

Original article

ABO-weighted estimation of screening burden based on Rh antigen distribution analysis for phenotype-matched transfusion in Thai patients with alloantibodies

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Abstract:

Introduction: The Rh blood group system is important in transfusion practice, as alloantibodies can cause hemolytic transfusion reactions and hemolytic disease of the fetus and newborn. Extended Rh antigen typing (C, c, E, and e) in donors helps optimize inventory and ensure timely provision of compatible blood. **Objectives:** This study analyzed in-house Rh antigen distribution and estimated the ABO-weighted screening burden for phenotype-matched transfusion in Thai patients with alloantibodies. **Materials and methods:** Laboratory data were obtained from the LIS of Thammasat University Hospital. Donor data included ABO group, RhD status, and Rh antigen typing (C, c, E, and e), while patient data included antibody screening and identification results. Antigen and phenotype frequencies and compatible donor probabilities for patients with Rh antibodies were calculated. **Results:** ABO and RhD status data from 11,295 Thai blood donors showed group O as the most common (38.41%), followed by B (33.19%), A (20.57%), and AB (7.84%); 99.57% were RhD-positive. The e antigen was most prevalent (96.95%), followed by C (95.25%), c (38.54%), and E (31.70%). The most common phenotype was C+ c- E- e+ (58.22%) among RhD-positive donors. Compatible donor probability varied by ABO group, with comparable likelihood observed between groups O and B, while group AB showed the lowest probability. **Conclusion:** This study supports establishing a registry of known RhCE phenotypes and implementing extended RhCE typing to improve identification of phenotype-matched units. Additionally, ABO-based screening burden estimation offers a practical approach to optimize inventory management, ensure timely access to compatible blood, and reduce alloimmunization risk.

Keywords : ● ABO blood group ● Rh antigens ● Phenotype-matched ● Thais

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นิพนธ์ต้นฉบับ

การประมาณการการคัดกรองโดยพิจารณาหมู่เลือด ABO จากการวิเคราะห์การกระจายของแอนติเจน Rh เพื่อให้เลือดที่ตรงพีโนไทป์ในผู้ป่วยคนไทยที่มีแอนติบอดี

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บทคัดย่อ

บทนำ หมู่เลือดระบบ Rh มีความสำคัญในการให้เลือดเนื่องจาก แอนติบอดีที่สร้างจำเพาะทำให้เกิดปฏิกิริยาอันไม่พึงประสงค์จากการได้รับเลือด และโรคเม็ดเลือดแดงแตกในทารกในครรภ์และแรกเกิด การตรวจแอนติเจนหมู่เลือด Rh (C, c, E, และ e) เพิ่มเติมในผู้บริจาคเลือดจะช่วยบริหารจัดการเลือดผู้บริจาคเพื่อช่วยในการจัดหาเลือดที่เข้ากันได้ให้กับผู้ป่วยได้ทันเวลา **วัตถุประสงค์** การศึกษาค้นคว้านี้มีวัตถุประสงค์เพื่อวิเคราะห์ข้อมูลการกระจายของแอนติเจน Rh เพื่อประมาณการการคัดกรองเลือดผู้บริจาคที่มีพีโนไทป์ตรงกับผู้ป่วยคนไทยที่มีแอนติบอดีโดยพิจารณาตามหมู่เลือด ABO **วัสดุและวิธีการ** ข้อมูลผลการตรวจทางห้องปฏิบัติการรวบรวมจากระบบ LIS โรงพยาบาลธรรมศาสตร์เฉลิมพระเกียรติ ส่วนข้อมูลผู้บริจาคเลือด คือ หมู่เลือด ABO และ RhD รวมทั้งผลตรวจแอนติเจน Rh (C, c, E, และ e) ขณะที่ข้อมูลผู้ป่วยคือ ผลตรวจกรองและแยกชนิดแอนติบอดี นำมาคำนวณความถี่ของแอนติเจน พีโนไทป์และโอกาสการได้เลือดผู้บริจาคที่เข้ากันได้จากผู้บริจาคที่สร้างแอนติบอดีต่อแอนติเจน Rh **ผลการศึกษา** ผลหมู่เลือด ABO และ Rh ในผู้บริจาคเลือดจำนวน 11,295 ราย พบว่า หมู่ O พบมากที่สุด (38.41%) รองลงมาคือ หมู่ B (33.19%), A (20.57%), และ AB (7.84%) และเป็น RhD-positive 99.57% แอนติเจน e พบได้บ่อยที่สุด (96.95%) รองลงมาคือ C (95.25%), c (38.54%), และ E (31.70%) พีโนไทป์ที่พบได้มากที่สุดของผู้บริจาค RhD-positive คือ C+ c- E- e+ (58.22%) โอกาสคัดกรองเลือดผู้บริจาคที่เข้ากันได้จะแปรตามหมู่เลือด ABO โดยผู้ป่วยหมู่ O และ B มีโอกาสใกล้เคียงกันในการจัดหาเลือดที่เข้ากันได้ ส่วนผู้ป่วยหมู่ AB มีโอกาสต่ำที่สุด **สรุป** การศึกษานี้ช่วยสนับสนุนการสร้างระบบการลงทะเบียนผลพีโนไทป์ RhCE เพิ่มเติม เพื่อช่วยพัฒนาการจัดหาเลือดที่มีพีโนไทป์ตรงกัน นอกจากนี้การวิเคราะห์ข้อมูลการกระจายของแอนติเจน Rh โดยพิจารณาตามหมู่เลือด ABO จะเป็นแนวปฏิบัติในการบริหารจัดการเลือดผู้บริจาคคงคลังที่ทันเวลาในการจัดหาเลือด และลดความเสี่ยงต่อการเกิด alloimmunization

คำสำคัญ : ● หมู่เลือด ABO ● แอนติเจน Rh ● พีโนไทป์ที่เข้ากันได้ ● คนไทย

วารสารโลหิตวิทยาและเวชศาสตร์บริการโลหิต. 2569;36:179-87.

Introduction

The Rh blood group system is clinically important in transfusion practice. Alloantibodies against Rh antigens are implicated in acute and delayed hemolytic transfusion reactions (HTRs) and hemolytic disease of the fetus and newborn (HDFN).¹⁻³ Regarding the International Society of Blood Transfusion (ISBT) Working Party on Red Cell Terminology and Immunogenetics, there are 56 antigens in the Rh blood group system.⁴ In clinical blood transfusion therapy, ABO and RhD matching are required between donors and recipients in pretransfusion testing. However, due to the immunogenicity of other Rh antigens (C, c, E, and e), antigen typing of these antigens is recommended in patients who require repeated transfusions.^{1,2,5-7}

Data from the National Blood Centre of the Thai Red Cross Society (NBC-TRCS) showed that among 2,821 multitransfused Thai patients struggling to find compatible blood donors, unexpected antibodies most often belong to the Rh system (42.2%), then the MNS system (31.9%), the Kidd system (10.5%), and other blood group systems (15.4%), respectively.⁸ Studies across Thailand have consistently report the highest prevalence of Rh alloantibodies was found in patients requiring transfusions,⁹⁻¹² with anti-E being the most common, followed by anti-c, anti-C, and anti-e, respectively. These data demonstrate the value of Rh antigen detection (C, c, E, and e) during pretransfusion testing to prevent alloimmunization in chronic transfusion therapy.^{7,13,14}

Thammasat University Hospital is a tertiary care hospital with 1,000 inpatient beds. The hospital blood bank operates as a branch of the NBC-TRCS and includes a blood donor collection unit. However, the NBC-TRCS is responsible for ABO and RhD blood group typing, antibody screening, and screening for infectious markers. The test results are then sent directly to the hospital blood bank. Regarding the above-mentioned study for alloantibodies found in patients at our hospital,¹⁰ additional Rh antigen typing—particularly for C, c, E, and e in blood donors within our inventory is

essential to optimize blood bank operations and ensure timely provision of compatible blood for patients with Rh alloantibodies. This study aimed to collect and analyze in-house data on Rh antigen distribution among our blood donors and to estimate the ABO-weighted screening burden for phenotype-matched transfusion in Thai patients with alloantibodies.

Materials and Methods

Study population and ethics considerations

This retrospective observational study was conducted at the Blood Bank, Thammasat University Hospital, Pathum Thani, Thailand. Data from January 2022 to August 2025 were included. A total of 11,295 unrelated healthy blood donors who underwent routine Rh antigen phenotyping during the study period were analyzed. Donor data were retrieved from the laboratory information system and included ABO blood group, RhD status, and serologic results for C, E, c, and e antigens.

For the alloantibody analysis, records of 347 patients with clinically significant Rh alloantibodies identified during routine pre-transfusion testing were reviewed. Only patients with confirmed Rh antibody specificity were included. Cases with incomplete serologic data were excluded from the analysis.

All data were anonymized prior to analysis. The study protocol was approved by the Human Research Ethics Committee of Thammasat University Hospital (HREC-TUH), Thailand (COE No. 014/2569). The study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

ABO grouping and RhD typing

ABO grouping and RhD typing were routinely performed using an automated column agglutination system (Ortho Clinical Diagnostics, Raritan, NJ, USA), in accordance with the manufacturer's instructions.

Rh antigen typing

Rh antigen typing for C, c, E, and e was performed using an automated column agglutination system (IH system, Bio-Rad Laboratories, Cressier, Switzerland) with

monoclonal antisera: anti-C [clone MS-24], anti-c [clone MS-33], anti-E [clone MS-260], and anti-e [clones MS-16, MS-21, and MS-63], according to the manufacturer's instructions. Testing was conducted as part of routine donor phenotyping, which refers to a first-time serologic determination using blood samples collected at the time of donation without repeat confirmation, according to standard transfusion laboratory practice.

Antibody screening

Antibody screening was performed using an automated column agglutination system (Ortho Clinical Diagnostics, Raritan, NJ, USA). Testing was conducted only in the indirect antiglobulin test (IAT) phase. For the antibody screening test, reagent red cells of three group O were used, consisting of O₁ and O₂ screening cells from Selectogen (Ortho Clinical Diagnostics, Raritan, NJ, USA) and an additional group O₃ screening cell with Mi^a and Di^a antigen positivity obtained from the National Blood Centre, Thai Red Cross Society (NBC-TRCS, Bangkok, Thailand). All tests were performed using an automated platform in accordance with the manufacturer's instructions.

Antibody identification

Antibody identification was performed using reagent red cell panels of 0.8% group O suspensions from 11 individuals obtained from the NBC-TRCS (Bangkok, Thailand). Testing was carried out using column agglutination technology with an automated system (Ortho Clinical Diagnostics, Raritan, NJ, USA) according to the manufacturer's instructions. Antibody specificity was determined based on reaction patterns in accordance with standard serological methods.²

Data collection

Laboratory data were extracted from the laboratory information system (LIS) of Thammasat University Hospital. Donor records included ABO blood group, RhD status, and Rh antigen typing results (C, c, E, and e). Patient records included antibody screening and antibody identification results. Only complete and analyzable datasets were included in the analysis. All anti-D

antibodies identified in this study were not considered to be passive anti-D resulting from Rh immunoglobulin administration.

Statistical analysis

Statistical analysis was descriptive in nature. Antigen and phenotype frequencies were calculated by direct counting and expressed as percentages. Compatible donor probability ($P_{\text{compatible}}$) was derived from the observed phenotype frequencies and defined as the cumulative frequency of donor phenotypes that lack the corresponding antigen(s). The expected number of donor units required to identify at least one compatible unit was calculated as the reciprocal of this probability ($1/P_{\text{compatible}}$).¹⁵

Results

Data from 11,295 unrelated healthy Thai blood donors collected from January 2022 through August 2025 were analyzed.

Distribution of ABO and RhD status among blood donors

The distribution of ABO and Rh blood groups among 11,295 blood donors was analyzed. Group O was the most common, with 4,338 donors (38.41%), followed by group B, with 3,749 donors (33.19%), group A, with 2,323 donors (20.57%), and group AB, with 885 donors (7.84%), respectively. Among them, 11,246 donors were RhD-positive donors (99.57%), and 49 were RhD-negative donors (0.43%).

Distribution of RhCE antigen frequencies stratified by ABO and RhD status

Regarding RhCE antigen frequencies among 11,295 donors, the e antigen was the most prevalent (10,950/11,295; 96.95%), followed by C antigen (10,758/11,295; 95.25%), c antigen (4,353/11,295; 38.54%), and E antigen (3,580/11,295; 31.70%). The estimated allele frequencies were 78.20% for C, 17.40% for E, 21.60% for c, and 82.50% for e, respectively.

Stratified analysis of RhCE antigens by ABO and Rh status is summarized in Table 1. Among RhD-positive donors, the prevalence of C and e antigens exceeded

Table 1 Prevalence of RhCE antigens stratified according to ABO and RhD status among 11,295 blood donors

RhCE antigen	ABO blood group, number (%)				
	A	B	O	AB	Total
	2,312 (20.59)	3,736 (33.22)	4,317 (38.38)	881 (7.80)	11,246 (100.00)
RhD-positive					
C	2,206 (95.42)	3,570 (95.56)	4,121 (95.46)	840 (95.35)	10,737 (95.47)
E	748 (32.35)	1,182 (31.64)	1,371 (31.76)	275 (31.21)	3,576 (31.80)
c	899 (38.88)	1,443 (38.62)	1,639 (37.97)	331 (37.57)	4,312 (38.34)
e	2,235 (96.67)	3,632 (97.22)	4,178 (96.94)	856 (97.16)	10,901 (96.93)
RhCE antigen	A	B	O	AB	Total
	11 (22.45)	13 (26.53)	21 (42.86)	4 (8.16)	49 (100.00)
RhD-negative					
C	4 (36.36)	5 (38.46)	10 (47.62)	2 (50.00)	21 (42.86)
E	0 (0.00)	0 (0.00)	4 (19.05)	0 (0.00)	4 (8.16)
c	9 (81.82)	12 (92.31)	17 (80.95)	3 (75.00)	41 (83.67)
e	11 (100.00)	13 (100.00)	21 (100.00)	4 (100.00)	49 (100.00)

95% across all ABO groups. The distribution of E and c antigens remained relatively consistent among ABO groups, with E observed in approximately 31-32% and c in 37-39% of donors.

Among RhD-negative donors, the e antigen was universally present (100.0%). The c antigen was highly prevalent (83.67%), whereas C and E antigens were less common, observed in 42.86% and 8.16%, respectively.

Distribution of RhCE phenotypes among RhD-positive and RhD-negative donors

The distribution of RhCE phenotypes among RhD-positive and RhD-negative donors from high to low frequency is presented in Table 2. Among 11,246 RhD-positive donors, the most common phenotype was C+ c- E- e+ (58.22%), followed by C+ c+ E+ e+ (23.48%) and C+ c+ E- e+ (9.75%). The phenotypes of C+ c- E+ e+, C- c+ E+ e- and C- c+ E+ e+ were also observed with the frequencies of 3.29%, 2.33% and 1.96%. Rare phenotypes such as C- c+ E- e+ (0.24%) and C+ c- E+ e- (0.15%) were identified at very low frequencies. The phenotype distribution was generally consistent across ABO groups.

The phenotype distribution among 49 RhD-negative donors is summarized in Table 2. The predominant phenotype was C- c+ E- e+ (48.98%), followed by C+

c+ E- e+ (26.53%), C+ c- E- e+ (16.33%) and C- c+ E+ e+ (8.16%), respectively.

Distribution of Rh alloantibody specificities in patients

From 2022 to 2025, a total of 1,119 patients with specific red blood cell (RBC) antibodies were identified. Among these, 579 patients with anti-Mi^a were the most prevalent (51.74%), followed by 346 patients with antibodies of the Rh system (30.92%). Only patients with antibodies of the Rh system were included in the present analysis. As multiple antibody specificities may coexist in individual patients, the study focused on Rh alloantibodies due to their clinical significance in transfusion practice (Table 3). Among these, single antibody specificities accounted for 257 cases (74.06%), while combinations of two antibodies were observed in 90 cases (25.94%).

Among the single antibodies, anti-E was the most frequently identified, representing 65.42% of the cases. This was followed by anti-c (4.03%), anti-D (2.31%), anti-C (1.44%), and anti-e (0.86%). For the two-antibody combinations, anti-c plus anti-E was the most common pairing (20.46%), followed by anti-C plus anti-e (4.90%) and anti-C plus anti-E (0.58%).

Table 2 Distribution of RhCE phenotypes stratified according to ABO and RhD status among 11,295 blood donors

RhCE phenotype	ABO blood group, number (%)				
	A	B	O	AB	Total
	2,312 (20.59)	3,736 (33.22)	4,317 (38.38)	881 (7.80)	11,246 (100.00)
RhD-positive					
C+ c- E- e+	1,334 (57.70)	2,159 (57.79)	2,537 (58.77)	517 (58.68)	6,547 (58.22)
C+ c+ E+ e+	553 (23.92)	878 (23.50)	1,013 (23.47)	197 (22.36)	2,641 (23.48)
C+ c+ E- e+	224 (9.69)	383 (10.25)	401 (9.29)	88 (9.99)	1,096 (9.75)
C+ c- E+ e+	75 (3.24)	131 (3.51)	132 (3.06)	32 (3.63)	370 (3.29)
C- c+ E+ e-	57 (2.47)	85 (2.28)	101 (2.34)	19 (2.16)	262 (2.33)
C- c+ E+ e+	43 (1.86)	69 (1.85)	87 (2.02)	21 (2.38)	220 (1.96)
C+ c+ E+ e-	16 (0.69)	16 (0.43)	29 (0.67)	5 (0.57)	66 (0.59)
C- c+ E- e+	6 (0.26)	12 (0.32)	8 (0.19)	1 (0.11)	27 (0.24)
C+ c- E+ e-	4 (0.17)	3 (0.08)	9 (0.21)	1 (0.11)	17 (0.15)
RhCE phenotype	A	B	O	AB	Total
	11 (22.45)	13 (26.53)	21 (42.86)	4 (8.16)	49 (100.00)
RhD-negative					
C- c+ E- e+	7 (63.64)	8 (61.54)	7 (33.33)	2 (50.00)	24 (48.98)
C+ c+ E- e+	2 (18.18)	4 (30.77)	6 (28.57)	1 (25.00)	13 (26.53)
C+ c- E- e+	2 (18.18)	1 (7.69)	4 (19.05)	1 (25.00)	8 (16.33)
C- c+ E+ e+	0 (0.00)	0 (0.00)	4 (19.05)	0 (0.00)	4 (8.16)

Table 3 Frequencies of Rh alloantibody specificities found in 347 patients during 2022-2025

Antibody specificity	Frequency	
	Number	%
Single antibody	257	74.06
Anti-E	227	65.42
Anti-c	14	4.03
Anti-D	8	2.31
Anti-C	5	1.44
Anti-e	3	0.86
Two antibodies	90	25.94
Anti-c and anti-E	71	20.46
Anti-C and anti-e	17	4.90
Anti-C and anti-E	2	0.58
Total	347	100.00

Estimated compatible donor probability and screening requirement

Estimated compatible donor probabilities and corresponding screening requirements based on RhCE phenotype frequencies are shown in Table 4. These

estimates are derived solely from RhCE phenotype frequencies and do not account for ABO compatibility. High compatible probabilities were observed for anti-E and anti-c (68.21% and 61.66%), requiring approximately two units to identify one compatible unit. In contrast,

Table 4 Estimated compatible donor probability and screening requirement for antigen-negative red cell units by Rh antibody specificity

Rh antibody specificity	Antigen-negative requirement	Compatible donor (%)	Units to screen for ≥ 1 compatible unit
Anti-E	E-	68.21	2
Anti-c	c-	61.66	2
Anti-C	C-	4.53	23
Anti-e	e-	3.07	33
Anti-c and anti-E	c- E-	58.22	2
Anti-C and anti-e	C- e-	2.33	43
Anti-C and anti-E	C- E-	0.24	417

Table 5 ABO-weighted projected screening burden model for RhCE antibody specificities in RhD-positive donor populations

Rh antibody specificity	Number of units screened by ABO blood group			
	O	A	B	AB
Anti-E	4	8	5	19
Anti-c	5	8	5	21
Anti-C	58	107	68	276
Anti-e	82	147	109	452
Anti-c and anti-E	7	12	8	30
Anti-C and anti-e	1,786	3,197	2,435	9,709
Anti-C and anti-E	85	158	100	401

anti-C and anti-e required screening of 23 and 33 units, respectively. Among combined antibodies, anti-C plus anti-e required 43 units, whereas anti-C plus anti-E showed the highest screening requirement at 417 units.

To better reflect clinical practice, an ABO-weighted screening burden model was constructed (Table 5) by integrating compatible donor probability with ABO blood group distribution using data of 11,295 blood donors. For each antibody specificity, the probability of identifying a compatible donor unit was first estimated based on the absence of the corresponding antigen(s) and then adjusted according to the proportion of ABO-compatible donor units for each blood group. The estimated number of units required for screening was calculated as the reciprocal of the ABO-adjusted compatible probability ($1/P_{\text{compatible}}$). As this model is based on aggregated phenotype frequencies rather than direct counts, the estimated screening requirements do not directly cor-

respond to the raw antigen frequencies presented in Table 2. The model was applied to RhD-positive donor populations.

Using this ABO-weighted model, screening requirements varied according to both antibody specificity and ABO blood group. Blood groups O and B demonstrated comparable screening requirements for certain antibody specificities, whereas blood group AB generally showed the highest screening burden.

Discussion

This study provides a comprehensive analysis of Rh antigen and phenotype distributions among Thai blood donors, as well as the occurrence of clinically significant Rh alloantibodies in patients. We also examined the frequencies of ABO blood groups among 11,295 blood donors who underwent additional Rh antigen typing, including the C, c, E, and e antigens. Our findings

revealed that blood group O was the most prevalent, followed by groups B, A, and AB, consistent with other studies conducted among Thai blood donor populations.¹⁶⁻¹⁸ Similarly, the RhD status in this study revealed that RhD-positive and RhD-negative donors accounted for 99.57% and 0.43%, respectively.¹⁶⁻¹⁸

A high prevalence of e and C antigens was confirmed among Thai blood donors in this study, while c and E antigens were found to be less common. Regarding RhCE phenotypes, the most common was C+ c- E- e+. Consequently, anti-E was identified as the predominant alloantibody, followed by anti-c, anti-C, and anti-e. This pattern is consistent with findings from related studies in Thai patient populations.⁸⁻¹² Notably, anti-D was found in 8 out of 257 patients, representing 2.31%. Overall, these findings have significant implications for transfusion practices, particularly concerning the provision of phenotype-matched blood.

The distribution of RhCE phenotypes among the Thai donor population in this study was generally consistent with findings from other Thai populations, including donors from Central and Northeastern Thailand.^{19,20} Specifically, the C+ c- E- e+ phenotype of RhD-positive donors remained the most predominant, aligned with the ABO groups. Moreover, a similar pattern was observed in other Asian populations,^{3,21} whereas lower frequencies of this phenotype were noted in Chinese and North Indian groups.^{22,23} In contrast, the prevalence of this phenotype was significantly reduced in European and Middle Eastern populations, such as Albanian and Kurdish groups,^{24,25} who had a relatively higher frequency of phenotypes expressing the c antigen. Furthermore, the C- c+ E- e+ phenotype was the most prevalent among RhD-negative donors, a finding consistent with other studies on Thai blood donors.^{16,17} Taken together, these findings emphasize the ethnic variations in the distribution of Rh haplotypes.

The probability of identifying at least one compatible blood unit for patients with Rh alloantibodies was relatively high for anti-E, anti-c, and combined anti-E plus

anti-c, requiring testing of only two units. In contrast, patients with anti-C and anti-e may require testing of more than 20 units, consistent with a related study in Thai populations.¹⁵ Notably, greater difficulty was observed in patients with anti-C plus anti-e and anti-C plus anti-E. When the likelihood is based on compatible units from blood groups O and B, group B would have a higher probability of yielding compatible blood units for certain Rh antibody specificities, as shown in Table 5. Blood group AB generally exhibited the lowest probability due to limited donor compatibility. Importantly, this study integrates donor Rh antigen distribution data with the spectrum of Rh alloantibodies identified in our patients, demonstrating concordance with findings from Thai populations. These results underscore the clinical utility of extended RhCE antigen typing (C, c, E, and e), as these alloantibodies remain among the most encountered and substantially influence the efficiency of locating compatible blood. Accordingly, maintaining a registry of donors and an inventory of known RhCE phenotypes—particularly rare phenotypes—would optimize inventory management and ensure timely access to compatible blood for transfusion.

Conclusion

This study analyzed Rh antigen distributions in conjunction with ABO blood groups among Thai blood donors. The findings support the establishment of a donor registry of known RhCE phenotypes and the implementation of extended RhCE antigen typing (C, c, E, and e) to improve the identification of phenotype-matched units for patients with alloantibodies. In addition, the ABO-based estimation of screening burden provides a practical framework for optimizing inventory management and facilitating timely access to compatible blood, thereby enhancing transfusion safety and reducing the risk of alloimmunization.

References

- Daniels G. Human blood groups: Rh and RHAG blood group systems. 3rd ed. Oxford: Blackwell Science; 2013.
- Cohn CS, Delaney M, Johnson ST, Katz LM, Schwartz J. Technical manual. 21st ed: Bethesda, MD: AABB; 2023.
- Reid ME, Lomas-Francis C, Olsson ML. The blood group antigen factsbook: Rh blood group system. 3rd ed. New York: Academic Press; 2012.
- International Society of Blood Transfusion. Red cell immunogenetics and blood group terminology. [cited 2026 March 13] Available from: <https://www.isbtweb.org/resource/008fy.html>.
- American Association of Blood Banks. Standards Program Committee. Standard for blood banks and transfusion practice. 31st ed. Bethesda, MD: AABB; 2018.
- Chiewsilp P, Bejrachandra S, Thongthaisin A. Standards for blood bank and transfusion practice. 5th ed. Bangkok, Udomsuksa; 2015.
- Fucharoen S, Tanphaichitr VS, Torcharus K, Viprakasit V, Mekaewkunchorn A. Clinical practice guidelines for diagnosis and management of thalassemia syndromes. Bangkok: P.A. Living; 2014.
- Kupatawintu P, Emthip M, Sungnoon D, O-vataga P, Manakul V, Limtamaporn S, et al. Unexpected antibodies of patients' blood samples sent for testing at NBC. TRCS. J Hematol Transfus Med. 2010;20:255-62.
- Bejrachandra S, Chandanayingyong D. Unexpected red cell antibodies in donors and patients at Siriraj Hospital. Southeast Asian J Trop Med Public Health. 1979;10:204-6.
- Chidtrakoon S, Jeumjanya N, Intharanut K, Nathalang O. Analysis of pretransfusion testing events occurring in patients at Thammasat University Hospital. J Hematol Transfus Med. 2020;30:345-51.
- Pongernnak P, Sasjeenpong S, Chuesakul K, Pangwangthong K. The prevalence of red blood cell alloantibodies in lower Northern Thailand. J Med Assoc Thai. 2016;99:1337-43.
- Promwong C, Siammai S, Hassarin S, Buakaew J, Yeela T, Soisangwan P, et al. Frequencies and specificities of red cell alloantibodies in the Southern Thai population. Asian J Transfus Sci. 2013;7:16-20.
- Bhuva DK, Vachhanai JH. Red cell alloimmunization in repeatedly transfused patients. Asian J Transfus Sci. 2017;11:115-20.
- Osman NH, Sathar J, Leong CF, Zulkifli NF, Raja Sabudin RZ, Othman A, et al. Importance of extended blood group genotyping in multiply transfused patients. Transfus Apher Sci. 2017;56:410-6.
- Intharanut K, Bejrachandra S, Nathalang S, Leetrakool N, Nathalang O. Red cell genotyping by multiplex PCR identifies antigen-matched blood units for transfusion-dependent Thai patients. Transfus Med Hemother. 2017;44:358-64.
- Fongsarun J, Nuchprayoon I, Yod-in S, Kupatawintu P, Kidprasirt C. Blood groups in Thai blood donors. J Hematol Transfus Med. 2002;12:277-86.
- Nathalang O, Kuvanont S, Punyaprasiddhi P, Tasaniyanonda C, Sriphaisal T. A preliminary study of the distribution of blood group systems in Thai blood donors determined by the gel test. Southeast Asian J Trop Med Public Health. 2001;3:204-7.
- Bejrachandra S, Nathalang O, Saipin J, Kuvanont S, Wichitchinda K, Vongpattranon A. Distribution of blood group systems in Thai blood donors determined by the gel test. Siriraj Hosp Gaz. 2002;54:403-9.
- Fongsarun J, Nuchprayoon I, Yenchitsomanus PT. Distribution of Rh blood group antigens in central Thai blood donors. Asian Pac J Allergy Immunol. 2002;20:235-9.
- Romphruk AV, Butryojantho C, Jirasakonpat B, Junta N, Srichai S, Puapairoj C, et al. Phenotype frequencies of Rh (C, c, E, e), M, Mi^a and Kidd blood group systems among ethnic Thai blood donors from the north-east of Thailand. Int J Immunogenet. 2019;46:160-5.
- Musa RH, Ahmed SA, Hashim H, Ayob Y, Asidin NH, Choo PY, et al. Red cell phenotyping of blood from donors at the National Blood Center of Malaysia. Asian J Transfus Sci. 2012;6:3-9.
- Zhao Y, Yao N, Lv Y, Xie J. Analysis of Rhesus (Rh) antigen distributions in donors and multi-transfused patients for phenotype-matched transfusion. Indian J Hematol Blood Transfus. 2024;40:130-8.
- Makroo RN, Bhatia A, Gupta R, Phillip J. Rh phenotype, allele and haplotype frequencies among blood donors in North India. Transfus Med. 2014;24:207-11.
- Getta HA, Amin SS, Khoshnaw N, Muhammad BA. Distribution of red cell antigens according to ABO, Rh and other rare blood group systems in Kurdish ethnicity. Iraqi J Hematol. 2016;5:55-80.
- Xhetani M, Seferi I, Férec C, Zoraci G, Fichou Y. Distribution of Rhesus blood group antigens and weak D alleles in the population of Albania. Blood Transfus. 2014;12:565-9.

