Clin. Lab. 2024;70:XXX-XXX

ORIGINAL ARTICLE

Prevalence of ABO, Rh, and Kell Antigens Among Blood Donors in Al-Qurayyat Region

Fehaid M. Alanazi

Department of Clinical Laboratory Sciences, College of Applied Medical Sciences Al-Qurayyat, Jouf University, Sakaka, Saudi Arabia

SUMMARY

Background: **The ABO, Rh, and Kell blood groups are the most immunogenic and clinically important blood antigens. These antigens can trigger strong immune responses after blood transfusions, leading to alloimmunization and post-hemolytic transfusion reactions. The aim of this study was to determine prevalence of ABO, Rh, and Kell blood group antigens at the Al-Qurayyat Regional Laboratory and Blood Bank Center, Al-Qurayyat region, Saudi Arabia.**

Methods: **This study was a prospective observational cross-sectional study conducted at the Al-Qurayyat Regional Laboratory and Blood Bank Center from November 2022 to September 2023. The selection of voluntary and replacement donors was based on recommendations by the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI). A total of 779 Saudi donors aged between 18 and 60 years participated in the study.**

Results: **In this study, O blood group was the most prevalent (50.1%), followed by B (32.0%), A (14.4%), and AB (3.6%). RhD positivity was relatively high (93.3%); a characteristic of global trends. Among RhD-positive individuals, R1r and R1R1 were the most prevalent Rh phenotypes, consistent with trends observed in Caucasian and Asian populations; however, the most frequent Rh phenotype in RhD-negative individuals was rr. Presence of the Kell antigen was observed in 9.5% of the participants, and interestingly all individuals who tested positive for the Kell antigen were also RhD positive. Conversely, no RhD-negative individuals exhibited the Kell antigen.**

Conclusions: **Findings from this study highlight the importance of implementing proper inventory management to ensure safe transfusion of blood products. Additionally, this study established a crucial baseline for clinically important blood antigens that also enhances understanding of blood groups and regional variations that could better inform healthcare management systems and public health policies in Saudi Arabia.**

(Clin. Lab. 2024;70:xx-xx. DOI: 10.7754/Clin.Lab.2024.240710)

Correspondence:
Fehaid M. Alanazi
Department of Clinical Laboratory Sciences
College of Applied Medical Sciences Al-Qurayyat
Jouf University
Sakaka 42421
Saudi Arabia
Email: fmaalanazi@ju.edu.sa

Manuscript accepted July 12, 2024

KEYWORDS

ABO, Rh, Kell, alloimmunization, donor, blood transfusion

INTRODUCTION

Blood products are therapeutic substances derived from human blood that are donated, processed, typed, and stored in blood banks. Blood products are distributed to hospitals, where they are administered whole or as components to treat patients. Prior to transfusion, donor red blood cells (RBCs) are matched with the recipient plasma to prevent post-transfusion reactions [1]. The International Society of Blood Transfusion (ISBT) has iden-

tified 43 blood group systems that can stimulate antibody production [2]. The ABO system, first described by Landsteiner in 1900, classifies blood based on the presence or absence of A or B antigens on the surface of RBCs and is the most clinically significant blood group system. Anti-A and anti-B antibodies, known as isoantibodies and usually IgM antibodies, develop naturally in the plasma without prior exposure to their corresponding antigens [3]. For example, individuals with blood group A have A antigens on the surface of their RBCs and anti-B antibodies in their plasma, which occur naturally within four months after birth. If an ABO mismatch occurs during transfusion, severe post-transfusion reactions can occur.

In addition to the ABO system, the Rh and Kell systems are the next most clinically important blood group system antigens, that can also cause immune reactions and post-hemolytic transfusion reactions [4]. For example, individuals with RhD or Kell negative blood types (i.e. who lack both D and K antigens) normally do not develop antibodies; however, these individuals will produce antibodies (i.e. IgG alloantibodies) if exposed to D or K antigens during mismatched blood transfusions or pregnancy [5,6]. In pregnancy, these antibodies can cause severe hemolytic disease of the fetus and newborn, when they cross the placenta and destroy RBCs [7]. Therefore, transfusing matched blood to patients minimizes RBC destruction and sensitization (i.e. producing antibodies against the antigen that is absent in a particular blood group) to these clinically significant antigens, improving the safety and efficacy of blood transfusions [8].

Hemoglobinopathies are highly prevalent in Saudi Arabia with beta-thalassemia present in approximately 1.36% of the population and sickle cell anemia affecting 4.96% of the population [9]. Iron deficiency anemia is also common in Saudi Arabia and affects approximately 20% - 40% of the susceptible population, which includes school-aged children and women of reproductive age [10]. Some of these disorders require frequent blood transfusions that increases the risk of alloimmunization development of alloantibodies. It has been reported that approximately 13 - 18% of sickle cell disease patients and 20% of thalassemia patients develop alloantibodies, with the most common being Rh and Kell. In chronically transfused patients, the therapeutic strategy is to administer Rh and K1 matched blood to avoid alloimmunization [11,12]. Additionally, approximately 2% of pregnant women are sensitized, mostly to anti-D antibodies [13].

Provincial distribution of ABO, RhD, and Kell antigens throughout Saudi Arabia is important for optimizing clinical practices associated with blood transfusions, organ transplants, and the management of Rh incompatibility during pregnancies. Across Saudi Arabia, the O blood group is highly prevalent, making it the most requested blood type for transfusions due to its universal donor status. For example, the O blood group is the most prevalent ABO blood group in the Eastern Province, Makkah City, and the Northern Asir region, followed by A, B, and AB. This trend is also present in the Al-Jouf Province, where the O blood group is the most prevalent, followed by A, B, and AB blood groups. Widespread prevalence of the O blood group highlights the importance of maintaining a robust supply of O-type blood in regional blood banks [14].

The Rh factor, particularly the RhD antigen, is predominantly positive in most regions, simplifying some transfusion procedures. In the Al-Jouf Province, the prevalence of RhD-positive blood significantly exceeds RhD negative, reflecting trends observed in Turabah Province and Northwestern Saudi Arabia where over 85% of the population is RhD positive [15,16]. This distribution necessitates a strategic reserve of RhD-negative blood to cater to the needs of RhD-negative individuals, preventing sensitization and other complications. The Kell blood group system, although less commonly studied, exhibits significant clinical relevance due to its immunogenic potential, which can cause hemolytic transfusion reactions and hyporegenerative anemia associated with hemolytic disease of the fetus and newborn (HDFN). In Taif City, approximately 8% of blood donors carry the Kell antigen, emphasizing the need for careful screening and matching in blood transfusions, especially in pregnancies where the mother is Kell-negative and the fetus is Kell-positive [17].

While several Saudi Arabian studies have examined distribution of ABO and Rh blood group systems, it is important to acknowledge the regional focus of these investigations, particularly on the Eastern region and the capital city. Unfortunately, a significant knowledge gap remains regarding the distribution of ABO, Rh (D, C, c, E, and e), and Kell antigens in Al-Qurayyat, the second-largest city in the Al-Jouf Region of Northern Saudi Arabia. Therefore, this study aimed to determine the prevalence of Rh phenotypes and frequency distribution of ABO, Rh, and Kell antigens and alleles among blood donors in the Al-Qurayyat Regional Laboratory and Blood Bank Center, compare these findings with other ethnic groups to provide transfusion support to multi-transfused patients with alloantibodies, and generate a database of individuals with rare antigens to enhance blood safety and prevent hemolytic transfusion reactions.

MATERIALS AND METHODS

This study employed a cross-sectional, descriptive, and observational design to examine the distribution of ABO, Rh, and Kell antigens among the Saudi population using one-point analysis. The research was conducted at the Al-Qurayyat CBAHI-accredited Regional Laboratory and Blood Bank Center, with data collected from November 2022 to September 2023. Ethical approval was obtained from the Al-Qurayyat Health Directorate Ethics Committee (IRB approval of research project no. 2023-199). This is the first study to report

frequency of clinically important ABO, Rh, and Kell antigens among the Al-Qurayyat population of Al-Jouf region, Saudi Arabia.

Participants and setting

Participants included Saudi blood donors attending the Al-Qurayyat Regional Laboratory and Blood Bank Center, who met the blood donation criteria and were aged 18 to 60 years. Written informed consent was obtained from each participant in accordance with ethically approved study protocols. Donors qualified for blood donation in accordance with guidelines prescribed by the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI).

Inclusion criteria

The study was conducted between 2013 and 2014 in Saudi Arabia. Inclusion criteria included being of Saudi nationality, healthy, aged between 18 - 60 years, meeting donation guidelines prescribed by CBAHI, and agreeing to take part in the study.

Exclusion criteria

Exclusion criteria were designed to support the focus of the study and include only a homogenous sample of participants. Exclusion criteria were: non-Saudi nationality, incomplete transfusion procedures, history of blood transfusions, hematological disease, reliance on blood transfusions, and ineligibility according to the selected inclusion criteria.

Sample size and sample collection

The study used a simple random sampling method to ensure sample selection involved eligible participants having an equal chance of being in the study, so subjectivity from choosing only a certain sample was eliminated. This study was approved by the Research Ethics Committee (Qurayyat Health Affairs). Written informed consent was obtained from all participants prior to blood donation. Samples were collected in 5 mL EDTA tubes, with all antigen typing performed within 48 hours of collection.

Blood group typing and Rh phenotyping

ABO and Rh blood typing were performed using the DiaMed technique with ID cards (ABO and Rh/ Grouping, ID-Card, Ortho-Clinical Diagnostics Ltd., Pencoed, UK) that utilize the gel column agglutination method. Next, 50 µL of red cell suspension were added to each ID card. Blood group was defined according to agglutination patterns observed in forward grouping and negative controls scoring 0 - 4 range. To identify the presence of C, c, E, e, and K antigens, extended Rh phenotyping was performed. This analysis utilized a specialized gel test (Ortho-Clinical Diagnostics ID-Card, Pencoed, UK) and followed a protocol similar to the ABO blood group typing, with careful interpretation of agglutination patterns on the ID cards.

Quality control

Controls were included in every typing to ensure validity and accuracy of all results. Each ID card underwent careful review to confirm precise results and adherence to the correct procedure using heterozygous positive controls for phenotyping. Controls were prioritized and examined first. Only if controls produced positive results were the test results for the samples recorded. The ID cards were checked and interpret visually for agglutination or hemolysis. This meticulous approach ensures accuracy and reliability of test results.

Statistical analysis

Data analysis was conducted using SPSS, version 22, software and included calculating the percentages presented in appropriate diagrams and tables.

RESULTS

Distribution of ABO and Rh blood groups, including the Kell antigen, was determined in 779 study participants. In Figure 1, results show the most prevalent ABO blood group system to be the O blood group (50.1%), followed by the B (32.0%), A (14.4%), and AB (3.6%) blood groups. As shown in Table 1, the most common Rh antigen observed was RhD (93.3%), while frequencies of other Rh antigens were 79.3% for C, 70.6% for c, 34.8% for E, and 76.1% for e. Table 1 also shows distribution of Kell system antigens with 9.5% of the Al-Qurayyat population possessing the Kell antigen (K) and 90.5% of the population being Kell negative (Table 1). Distribution of Rh and Kell antigens within the different ABO blood groups is presented in Table 2, revealing that across all ABO blood groups, antigens D, C, c, and e were more prevalent. Conversely, antigens E and K were less prevalent in the sampled population, with all K antigen positivity (9.5%) observed only in RhD-positive individuals. Findings from this study are consistent with a previous study conducted in the Jammu region of India by Irm Yasmeen [18].

To compare frequencies of Rh blood group types across different ethnicities, Table 3 presents the frequencies of different Rh blood group types observed in this study compared to frequencies measured in other ethnicities by different studies. The present study identified the most prevalent Rh-positive phenotypes as R1r (28.8%), followed by R1R1 (27.0%), while the most common Rh-negative phenotype observed was rr (4.9%). Furthermore, Table 4 compares findings from the present study with the distribution of Rh and K antigens observed in other studies conducted in Saudi Arabia and other countries. These comparisons show that results from the present study are consistent with a study conducted in the Eastern region where relative prevalence of Rh antigens (i.e. D > e > C > c > E) showed a similar pattern. Across the various ethnicities presented in Table 4, the e antigen is most prevalent among Caucasians, Indians, Pakistani, and Yemenis, except for indi-

Table 1. Frequencies of Rh and Kell antigens in the sampled population.

Rh antigens		Frequency	Percentage
D	positive	727	93.3
	negative	52	6.7
C	positive	618	79.3
	negative	161	20.7
c	positive	550	70.6
	negative	228	29.3
E	positive	271	34.8
	negative	508	65.2
e	positive	593	76.1
	negative	186	23.9
K	positive	74	9.5
	negative	705	90.5

Table 2. Frequencies of Rh and Kell antigens in different ABO blood groups.

		ABO system				Total
		A	B	AB	O	
Rh-D	positive	103	234	26	364	727
		92.0%	94.0%	92.9%	93.3%	93.3%
	negative	9	15	2	26	52
		8.0%	6.0%	7.1%	6.7%	6.7%
Rh-C	positive	91	194	23	310	618
		81.2%	77.9%	82.1%	79.5%	79.3%
	negative	21	55	5	80	161
		18.8%	22.1%	17.9%	20.5%	20.7%
Rh-c	positive	82	167	18	283	550
		73.2%	67.1%	64.3%	72.8%	70.7%
	negative	30	82	10	106	228
		26.8%	32.9%	35.7%	27.2%	29.3%
Rh-E	positive	35	87	6	143	271
		31.2%	34.9%	21.4%	36.7%	34.8%
	negative	77	162	22	247	508
		68.8%	65.1%	78.6%	63.3%	65.2%
Rh-e	positive	90	189	24	290	593
		80.4%	75.9%	85.7%	74.4%	76.1%
	negative	22	60	4	100	186
		19.6%	24.1%	14.3%	25.6%	23.9%
K	positive	8	25	3	38	74
		7.1%	10.0%	10.7%	9.7%	9.5%
	negative	104	224	25	352	705
		92.9%	90.0%	89.3%	90.3%	90.5%

Table 3. Comparison of Rh phenotype frequencies measured in the present study with different ethnic groups.

Rh phenotype	Present study	Indian	Caucasian	Black	Asian
r' r''	0.1%	0.002%	*	*	*
r'r	1.7%	2.32%	0.8%	0.01%	0.1%
rr	4.9%	4.76%	15.1%	6.8%	*
R_0r	3.3%	1.15%	1.7%	45.8%	0.3%
R_1r	28.8%	34.9	21	8.5	35.6
R_1R_1	27.0%	40.95%	19.5%	2%	51.8%
R_1R_2	15.5%	14.537%	12.5%	4%	30%
R_2r	5.1%	3.69%	11.3%	18.6%	2.5%
R_2R_2	7.2%	0.78%	2%	0.2%	4.4%
R_1R_z	0.4%	0.32%	0.43%	*	1.4%
R_2R_z	6.0%	0.4%	0.002%	*	0.4%

*** Note - not mentioned.**

Tabłe 4. Comparison of Rh and K antigen distribution in Saudi Arabia with other ethnicities.

Saudi Arabia			
Country/Region	**Prevalence order (high to low)**	**K %**	**References**
Present study	D > C > e > c > E	9.5	
Southwestern region (Jazan)	e > D > C > E > c	4.54	[19]
Southwestern region (Samtah)	e > D > C > E > c	11.9	[20]
Western region (Taif)	e > D > c > C > E	22.1	[17]
Central region (Riyadh)	e > D > c > C > E	13.9	[21]
Northwestern region (Hail)	e > c > D > C > E	*	[22]
Eastern region	D > e > C > c > E	9.5	[23]
Other ethnicities			
USA (Caucasians)	e > D > c > C > E	9	[24]
Egyptians	e > D > c > C > E	8.23	
Indians	e > D > C > c > E	3.5	[25]
Pakistani	e > D > C > c > E	4.1	[20]
Yemenis	e > D > c > C > E	12.6	
Black population	e, c > D > C > E	2	[26]

*** Note - not mentioned.**

viduals of African descent, who showed equal occurrence of both e and c antigens. Conversely, the E antigen exhibited the lowest prevalence across all ethnicities.

DISCUSSION

Blood group antigens reflect interactions between human genomes and environmental pressures and are often useful markers for regional adaptations. To the best of our knowledge, this is the first study performed in Al-Qurayyat region to determine frequencies and distribution of ABO, RhD, and Kell blood group antigens among its population. This research is predicted to play

Table 5. Comparison of ABO blood group distribution in different regions of Saudi Arabia.

Region	ABO prevalence order	References
Present study (Al-Qurayyat)	O > B > A > AB	present study
Eastern region	O > A > B > AB	[27]
Southwestern region (Jazan)	O > A > B > AB	[19]
Western region	O > A > B > AB	[28]
Northern region (Al-Jouf)	O > A > B > AB	[15]
Central region (Riyadh)	O > A > B > AB	[4, 29]
Northwestern region (Hail)	O > B > A > AB	[22]

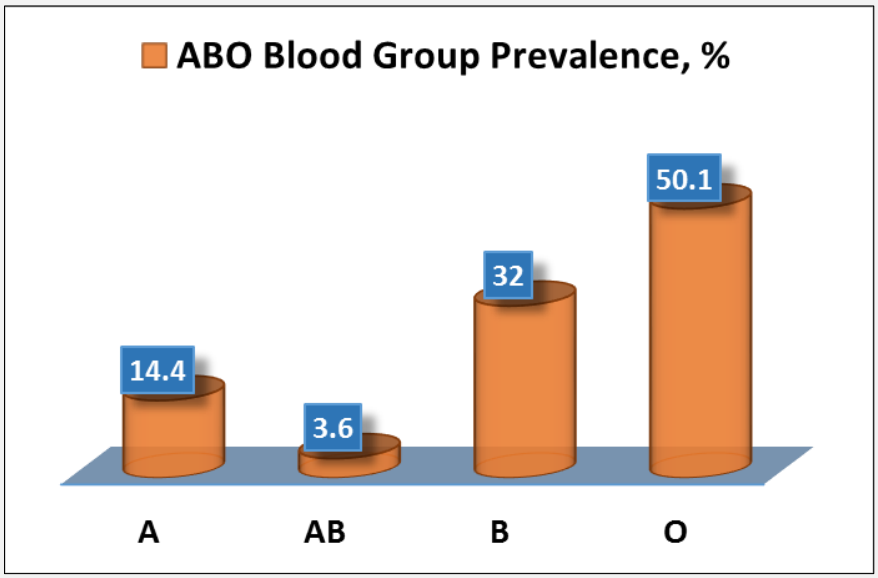

Figure 1. Distribution of ABO blood groups in the sampled population.

a role in regional and global genetic comparisons by emphasizing the need to consider regional variations when striving to understand the genetic architectures of various human populations.

Distribution of ABO blood groups in Al-Qurayyat region (Table 5) showed a unique O > B > A > AB order. Conversely, O > A > B > AB has been the more prevalent distribution pattern of rare blood type alleles observed in several other regions of Saudi Arabia [23]. In the eastern province of Saudi Arabia, a similar study showed high prevalence of O blood group (51 - 52%) and almost equal frequencies of D positivity among study participants (91.5% - 93%) [27]. Findings are consistent across different regional studies from various parts of Saudi Arabia, such as Eastern, Southwestern (Jazan), Western, Northern (Al-Jouf), Central (Riyadh), and Northwestern (Hail) regions, that all reported ABO blood group prevalence as O > A > B > AB. But in Hail, B is more prevalent than A [27]. Including multiple regional studies strengthens the scientific validity of these findings and provides a comprehensive understanding of the ABO blood group distribution within Saudi Arabia. The present study revealed a significant regional disparity in ABO blood group frequencies within the population of Saudi Arabia and highlights the need to pay more attention to community specific populations when studying blood groups.

Prevalence of the D positive antigen was consistent across all regions when compared to prevalence of the D negative antigen. However, the order of Rh antigen

prevalence varies. For example, in the present study, the D > C > e > c > E order of Rh antigen prevalence in Al-Qurayyat differs from trends observed in Jazan, Taif, Riyadh, and the eastern regions, as presented in Table 4 [17,19,21]. However, similar distribution patterns have been observed in the southwestern regions of Jazan and Samtah, where the order pattern is e > D > C > E > c. Additionally, a similar distribution pattern is observed in Taif and Riyadh, where the order is e > D > c > C > E [30]. These studies reveal variations in Rh antigen distribution across different regions of Saudi Arabia, emphasizing the importance of regional data when considering blood transfusion protocols and healthcare strategies. When comparing these findings with international data, a prevalence pattern of e > D > c > C > E is observed among Caucasian Americans, Egyptians, and Yemenis, while Indians and Pakistani exhibit an e > D > C > c > E pattern. However, it is worth noting that Black population display a different order with e and c sharing the highest prevalence, followed by D, C, and E [30]. These observations reveal obvious global trends, as well as localized peculiarities in Rh antigens.

The blood group profiles observed in Al-Qurayyat region have not been previously detected in any other populations. This could be due to genetic drift or founder effects affecting small populations where limited admixture occurred [31]. Subsequently, investigating the genetic history and demographic make-up of the Al-Qurayyat populations could enhance understanding of how these unique prevalence patterns emerged. More research into these areas is critical and could provide invaluable information about the factors that influence these unique distribution patterns. The results of the present study also showed high prevalence of RhD-positive individuals (93.3%) in the population of Al-Qurayyat, consistent with global trends that highlight how this antigen is the most dominant worldwide. However, differences in the e antigen indicate a specific genetic difference that separates Jazan from Al-Qurayyat region, reflecting diversity between these populations [21]. These differences could be due to ancient population movement, genetic drift, or force of natural selection in one direction on a specific Rh antigen. This variation may reflect complex interactions between genetic and environmental forces influencing distribution and frequencies of Rh blood groups.

Increased frequencies of R1r and R1R1 Rh phenotypes in RhD-positive individuals from the Al-Qurayyat population are also reported by studies conducted in different regions throughout Saudi Arabia suggesting distribution and frequencies of Rh phenotypes that are common among the Saudi population. This observation indicates that a common genetic origin or environmental etiologic factors have modified Rh gene expression [21, 30]. However, consistent and inconsistent trends have been observed across demographic groups. For example, higher prevalence of R1R1 and R1r is also observed in both Caucasian and Asian populations [32], while prevalence of alternative blood group types varies among different populations, like the Rh blood group type distribution in Al-Qurayyat. Therefore, more research is needed into the genetic and environmental factors influencing Rh phenotype, which could reveal the mechanisms underlying these shared expression patterns and provide further insights into blood compatibility for transfusion medicine.

Low prevalence of the Kell antigen observed in Al-Qurayyat is consistent with findings from various regions in Saudi Arabia and other countries, supporting emerging evidence of low Kell antigen prevalence among diverse populations [24]. In addition, these findings highlight how the K antigen is only prevalent among RhD positives (9.5%). However, prevalence of Kell antigens in Al-Qurayyat region is higher than prevalence reported in some regions of Saudi Arabia, although multiple studies have reported different prevalence rates of 4.54% in Southwestern region (Jazan), 11.9% in Southwestern region (Samtah), 18.2% in Central (Riyadh) region, and 9.5% in the Eastern region [19, 20,21,23]. Conversely, Kell antigen has been observed in 9% of Caucasian Americans, 8.23% of Egyptians, 4.1% of Pakistani, and 2% of Black population [20,33, 34]. These observations suggest that global distribution of the Kell system is homogeneous, despite regional differences, and could be due to the Kell antigen under a selective disadvantage or because it reached various populations through different paths during human evolution. These observations also invoke exciting implications regarding the distribution and clinical importance of the Kell antigen.

The results of the present study demonstrate the complexity of the genetic properties of Saudi Arabia and blood group antigens. Consequently, analyzing antigen patterns and diversity contributes significantly to understanding the genetic history and demographic parameters of the Saudi population. Findings were consistent with current literature and highlight the importance of addressing regional variations in blood group antigen prevalence to promote comprehensive healthcare management and public health practice. Determining blood group allelic frequencies within populations is important for safety during the transfusion process and for administering blood bank inventory. The results of this study offer important practical considerations for blood banks in the Al-Qurayyat region by helping them to establish and quantify regional needs for blood products. Blood banks use these regional differences to predict potential incompatibilities and minimize the risks of adverse reactions during transfusions. When treating patients, this knowledge is imperative for better patient care and outcomes.

CONCLUSION

Prevalence and frequency distribution of blood antigens were heterogenous between different Saudi regions and among various ethnic groups. ABO blood group distri-

bution in Al-Qurayyat region exhibited a different pattern to other Saudi Arabia regions but was similar to findings reported by Hail. In addition, frequencies of Rh and K antigens differed across various ethnic groups and regions of Saudi Arabia. These findings emphasize the need to consider regional and ethnic factors when designing transfusion protocols and healthcare interventions that minimize the risks of RBC antigen alloimmunization and associated complications.

Acknowledgment:
The author would like to thank the Health Affairs and the Regional Laboratory and Blood Bank Center, Al-Qurayyat region, Saudi Arabia, for their time and support in providing blood samples for the community and for enabling this research.

Declaration of Interest:
The author declares that he has no conflicts of interest.

References:

1. Apecu RO, Mulogo EM, Bagenda F, Byamungu A. ABO and Rhesus (D) blood group distribution among blood donors in rural south western Uganda: a retrospective study. BMC Res Notes 2016;9(1):513. (PMID: 28003029)

2. Li H-Y, Guo K. Blood Group Testing. Front Med (Lausanne) 2022;9:827619. (PMID: 35223922)

3. Farhud DD, Zarif Yeganeh M. A brief history of human blood groups. Iran J Public Health 2013;42(1):1-6. (PMID: 23514954)

4. Elsayid M, Alfaifi AM, Almutairi AK, Almajed F, Al Saqri F, Qureshi S. Phenotypic Profile of Kell blood group system among saudi donors at King Abdulaziz Medical City-Riyadh. J Med Sci Clin Res 2017;5:15654-7. DOI: https://dx.doi.org/10.18535/jmscr/v5i1.75

5. Avent ND, Reid ME. The Rh blood group system: a review. Blood 2000;95(2):375-87. (PMID: 10627438)

6. Dean L. Blood Groups and Red Cell Antigens. National Center for Biotechnology Information (US) 2005. https://www.ncbi.nlm.nih.gov/books/NBK2261/

7. Delaney M, Matthews DC. Hemolytic disease of the fetus and newborn: managing the mother, fetus, and newborn. Hematology Am Soc Hematol Educ Program 2015;2015:146-51. (PMID: 26637714)

8. Tormey CA, Hendrickson JE. Transfusion-related red blood cell alloantibodies: induction and consequences. Blood 2019;133(17):1821-30. (PMID: 30808636)

9. Alhuthali HM, Ataya EF, Alsalmi A, et al. Molecular patterns of alpha-thalassemia in the kingdom of Saudi Arabia: identification of prevalent genotypes and regions with high incidence. Thromb J 2023;21(1):115. (PMID: 37950286)

10. Almasmoum HA, Iqbal MS, Aljaadi A, et al. Prevalence of undiagnosed iron deficiency anemia and associated factors among female undergraduate medical students in Makkah, Saudi Arabia. Cureus 2023;15(12):e50046. (PMID: 38186469)

11. Rankin A, Darbari D, Campbell A, et al. Screening for new red blood cell alloantibodies after transfusion in patients with sickle cell disease. Transfusion 2021;61(8):2255-64. (PMID: 34002408)

12. Jariwala K, Mishra K, Ghosh K. Comparative study of alloimmunization against red cell antigens in sickle cell disease & thalassaemia major patients on regular red cell transfusion. Indian J Med Res 2019;149(1):34-40. (PMID: 31115372)

13. Isaac IZ, Osaro E, Adias TC, et al. Prevalence of clinically significant alloantibodies among transfusion requiring patients in a tertiary hospital in Sokoto, Nigeria. Int Blood Res Rev 2017;7(4):1-9. DOI: http://dx.doi.org/10.9734/IBRR/2017/29073

14. Belali TM. Distribution of ABO and Rhesus Types in the Northern Asir Region in Saudi Arabia. J Blood Med 2022;13:643-8. (PMID: 36386043)

15. Eweidah MH, Rahiman S, Ali MDH, Al-Shamary AMD. Distribution of ABO and Rhesus (RHD) Blood Groups in Al-Jouf Province of the Saudi Arabia. The Anthropologist 2011;13(2):99-102. DOI: http://dx.doi.org/10.1080/09720073.2011.11891182

16. Nasir O, Mustafa MHI, Elmisbah TE, Salim A-MMM, Ahmed MAM, Babiker S. RHD and RHCE frequencies and gene complexes among major tribes of Turabah Province, Saudia Arabia. International Journal of Multidisciplinary and Current Research 2014;2:573-8. http://ijmcr.com/rhd-and-rhce-frequencies-and-gene-complexes-among-major-tribes-of-turabah-province-saudia-arabia/

17. Felimban R, Al-Ghamdi A, Elmissbah T, et al. ABO, Rh, and Kell Blood Group Antigen Frequencies in Blood Donors of Taif City, Saudi Arabia. Clin Lab 2023;69(7). (PMID: 37436389)

18. Yasmeen I, Sidhu M, Ahmed I. Distribution of RH and Kell (K) blood group antigens among blood donors in a tertiary care hospital of Jammu region, India. Internat J Res Med Sciences 2019;7(4):1308-12. DOI: org/10.18203/2320-6012.ijrms20191344

19. Halawani AJ, Arjan AH. ABO, RH, and KEL1 antigens, phenotypes and haplotypes in Southwestern Saudi Arabia. Clin Lab 2021;67(2). (PMID: 33616335)

20. Hamali HA, Madkhali MM, Dobie G, et al. Prevalence of Rh and K phenotypes among blood donors from different ethnicities in Samtah (Southwestern Region) Saudi Arabia. Int J Immunogenet 2022;49(3):202-8. (PMID: 35513355)

21. Alalshaikh M, Almalki Y, Hasanato R, et al. Frequency of Rh and K antigens in blood donors in Riyadh. Hematol Transfus Cell Ther 2022;44(4):555-9. (PMID: 33992594)

22. Qanash H, Alcantara JC, Alshammari AM, et al. The Frequencies of ABO and Rh Phenotypes among Male Blood Donors in Northwestern Saudi Arabia. Clin Lab 2022;68(11). (PMID: 36377997)

23. Owaidah AY, Naffaa NM, Alumran A, Alzahrani F. Phenotype Frequencies of Major Blood Group Systems (Rh, Kell, Kidd, Duffy, MNS, P, Lewis, and Lutheran) Among Blood Donors in the Eastern Region of Saudi Arabia. J Blood Med 2020;11:59-65. (PMID: 32104128)

24. El-Gemmezi TMA, Abou El-Fetouh RM, Moftah FM, Fouda MA. Prevalence of Red Cell Blood Group Antigens Among Egyptian Population in Comparison with Other Ethnic Groups. Medical Journal of Cairo University 2018;86:989-94. DOI: https://doi.org/10.21608/mjcu.2018.55771

25. Thakral B, Saluja K, Sharma RR, Marwaha N. Phenotype frequencies of blood group systems (Rh, Kell, Kidd, Duffy, MNS, P, Lewis, and Lutheran) in north Indian blood donors. Transfus Apher Sci 2010;43(1):17-22. (PMID: 20558108)

26. Siransy Bogui L, Dembele B, Sekongo Y, Abisse S, Konaté S, Sombo M. Phenotypic Profile of Rh and Kell Blood Group Systems among Blood Donors in Cote d'Ivoire, West Africa. J Blood Transfus 2014;2014:309817. (PMID: 25328758)

27. Bashwari LA, Al-Mulhim AA, Ahmad MS, Ahmed MA. Frequency of ABO blood groups in the Eastern region of Saudi Arabia. Saudi Med J 2001;22(11):1008-12. (PMID: 11744976)

28. Alzahrani F, Shaikh S, Rasheed MA. Frequency of ABO-Rhesus Blood Groups in the Western Region of Saudi Arabia. Journal of King Abdulaziz University: Medical Sciences 2018;25:9-13. https://www.researchgate.net/publication/337392166_Frequency_of_ABO-Rhesus_Blood_Groups_in_the_Western_Region_of_Saudi_Arabia

29. Abu-Zaid A, Alsabban M, Abuzaid M, Alomar O, Al-Badawi IA, Salem H. ABO Blood Group and Endometrial Carcinoma: A Preliminary Single-Center Experience from Saudi Arabia. Cureus 2017;9(12):e1959. (PMID: 29487773)

30. AlSuhaibani ES, Kizilbash NA, Malik S. Heterogeneity and diversity of ABO and Rh blood group genes in select Saudi Arabian populations. Genet Mol Res 2015;14(3):7850-63. (PMID: 26214466)

31. Cortázar-Chinarro M, Lattenkamp EZ, Meyer-Lucht Y, Luquet E, Laurila A, Höglund J. Drift, selection, or migration? Processes affecting genetic differentiation and variation along a latitudinal gradient in an amphibian. BMC Evol Biol 2017;17(1):189. (PMID: 28806900)

32. Subramaniyan R. Phenotyping of clinically significant blood group antigens among the South Indian donor population. Hematol Transfus Cell Ther 2023;45 Suppl 2(Suppl 2):S30-5. (PMID: 34998784)

33. El-Beshlawy A, Salama AA, El-Masry MR, El Husseiny NM, Abdelhameed AM. A study of red blood cell alloimmunization and autoimmunization among 200 multitransfused Egyptian β thalassemia patients. Sci Rep 2020;10(1):21079. (PMID: 33273689)

34. Kausar T, Noureen S, Malik M, Talib S, Tariq N. Genotypic Prevalence of KELL1/KELL2 and KELL3/KELL4 Blood Group Antigens in Individuals from Four Cities of Punjab, Pakistan. BioScientific Review 2022;4:21-9. DOI: https://doi.org/10.32350/BSR.42.01