T and S only for others, without C and M for either, significantly reduce blood bank workload, cost, and blood wastage. T and S only saves time if C and M is subsequently ordered intraoperatively. However, both no T and S and T and S only may result in delay during surgery of up to 45–60 min[2] in doing C and M for a patient who unexpectedly needs blood.[3,4]

The fundamental trade-off is between excessive preoperative C and M that is costly and may waste blood versus delays for intraoperative C and M for patients needing more units than anticipated for them. To optimize this trade-off, decades ago, Friedman *et al.* derived from empirical data at the University of Michigan Hospital guidelines for choosing between T and S

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Access this article online

Website: www.asianjns.org

DOI: 10.4103/ajns.AJNS_104_16

Quick Response Code:

How to cite this article: 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.

only and the number of C and M RBC units that should be requested preoperatively for specific surgical procedures, which they called a maximal surgical blood order schedule (MSBOS).[5,6] Others have followed this example to develop their own blood ordering guidelines for all types of surgery.[7-16]

To develop an MSBOS for elective neurosurgery in Chiang Mai University Hospital (CMUH), we adopted previous methods to analyze blood ordering practices and transfusion events in our tertiary care, teaching facility serving the northern region of Thailand.

Subjects and Methods

On approval by the institutional review board for ethics, from January 1 to December 31, 2015, a nurse investigator (author SC) collected data for elective neurosurgical operations for events occurring up to 24 h after surgery from patient medical charts including blood banking, anesthesia, and surgical logs and notes. Data collected contemporaneously or retrospectively included diagnosis, demographics (e.g., age, sex), clinical findings (weight, height), hematological results (hemoglobin, hematocrit), blood-related data (ABO-Rh group, T and S orders, pre- and intra-operative C and M orders, RBC units transfused, surgical blood loss), and costs.

In CMUH neurosurgery, decisions to infuse RBCs are made by the neurosurgeon, intraoperatively in consultation with the anesthesiologist, and postoperatively independently.

Excluded from data collection were patients under 18 years of age or those with congenital heart disease, hematological disorders such as thalassemia and hemophilia. The operations were classified prospectively in ten diagnostic or procedural categories [Table 1].

Maximal surgical blood order schedule development

To develop our MSBOS, we first applied published definitions for various transfusion measurements.[7,17-20] The transfusion probability (%T) was the percentage of patients who received any RBC transfusion. Transfusion index (Ti) was the average number of RBC units transfused per patient in the study, determined by dividing the total number of units transfused by the number of patients in our study population, overall and by procedure type. The crossmatch-transfusion ratio (C/T) was the total number of units cross-matched in advance of surgery units divided by the total units actually transfused. Then, we amalgamated various cut-offs, features, and methods from published MSBOS of other institutions for incorporation into our own.[3,4,7,12,18,21]

As starting criteria for neither preoperative T and S nor any C and M units, we applied the example from Johns Hopkins University Medical Institutions of Frank *et al.*[21] of %T <5 and Ti <0.3 and median estimated blood loss (EBL) ≤50 mL [left side boxes in Figure 1]. However, we did not apply their criterion of the risk of major bleeding by the proximity of specific procedures to large vascular structures [ovals in Figure 1]. Starting criteria for T and S only, without any preoperative C and M units, were an amalgam of cut-offs used at Letterman Army Medical Center,[7] from the University of Malaya Medical Centre[12] and from the Thomas Jefferson University Hospital (Dexter *et al.*[18] of %T ≥5–≤30 or Ti ≥0.3–≤0.5 or Dexter's median EBL >50 mL).

For remaining patients not satisfying above criteria for no T and S or for T and S alone and for whom preoperative C and S is recommended, the number of such RBC units in the proposed MSBOS was based on the example of Mead *et al.*[7] (units = Ti times 1.5) and Frank *et al.*[21] (4 units when experience showed ≥4 units in >10% of patients). In addition, neurosurgeons of the Chiang Mai University Hospital were consulted for their clinical judgment, and the starting criteria were adjusted to create the MSBOS for our university hospital [ovals in Figure 1].

Table 1: Red blood cell (RBC) transfusion during, and after elective neurosurgery by procedure type

Neurosurgical procedures	Actual 2015 RBC transfusions						
	Intra-operative			Post-operative (24 hours)			Total unit no. intra- & post-op
Categories/Groups (No. patients)	No. patient (% all)	Total unit no.	Mean/median (range)	No. patients	Total unit no.	Mean/median (range)	
1. Aneurysm/AVM (35)	20 (57%)	40	2/1.5 (1-6)	8	10	1.3/1 (1-2)	50
2. Cerebrovascular bypass (10)	0	0	0/0	2	3	1.5/1.5 (1-2)	3
3. Meningioma (79)	39 (49%)	96	2.5/2 (1-10)	11	14	1.3/1 (1-2)	110
4. Other tumour (59)	16 (27%)	35	1.9/2 (1-8)	5	6	1.2/1 (1-2)	41
5. Cerebellopontine angle (25)	8 (32%)	12	1.5/1 (1-3)	1	1	1/1	13
6. Pituitary/craniopharyngioma (11)	5 (46%)	10	2/2 (1-3)	3	4	1.3/1 (1-2)	14
7. Endoscopic pituitary (32)	3 (9%)	6	2/2 (1-4)	1	1	1/1	7
8. Cranioplasty (30)	1 (3%)	2	2/2	0	0	0/0	2
9. Spine (31)	4 (13%)	5	1.3/1 (1-2)	1	1	1/1	6
10. Other (65)	4 (6%)	10	2.5/2.5 (1-4)	2	4	2/2	14
Total=377	100 (27%)	216	2.2/2 (1-10)	34	44	1.3/1 (1-2)	260

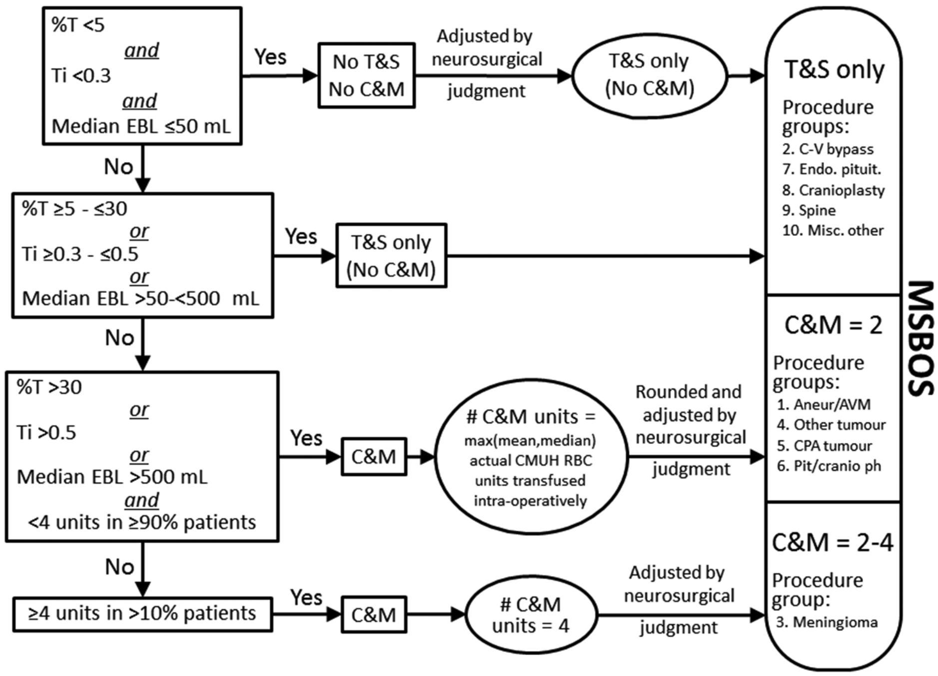

Figure 1: Algorithm for the development of maximal surgical blood order schedule. Rectangles left and center amalgamate various published criteria and cut-offs. Ovals center and right reflect empirical transfusion experience of the 2015 cohort and clinical neurosurgical judgment

Performance and cost analyses

The actual numbers of transfusions administered to patients in the cohort were used to calculate whether the proposed MSBOS would recommend sufficient preoperative RBC units. This allowed visualizing the probability for urgent C and M processing of additional units during surgery, according to the hypothetical number of C and M units preordered.

To illustrate the potential cost savings of the proposed MSBOS, we compared the blood banking fees for actual RBC units that were cross-matched but not transfused intraoperatively into our 2015 cohort, with what the same fees would have been if preoperative orders for blood had conformed to the MSBOS. The C and M fee in 2015 for RBCs was 120 Thai baht (฿120 [$3.59]) per unit. Conversions to US dollars ($) were based on the midpoint exchange of ฿33.72 per US$1.00 in effect midyear on June 30, 2015. The hospital fees for T and S (฿220 [$6.52] per patient) were ignored in the comparison because our MSBOS suggests at least T and S for all elective neurosurgical patients. Mathematical analysis was performed with the Statistical Package for Social Sciences, version 20 (SPSS 20, IBM, Armonk, NY, USA).

Results

Patient recruitment and transfusion experience

During the full year of 2015, a total of 438 elective neurosurgical operations were performed, of which 61 operations were excluded from analysis due to patient age under 18. No adults were excluded for having met any exclusion criteria, leaving 377 for analysis. The mean age of all 377 patients was 48.3 years (range 18–86). The proportion of male and female were 41% and 59%, respectively.

The most frequent procedure was resection for meningioma (79 patients, in Group 3), followed by miscellaneous nontumor, nonvascular procedures (65, Group 10), and then miscellaneous tumor resections (59, Group 4) [Table 1].

A total of 358 (95%) patients had preoperative C and M ordered for a total of 1422 RBC units, while 12 (3%) had no T and S ordered (and none needed transfusion intraoperatively of postoperatively within 24 h of surgery). Of the remaining 7 (2%) patients ordered for T and S only (no preoperative C and M), only 2 needed intraoperative C and M and immediate transfusion.

Only 216 (15%) of the total 1,422 C and M units were transfused intraoperatively, and 44 (3%) postoperatively. The inverse of this proportion (total preoperative crossmatches divided by total intraoperative units transfused, C/T ratio) ranged from a low of 4 for meningioma (Group 3) to a high of 53 for cranioplasty (Group 8), excluding the C/T of infinity for cerebrovascular bypass (Group 2), which required no transfusions.

The proportion of all patients requiring any transfusion (%T) was 27% (100/377) intraoperatively and was 9% (34) postoperatively [Table 2]. The procedure groups requiring

Table 2: Blood-banking, transfusion measures, and proposed Maximal Surgical Blood Order Schedule (MSBOS), in comparison with typical U.S. MSBOS[16]

Neurosurgical procedure	Intra-operative median EBL in mL (range)	Actual intraoperative 2015 transfusion measures (intra- + post-op)			Range of 2015 preop C & M units, per patient	MSBOS	
		%T	Ti	C/T		Proposed for CMUH	U.S.A. example[16]
1. Aneurysm/AVM	300 (70-3000)	57.1 (62.9)	1.1 (1.4)	4.1 (3.3)	2-6	2	2[a]
2. Cerebrovascular bypass	158 (50-650)	0 (20)	0 (0.3)	~ (14)	4-6	T&S	-[a]
3. Meningioma	500 (50-2600)	49.4 (51.9)	1.2 (1.4)	4.0 (3.5)	2-10	2-4	2
4. Other tumour	200 (10-2000)	27.1 (28.8)	0.6 (0.7)	7.2 (6.1)	2-10	2	2
5. Cerebellopontine angle	300 (60-1600)	32 (36)	0.5 (0.5)	8.7 (8)	4-8	2	2
6. Pituitary/craniopharyngioma	600 (50-1000)	45.5 (54.5)	0.9 (1.3)	4.2 (3.0)	2-10	2	1
7. Endoscopic pituitary	200 (20-1500)	9.4 (12.5)	0.2 (0.2)	13.7 (11.7)	2-4	T&S	-[a]
8. Cranioplasty	150 (50-500)	3.3 (3.3)	0.1 (0.1)	53.0 (53.0)	2-6	T&S	T&S
9. Spine	100 (10-1400)	12.9 (13.6)	0.2 (0.2)	21.8 (18.2)	2-6	T&S	0[b] (1-2 levels) T&S[b] (>2 levels)
10. Other	50 (3-1600)	6.2 (9.2)	0.2 (0.2)	14.1 (10.1)	1-6	T&S	0 or T&S only
Total	200 (3-3000)	26.5 (29.7)	0.6 (0.7)	6.6 (5.5)	1-10		

[a]McPherson *et al*.[16] provide no MSBOS recommendation specifically for A-V malformation (in procedure Group 1), cerebrovascular bypass (in procedure group 2), or endoscopic transphenoidal pituitary resection (in procedure group 7). [b]McPherson *et al*.[16] provide no MSBOS recommendation specifically for vascular or tumour resection in the spine (procedure group 9); only for laminectomy of levels 1-2, or>2

Table 3: Cost of pre-operative cross and match (C&M) blood units

Procedure	Actual experience from 2015 cohort of elective neurosurgical patients							
	ALL Pre-operative C&M			Intra-operative transfusions		NON-USE intra-operatively of C&M RBCs ordered/reserved		
	No. patients with pre-op C&M	Total no. RBCs units ordered	Total fees	No. patients	Total no. units	No. patients NOT transfused	No. units NOT transfused	Total Fees units NOT transfused
1. Aneurysm/AVM	35	164	$812	20	40	15	124	$441
2. Cerebrovascular bypass	10	42	$215	0	0	10	42	$149
3. Meningioma	79	380	$1,868	39	96	40	284	$1,011
4. Other tumour	58	252	$1,275	16	35	41	217	$772
5. Cerobellopontine angle	25	104	$533	8	12	17	92	$327
6. Pituitary/craniopharyngioma	11	42	$221	5	10	6	32	$114
7. Endoscopic pituitary	31	82	$494	3	6	28	76	$270
8. Cranioplasty	29	106	$566	1	2	28	104	$370
9. Spine	30	109	$584	4	5	26	104	$370
10. Other	50	141	$828	4	10	46	131	$466
Total	358	1,422	$7,396	100	216	257	1206	$4,292

intraoperative transfusion more than 40% of the time were aneurysm/arteriovenous malformation (AVM) (57%, Group 1), meningioma (49%, Group 3), and pituitary tumor or craniopharyngioma (45%, Group 6).

The two procedures with the highest average of required intraoperative transfusions (Ti) were meningioma (Group 3: mean 1.2 units per total 79 patients, including those receiving no blood) and aneurysm/AVM (Group 1: 1.1 units per 35 patients) [Table 2]. All other procedure groups had Ti <1.0. Patients requiring transfusion intra- and/or post-operatively were more likely to be female (74%) and older (mean age 51.8 years) than patients not requiring transfusion (mean 46.7 years, $P = 0.006$).

Maximal surgical blood order schedule components and analysis

The proposed MSBOS recommended preoperative T and S only, without C and M, for 5 procedural groups (no. 2, 7, 8, 9, and 10) [Table 2 and Figure 1]. Four were recommended for 2 preoperative C and M units (1, 4, 5, and 6). For procedure 3 (meningioma), a range of 2–4 RBC units for preoperative C and M was recommended, to be determined by clinical neurosurgical judgment based on tumor size, location, and other relevant factors.

Considering the recommended "T and S only" order of the proposed MSBOS for groups 2, 7, 8, 9, and 10, ≥86% of

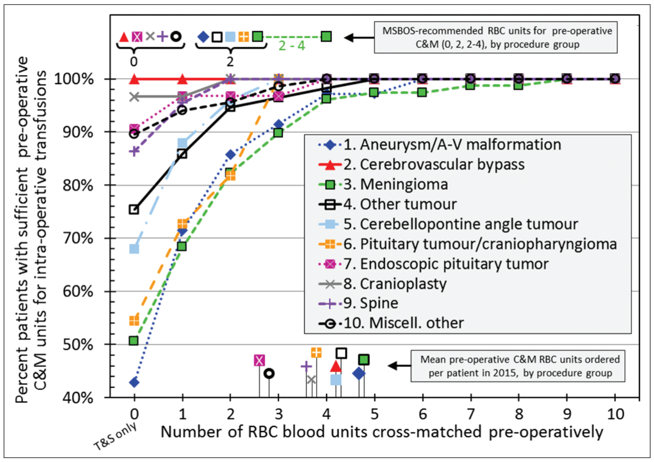

Figure 2: Proportions of patients (*y*-axis) for whom specific numbers of preoperative cross-and-match red blood cell units (*x*-axis) would satisfy intraoperative transfusion needs, based on experience of the 2015 cohort of elective neurosurgical patients, by procedure group

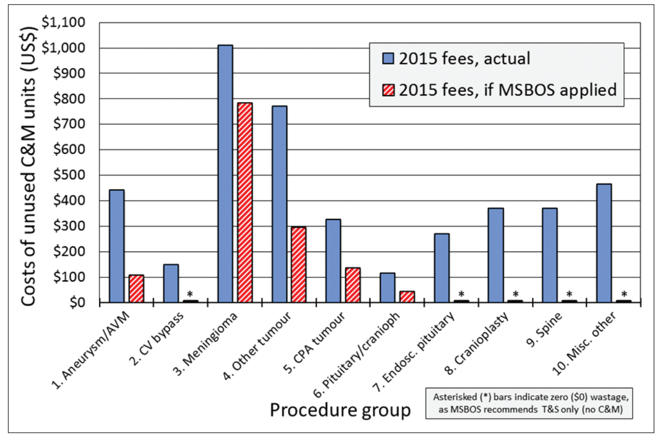

Figure 3: Potential wastage costs of cross-and-match units reserved but not transfused intraoperatively in 2015 (solid blue), compared with maximal surgical blood order schedule applied to same cohort and transfusion rates (red crosshatch). cross-and-match cost US$3.46 each (Thai baht 120 at ฿34.72/$1.00)

the 2015 patient cohort undergoing these procedures did not need any intraoperative transfusion blood [Figure 2]. Similarly, among the remaining groups recommended for 2 preoperative C and M units (including Group 3 [range 2–4] when only 2 units are ordered), the proportion of patients with sufficient units on hand would have been ≥82%. For meningioma patients (Group 4) who might have had 3 or 4 units order preoperatively, the proportions that would have been covered were 90% and 96%, respectively.

Cost analyses

When the blood banking fees for blood reserved by C and M but not transfused intraoperatively in the 2015 cohort were compared to the number of C and M units that would have been unused if the proposed MSBOS had been followed, at the same transfusion rates, the C and M costs dropped 23% for Group 3 procedures, dropped more than half for procedure groups 1, 4, 5, and 6, and dropped to nothing for groups 2, 7, 8, 9, and 10 [Table 3 and Figure 3].

Discussion

Donor blood is usually a scarce commodity. This requires a difficult trade-off to ensure sufficient units on hand for elective surgery versus having enough remaining for other elective patients to avoid scheduling delays or putting emergency patients at risk of disability or even death for timely lack of blood. A tendency for excessive preoperative C and M orders may result from worries about the 45–60 min required for C and M if additional units become necessary during surgery.[2]

Optimizing the trade-off requires changing the C/T ratio of preoperative C and M units to actual transfusions needed, whose theoretical ideal is 1.[8] To be realistic, some authors have suggested an acceptable C/T ratio would be around 2.5 (range 2–3).[4,7,8,19,22]

It is difficult to compare our current practices with institutions elsewhere because of differences in classifying neurosurgical procedures, their inclusion of children, and combining elective and emergency ones. Furthermore, as a large public teaching hospital, orders for preoperative blood testing are often made by residents in training, who may be more worried than experienced faculty surgeons about having sufficient intraoperative blood ready.

With these caveats in mind, we did find our C/T ratio of 4.1 for aneurysm/AVM (Group 1) to be substantially lower than that reported from the University of Virginia, USA, for unruptured aneurysm [C/T 32, recalculated from a seeming error in its Table 3] and AVM (18).[11] However, this may be explained by their lower transfusion frequencies for such elective procedures, as reflected by their 4.3%T and 0.85 Ti for unruptured aneurysms, and 7.4%T and 0.22 Ti for AVM, compared to our 57%T and 1.1 Ti for aneurysm/AVM (Group 1).

Our C/T ratio was also lower than that reported from a German hospital for an apparently elective procedure comparable to our "Tumor resection" groups 3–7 (overall 5.4 C/T). their "brain tumor" group was 10.7 C/T.[20] Again, this may be explained by their 1.4%T for this group, compared to 34 for our groups 3–7.

Our overall intraoperative %T of 27 was similar to that reported for all elective neurosurgery in India of 31% (but including children, which we excluded).[23] However, we differed from an overall intraoperative %T of 8.6% in Jamaica,[14] however, that report combined both emergency and elective procedures.

A number of MSBOS guidelines have been developed elsewhere to optimize transfusion practice for neurosurgery, including in Thailand's capital,[13] Australia,[24] the United States,[7,10,11,16,21] the United Kingdom,[8] and Jamaica.[14]

Some used very broad procedure categories that make difficult direct comparison with our ten groups, such as "craniotomy" (2 C and M),[16] "intracranial surgery" (2 C and M),[21] and "tumor removal" (T and S only except for those with blood dyscrasias,[14] 0–2 C and M,[7] or 6 C and M[13]).

For elective surgery for aneurysm (our Group 1), in contrast to our recommendation of 2 units preoperative C and M, there was a range of recommendations by others. A few indicated T and S only,[10,11,14] with exceptions such as for patients with hematological disorders (for which C and M was recommended for 2 units[14] or in unspecified number[10]). The MSBOS of others for aneurysm was either 2,[16,21] 3,[8] or 4[13] preoperative C and M. For meningioma resection (Group 3), while we recommended from 2 to 4 C and M RBC units, an MSBOS in the United Kingdom indicated 4 units.[8] Our suggestions of 2 units of C and M for conventional resection of pituitary tumors and craniopharyngioma (Group 6), and T and S only for endoscopic technique (Group 7), compares with 1 C and M from a group of hospitals in the northeastern USA,[16] and T and S only for endoscopic method in the United Kingdom.[8]

For cranioplasty (Group 8), for which we proposed T and S only, recommendations by others ranged from no T and S at all in one of four regional medical centers in the United States,[7] to T and S only,[7,8,16,24] with the exception of 2 C and M for patients with blood disorders.[24] For spinal surgery (Group 9), our recommendation of T and S only was comparable to the most common recommendations for laminectomies,[7,8,16,21,24] with qualifications and exceptions. In one MSBOS, neither T and S nor C and M were suggested for operations on only 1–2 vertebral levels and T and S only for >2.[16] In an Australian recommendation for any spinal procedure, if the patient had uncommon antibodies detected on T and S, then 2 C and M were indicated.[24] For spinal tumors, 2 C and M were recommended in two MSBOS.[8,21] For our miscellaneous "other" category Group 10, for which we recommended T and S only, others included suggestions for specific procedures we included. For cerebrospinal fluid shunts, two indicated no T and S nor C and M,[21,24] while one also indicated T and S only.[8] For trephination, one also suggested T and S only.[16]

There are a number of limitations in this work. First, our number of subjects was sometimes insufficient to subdivide them by various factors such as patient age, severity of diagnosis, and other clinical conditions. These might have provided more precise data on which to make more specific recommendations for preoperative blood testing. Second, our "other" groups 4 (tumor) and 10 (miscellaneous) lumped together infrequent and disparate diagnoses and procedures that were too rare to constitute their own group.

Third, the blood banking fees used to calculate potential savings by the adoption of the proposed MSBOS for our hospital, do not represent their true costs. As a public university teaching hospital, it is quite unlikely that our US$6.52 for T and S and $3.56 per C and M unit would cover all the salaries, infrastructure, training, reagents, and supplies for donor blood collection, storage, and testing. These low fees likely reflect large government subsidies for public policy reasons in providing health care to the population. This may partially explain why fees elsewhere are so much higher, such as the United States, where in 2002, a T and S was reported to cost $30.50 and a C and M $37.00.[11] Thus, the financial benefits from reducing excessive C and M would likely be higher than we report here.

Fourth, we did not perform follow-up on RBC units that were cross-matched but not transfused into our patients to see if they were transfused into other patients, or expired and thus were wasted. Thus, neither our study nor any previous ones of which we are aware reflect the true overall costs – both economic and social – of over- and under-cross-matching. This would better assess the impact of applying an MSBOS that changes current practice. These costs are difficult to investigate and hard to quantify. For example, if too much blood has been reserved for some patients, how many operations must be postponed for others resulting in adverse consequences to them? The converse situation, if too few units have been reserved for a patient, is how many will suffer if unexpected bleeding results intraoperatively and there is a delay in getting additional units in time to the patient? Careful future studies might try to determine these costs and benefits for optimized transfusion practice.

Conclusions

The proposed MSBOS is offered as a first step toward such optimization of elective neurosurgical blood practices and may be an example for similar efforts for other surgical specialties. Our analysis suggested that 82% or more of all patients in our cohort would have had sufficient RBC units preoperatively cross-matched if our MSBOS had been followed [Figure 2]. In actual practice, however, the clinical judgment of the neurosurgeon for factors specific to the individual patient should prevail over MSBOS guidelines.

Acknowledgment

The authors gratefully acknowledge neurosurgeons Kriengsak Limpastan, Thunya Norasethada, Wanarak Watcharasaksilp, Tanat Vaniyapong, and Chumpol Jetjumnong for their assistance with developing the MSBOS, and Bruce G. Weniger of the Research Institute for Health Sciences of Chiang Mai University for editorial advice.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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