Original Article

Association of ABO, Rh-D and Kell blood groups with transfusion transmitted infections among blood donors from the Asir Region, Saudi Arabia

A retrospective observational study

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ABSTRACT

الأهداف: تقييم العلاقة بين العدوى المنقولة عن طريق نقل الدم (TTIs)وأنظمة الدم ABO وRh-D وKell blood بين المتبرعين بالدم.

المنهجية: كانت هذه دراسة بأثر رجعي أجريت على 10,095 متبرعًا قاموا بزيارة بنك الدم في مستشفى عسير، أبها، المملكة العربية السعودية. تم الحصول على البيانات بما في ذلك المعلومات الديموغرافية، ومجموعات الدم ABO، وRh-D، وKell blood، ونتائج الاختبارات المصلية والجزيئية لـTTIs من سجلات المتبرع. استخدمت الدراسة اختبارات مربع كاي وفيشر الدقيقة لإثبات أي ارتباط محتمل بين فصائل الدم و TTIs.

النتائج: كان معدل انتشار TTIs بين المتبرعين 6.3%، وكان HBcAb 70 هو المؤشر الحيوي الأكثر انتشارًا بين المتبرعين الإيجابيين. كان المتبرعون من فصيلة الدم O أكثر عرضة للإصابة بعدوى. لوحظت ارتباطات مهمة بين فيروس نقص المناعة البشرية وفصيلة الدم (χ^2=6.30, p=0.01) والمجموعة HBsAg and group AB (χ^2=17.3193, p=0.00003)، والملاريا والمجموعة A (χ^2=5.0567, p=0.02). و AB والمجموعة (χ^2=12.3163, p=0.0004). أيضًا، ارتبطت فصيلة دم كيل بشكل كبير بفيروس نقص المناعة البشرية (χ^2=14.5, p=0.0001)، و HBcAb (χ^2=78.51, p<0.0001)، والزهري (χ^2=25.225, p<0.00001).

الخلاصة: ترتبط فصائل الدم ABO وKell blood groups بعلامات TTI. تسلط هذه النتائج الضوء على الحاجة إلى تحسين الاستراتيجيات والأساليب في فحص وإدارة التبرعات بالدم لتقليل مخاطر الإصابة بعدوى TTIs.

Objectives: To evaluate the association between transfusion-transmitted infections (TTIs) and ABO, Rh-D, and Kell blood systems among blood donors.

Methods: This was a retrospective study of 10,095 donors who visited the Blood Bank at Asir Hospital, Abha, Saudi Arabia. Data including demographic information, ABO, Rh-D, and Kell blood groups, and serological and molecular test results of TTIs (the TTIs were obtained from each donor's records). Chi-squared and Fisher's exact tests were employed to establish possible associations between blood groups and TTIs.

Results: The prevalence rate of TTIs among donors was 6.3%, with HBcAb (70%) being the most prevalent biomarker among positive donors. Donors with the O blood group were at a higher risk of contracting TTIs. Significant associations were observed between HIV and blood group A (χ^2=6.30, p=0.01), HBsAg and group AB (χ^2=17.3193, p=0.00003), malaria and group A (χ^2=5.0567, p=0.02), and HBV-DNA and group AB (χ^2=12.3163, p=0.0004). Also, Kell blood group was significantly associated with HIV (χ^2=14.5, p=0.0001), HBcAb (χ^2=78.51, p<0.0001), and syphilis (χ^2=25.225, p<0.00001).

Conclusion: ABO and Kell blood groups are associated with TTI markers. These findings highlight the need for improved strategies and approaches in screening and managing blood donations to minimize the risk of TTIs.

Keywords: transfusion transmitted infections, ABO, Rh-D, Kell, blood groups, donors

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Blood transfusions are essential and life-saving in healthcare.[1] According to the World Health Organization (WHO), more than 118 million blood donations are collected globally.[2] Several complications are associated with blood transfusions, with transfusion-transmitted infection (TTI) being a potential major complication.[3] Transfusion-transmitted infections receive considerable attention due to their transient nature and potential lethal consequences.[4] Numerous pathogens can be transfusion-transmitted, including syphilis, hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV).[5] Globally, approximately 12 million individuals are affected by syphilis each year; meanwhile, approximately 2 billion people have HBV, 150 million have HCV, and 33 million have HIV.[4] In developing countries, the primary cause of TTIs is transfusion of blood or blood products without adequate or acceptable screening.[4] In general, infectious diseases contribute to declines in male and female life expectancy.[6] Transfusion-transmitted infection acquisition is thus a critical obstacle to human health and safety that must be addressed.

The ABO is the most significant blood group system in transfusion, followed by the Rhesus (Rh) and Kell systems.[7] Accordingly, ABO and Rh are the most extensively researched blood group antigens.[8] The ABO blood group status has been linked to a variety of conditions, including cardiovascular disease, cancer, and some infectious diseases.[8-10] Indeed, studies have demonstrated an association between ABO blood group and host susceptibility to pathogens such as *Helicobacter pylori*, *Escherichia coli*, *Plasmodium falciparum*, HIV, and SARS-CoV-2.[7,9]

Several studies have likewise examined the relationship of ABO and Rh status with TTIs in blood donors. Legese et al[8] reported HBV to be the most frequent TTI among Ethiopian donors, but found no significant association of either ABO or Rh blood group with TTIs. In contrast, researchers from north India found AB/Rh-positive blood group to be associated with syphilis infection and Rh-positive blood group with HBsAg.[11] Finally, recent research reported that patients negative for the Kell blood group are more susceptible to COVID-19.[12]

In Saudi Arabia, few studies have examined the prevalence and association of TTIs with ABO and Rh blood groups. In 2 studies of TTI prevalence, Alshehri et al[13] and Abdulmonem et al[14] demonstrated the anti-hepatitis B core (AHBC) to be the most common TTI marker among donors from Najran and the Central region of Saudi Arabia. Altayar et al[15] concluded that HBcAb was the most detected TTI marker among blood donors from the Western region of Saudi Arabia, and further identified a correlation of RhD with malaria. However, there is only a limited amount of information available for the Asir region. Considering the evidence regarding the importance of blood groups for TTIs, this study aimed to assess the association of ABO, Rh, and Kell status with TTIs among blood donors from the Asir region, Saudi Arabia. The findings may provide evidence that can improve blood safety in Saudi Arabia and reduce the spread of TTIs.

Methods. This single-center retrospective study was carried out from November 2020 until December 2022. It included 10,095 donors who visited the Blood Bank Center at Asir Central Hospital, Abha, Asir region, Saudi Arabia. Asir Central Hospital is a tertiary hospital with over 500 available beds that provides healthcare services to patients from the southern region of the country. Donors who fulfilled the Saudi Arabian Ministry of Health (MOH) donation criteria were accepted. To ensure the safety of the blood supply, the MOH requests that all blood donors complete a detailed donor history questionnaire containing questions relating to clinical and infectious conditions. All donors in this study underwent counseling and evaluation before donating blood, as per standard operating procedure. Donors were selected for blood donation if they were healthy with no history of TTIs, aged between 18-65 years, and had weight of ≥50 kg, hemoglobin level of ≥13 g/dl, normal pulse, blood pressure <120/80 mmHg, and temperature ≤37.5°C. Those donors who were diagnosed with hepatitis, some chronic diseases, or sexually transmitted diseases; underwent surgery; had traveled to areas with endemic diseases; had donated blood within the past 2 months; or were pregnant or a drug addict were excluded. All donors gave their written informed consent before donation. Throughout the donation process, donors were observed to ensure safety and prevent any adverse events. During both blood collection and testing, all necessary biosafety precautions and infection control protocols were followed. Donor data such as age, gender, blood groups (ABO, Rh, and Kell), and the outcomes of TTI marker tests were obtained from the donor register logbooks.

The study was approved by the ethical committee in the Deanship of Scientific Research at King Khalid University, Abha, Saudi Arabia (approval no.: ECM#2023-1201).

After donation, laboratory tests were carried out using commercially available kits according to the manufacturer's recommendations. The ABO/Rh-D

blood groups were determined using a gel agglutination identification card (Bio-RAD1000, Switzerland). Kell antigen status was determined using an anti-K identification card. The Alinity S analyzer (Abbott Laboratories, USA) was used to detect HBcAb, HBsAg, anti-HCV, HIV, syphilis, and antihuman T-cell lymphotropic virus (HTLV). A rapid qualitative test was used to detect malaria. Nucleic acid testing (NAT) was carried out in parallel to detect the presence of HCV, HBV, and HIV (Cobas 6800, Switzerland). To reduce the possibility of false positives or false negatives, samples from donors were tested in triplicate. Also, a new sample was collected and tested individually in the event of positive serology or molecular results. Upon completing the screening, all donors were provided with a serological report indicating whether or not they had tested positive for any TTIs.

Statistical analysis. GraphPad Prism (version 9.3.2.471, San Diego, CA) and Microsoft Excel, version 16.67 (22111300) were used for qualitative statistical analysis and graph preparation. Prevalence of TTIs and blood groups were expressed in percentages and numbers. The Chi-squared test and Fisher's exact test were used to determine associations between blood groups and TTIs. Specifically, 2 non-parametric data sets were analyzed using the Chi-squared test, and Fisher's exact test was employed to determine the significance of associations between categorical-nominal variables. A *p*-value of <0.05 was considered significant.

Results. A total of 10,095 participants were included in this study. Table 1 presents their demographic and clinical characteristics. The average age was 33.5±9.1 years, ranging from 18-65 years. The vast majority of participants 10,021 (99.3%) were males; only 74 (0.7%) were female. The number of donors having O blood type was 5553 (55%), 3311 (32.8%) for the A blood type, 967 (9.6%) for the B blood type, and 264 (2.6%) for the AB blood type. A total of 9097 (90.1%) donors were Rh-D positive (+ve), and 998 (9.9%) were Rh-D negative (-ve). The Kell test was only carried out for 1026 donors, of whom 946 (92.2%) were negative and 80 (7.8%) were positive (Table 1). The ABO/Rh-D blood group analysis revealed O positive (O+) to be the most common type at 49.1% of donors, followed by A positive (A+) at 29.9%, B positive (B+) at 8.57%, O negative (O-) at 5.91%, A negative (A-) at 2.87%, AB positive (AB+) at 2.50%, B negative (B-) at 1.01%, and finally AB negative (AB-) at 0.12% of donors (Figure 1A).

There were 633 (6.3%) confirmed TTI cases among biomarker-reactive donors, while the other 9462 (93.7%) donors were negative (Figure 1B). We next evaluated the prevalence of TTIs among biomarker-positive donors. The most prevalent biomarkers were HBcAb in 443 (70%) participants, syphilis in 45 (7.1%), HCV in 43 (6.8%), HbsAg in 37 (5.8%), malaria in 5 (0.8%), and HTLV in 2 (0.3%). Based on the molecular tests, 32 (5.1%) were positive for HBV-DNA, 9 (1.4%) were positive for HIV-RNA, and 3 (0.5%) were positive for HCV-RNA (Figure 1C). We further categorized biomarker-positive reactive donors based on gender. Of the 633 positive donors, 626 (98.9%) were male, and 7 (1.1%) were female (Figure 1D). Among male donors, HBcAb was the most common TTI with 437 (69.8%) positive cases, followed by syphilis with 45 (7.2%), HCV with 42 (6.7%), HBsAg with 37 (5.9%), HBV-DNA with 32 (5.1%), HIV with 14 (2.2%), HIV-RNA with 9 (1.4%), malaria with 5 (0.8%), HCV-RNA with 3 (0.5%), and finally HTLV with 2 (0.3%, Figure 1E). Of the female donors with TTIs, 6 (85.7%) were positive for HBcAb and one (14.3%) for HCV; none were positive for any other TTI markers (Figure 1F).

We further examined the presence of TTI markers in relation to ABO blood type. The most common blood group was O, in 322 (50.9%) positive donors, then A in 221 (34.9%), B in 69 (10.9%), and lastly AB in 21(3.3%) (Table 2). These results suggest that donors with the O blood group may be at higher risk of contracting TTIs. Among O group donors, HBcAb was the biomarker most often detected at 4.3%, followed by syphilis at 0.4%, HCV at 0.37%, HBsAg at 0.27%, HBV-DNA at 0.26%, HIV at 0.1%, HIV-RNA at

Table 1 - Personal characteristics of study participants.

Personal data	n (%)
Age in years, mean±SD (range)	33.5±9.1 (18-65)
Gender	
Male	10,021 (99.3)
Female	74 (0.7)
ABO	
A	3311 (32.8)
B	967 (9.6)
AB	264 (2.6)
O	5553 (55.0)
Rh	
Negative	998 (9.9)
Positive	9097 (90.1)
Kell	
Negative	946 (92.2)
Positive	80 (7.8)

Values are presented as numbers and precentages (%) or mean ± standard deviation (SD).

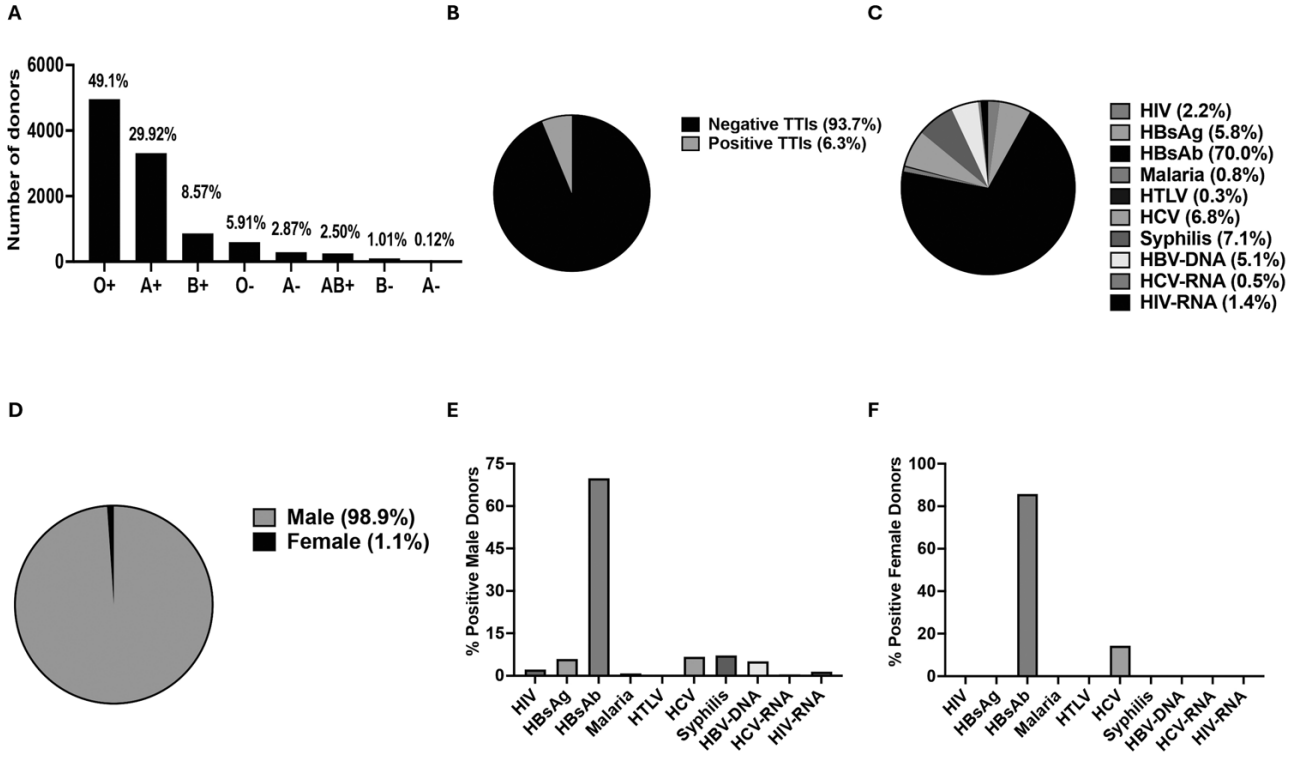

Figure 1 - Graphs showing blood group distribution, the prevalence of transfusion-transmitted infections (TTIs) and gender among donors. **A**) Column graph showing ABO/Rh-D blood group distribution among donors. **B**) Pie chart showing the percentage of confirmed cases among biomarker-reactive donors. **C**) Pie chart showing the prevalence of TTIs among all positive donors. **D**) Pie chart showing gender distribution of total TTI positive donors. **E**) Column graph showing the prevalence of TTIs among positive male donors. **F**) Column graph showing the prevalence of TTIs among positive female donors. HIV: human immunodeficiency virus, HBsAg: hepatitis B surface antigen, HBcAb: hepatitis B core antibody, HTLV: human T-lymphotropic virus, HCV: hepatitis C virus, HBV-DNA: hepatitis B virus-deoxyribonucleic acid, HCV-RNA: hepatitis C virus-ribonucleic acid, HIV-RNA: human immunodeficiency virus-ribonucleic acid

0.07%, HCV-RNA at 0.04%, and finally malaria at 0.02%. Likewise, in A group donors, the most common marker was HBcAb (4.3%), then syphilis (0.6%), HCV (0.5%), HBsAg (0.4%), HIV (0.3%), HBN DNA (0.33%), HIV RNA (0.15%), malaria (0.12%), and HTLV (0.06%). The B donors also most frequently tested positive for HBcAb (5.4%), followed by HCV and HBsAg (0.5%), then syphilis (0.4%), HBV-DNA (0.31%), and finally HCV-RNA (0.10%). In AB donors, HBcAb was again the most frequent (4.2%), then HBsAg (1.9%), HBV-DNA (1.52%), and HCV (0.4%). All told, significant associations were observed between the ABO system and HBsAg (χ^2=18.40, p=0.0004) and HBV-DNA (χ^2=12.76, p=0.005). There were no significant associations of the ABO system with any other TTI markers (Table 2). Comparing the relationship of each blood group (O, A, B, and AB) with TTI status revealed a significant link of HIV with blood group A (χ^2=6.30, p=0.01), HBsAg with blood group AB (χ^2=17.3193, p=0.00003), malaria with blood group A (χ^2=5.0567, p=0.02), and HBV-DNA with blood group AB (χ^2=12.3163, p=0.0004). We observed no significant associations of other TTIs with ABO blood group (Table 3).

We also investigated the presence of TTI markers according to Rh-D blood type. A higher number of TTI cases was observed in Rh-D +ve donors compared with Rh-D -ve donors; specifically, 582 (6.40%) of Rh-D +ve donors were TTI-positive and 8497 (93.60%) negative, while 51 (5.11%) of Rh-D -ve donors were TTI-positive and 947 (94.88%) negative. Of Rh-D +ve donors, reactivity was detected for HBcAb in 4.5%, HCV in 0.43%, syphilis in 0.43%, HBsAg in 0.40%, HBV-DNA in 0.34%, HIV in 0.1%, HIV-RNA in 0.1%, malaria in 0.05%, and HCV-RNA in 0.03%. Among Rh-D -ve donors, HBcAb frequency was 3.5%, syphilis was 0.6%, HCV was 0.4%, HTLV was 0.2%, and 0.1% for HIV, HIV-RNA, HBV-DNA, and HBsAg. We only found an association between HTLV and Rh-D (p<0.01), while no significant association was observed between TTI status and Rh-D blood group (p>0.05; Table 4).

Table 2 - Distribution of transfusion-transmissible infection markers among blood donors according to ABO blood type.

Markers	A	B	AB	O	*P*-values
HIV					
Positive	9 (0.3)	0 (0.0)	0 (0.0)	5 (0.1)	0.137*
Negative	3302 (99.7)	967 (100)	264 (100)	5548 (99.9)	
HBsAg					
Positive	13 (0.4)	4 (0.4)	5 (1.9)	15 (0.3)	X^2=18.40
Negative	3298 (99.6)	963 (99.6)	259 (98.1)	5538 (99.8)	0.0004**
HBcAb					
Positive	142 (4.3)	52 (5.4)	11 (4.2)	238 (4.3)	X^2=2.503
Negative	3169 (95.7)	915 (94.6)	253 (95.8)	5315 (95.7)	0.47**
Malaria					
Positive	4 (0.1)	0 (0.0)	0 (0.0)	1 (0.0)	0.23*
Negative	3307 (100)	967 (100)	264 (100)	5552 (100)	
HTLV					
Positive	2 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0.33*
Negative	3309 (99.9)	967 (100)	264 (100)	5553 (100)	
HCV					
Positive	16 (0.5)	5 (0.5)	1 (0.4)	21 (0.4)	X^2=0.7582
Negative	3295 (99.5)	962 (99.5)	263 (99.6)	5532 (99.7)	0.85**
Syphilis					
Positive	19 (0.6)	4 (0.4)	0 (0.0)	22 (0.4)	0.54*
Negative	3292 (99.4)	963 (99.6)	264 (100)	5531 (99.6)	
HBV					
Positive	11 (0.3)	3 (0.3)	4 (1.5)	14 (0.3)	X^2=12.76
Negative	3300 (9.7)	964 (99.7)	260 (98.5)	5539 (99.7)	0.005**
HCV					
Positive	0 (0.0)	1 (0.1)	0 (0.0)	2 (0.0)	0.25*
Negative	3311 (100)	966 (99.9)	264 (100)	5551 (99.9)	
HIV					
Positive	5 (0.1)	0 (0.0)	0 (0.0)	4 (0.1)	0.56*
Negative	3306 (99.8)	967 (100)	264 (100)	5549 (99.9)	

Values are presented as numbers and percentages (%). *Fisher exact test. **Chi-square test.
HIV: human immunodeficiency virus, HBsAg: hepatitis B surface antigen,
HBcAb: hepatitis B core antibody, HTLV: human T-lymphotropic virus, HCV: hepatitis C virus,
HBV: hepatitis B virus, NAT: nucleic acid test

Among Kell +ve blood donors, HBcAb was the most prevalent TTI (20%), followed by syphilis (3.8%), HIV (2.5%), HBsAg (1.3%), HBV-DNA (1.3%), and HIV-RNA (1.3%). Of donors with negative Kell tests, a prevalence of 1.8% was observed for HBV-DNA, HBsAg, and HBcAb, followed by 0.21% for HCV-RNA and HIV-RNA and 0.1% for HIV and syphilis (0.1%). Significant associations were observed between the Kell blood group system and HIV (χ^2=14.5, p=0.0001), HBcAb (χ^2=78.51, p<0.0001), and syphilis (χ^2=25.225, p<0.00001; Table 5).

Discussion. Despite the fact that blood and blood components can save patient lives, contaminated blood still poses a threat in regard to spreading infection. Extensive research has been carried out on the relationship between blood groups and numerous diseases, including TTIs. The purpose of this study was to determine the distribution of ABO, Rh-D, and Kell blood groups; determine the prevalence of TTIs; and explore whether there is any correlation between TTIs and blood group type among donors from the Asir region specifically. The vast majority of the donors in our study were male (99.3%). This is consistent with findings from Saudi Arabia, Ethiopia (67.7%), Qatar (91%), Turkey (91.24%), and North India (95%).[8,11,14-17] Some studies have reported almost equal proportions of male and female donors; for instance, a study from China stated males to make up 53.73% of donors, one (47.0%) in the United Kingdom, and one (49.1%) in

Table 3 - Pairwise comparisons of blood groups based on presence and absence of transfusion-transmissible infection markers.

Markers	Blood group A		Blood group B		Blood group AB		Blood group O	
	A	Other groups	B	Other groups	AB	Other groups	O	Other groups
HIV								
Positive	9 (0.3)	5 (0.1)	0 (0.0)	14 (0.2)	0 (0.0)	14 (0.1)	5 (0.1)	9 (0.2)
Negative	3302	6779	967	9114	264	9817	5548	4533
P-value	X^2=6.30, *p*=0.01**		*p*=0.38*		*p*=0.99*		X^2=2.10, *p*=0.14**	
HBsAg								
Positive	13 (0.4)	24 (0.4)	4 (0.4)	33 (0.4)	5 (1.9)	32 (0.3)	15 (0.3)	22 (0.5)
Negative	3298	6760	963	9095	259	9799	5538	4520
P-value	X^2=0.092, *p*=0.76**		X^2=0.065, *p*=0.79**		X^2=17.319, *p*=0.00003**		X^2=3.140, *p* =0.07**	
HBsAb								
Positive	142 (4.3)	301 (4.4)	52 (5.4)	391 (4.3)	11 (4.2)	432 (4.4)	238 (4.3)	205 (4.5)
Negative	3169	6483	915	8737	253	9399	5315	4337
P-value	X^2=0.178, *p*=0.67**		X^2=2.493, *p*=0.11**		X^2=0.031, *p*=0.85**		X^2=0.308, *p*=0.57**	
Malaria								
Positive	4 (0.1)	1 (0.0)	0 (0.0)	5 (0.1)	0 (0.0)	5 (0.1)	1 (0.0)	4 (0.1)
Negative	3307	6783	967	9123	264	9826	5552	4538
P-value	X^2=5.056, *p*=0.02**		*p*=0.99*		*p*=0.99*		X^2=2.477, *p*=0.11**	
HTLV								
Positive	2 (0.1)	0 (0.0)	0 (0.0)	2 (0.02)	0 (0.0)	2 (0.02)	0 (0.0)	2 (0.04)
Negative	3309	6784	967	9126	264	9829	5553	4540
P-value	*p*=0.10*		*p*=0.99*		*p*=0.99*		*p*=0.20*	
HCV								
Positive	16 (0.5)	27 (0.4)	5 (0.5)	38 (0.4)	1(0.4)	42 (0.4)	21 (0.4)	22 (0.5)
Negative	3295	6757	962	9090	263	9789	5532	4520
P-value	X^2=0.381, *p*=0.53**		X^2=0.209, *p*=0.64**		X^2=0.014, *p*=0.90**		X^2=0.664, *p*=0.41**	
Syphilis								
Positive	19 (0.6)	26 (0.4)	4 (0.4)	41(0.4)	0 (0.0)	45 (0.5)	22 (0.4)	23 (0.5)
Negative	3292	6758	963	9087	264	9786	5531	4519
P-value	X^2=0.664, *p*=0.41**		X^2=0.024, *p*=0.87**		*p*=0.63*		X^2=0.683, *p*=0.40**	
HBV								
Positive	11 (0.3)	21 (0.3)	3 (0.3)	29 (0.3)	4 (1.5)	28 (0.3)	14 (0.3)	18 (0.4)
Negative	3300	6763	964	9099	260	9803	5539	4524
P-value	X^2=0.036, *p*=0.84**		X^2=0.001, *p*=0.96**		X^2=12.316, *p*=0.0004**		X^2=1.643, *p*=0.19**	
HCV								
Positive	0 (0.0)	3 (0.0)	1 (0.1)	2 (0.0)	0 (0.0)	3 (0.0)	2 (0.0)	1 (0.0)
Negative	3311	6781	966	9126	264	9828	5551	4541
P-value	*p*=0.55*		X^2=1.955, *p*=0.16**		*p*=0.99*		X^2=0.164, *p*=0.68**	
HIV								
Positive	5 (0.2)	4 (0.1)	0 (0.0)	9 (0.1)	0 (0.0)	9 (0.1)	4 (0.1)	5 (0.1)
Negative	3306	6780	967	9119	264	9822	5549	4537
P-value	X^2=2.116, *p*=0.14**		*p*=0.99*		*p*=0.99*		X^2=0.406, *p*=0.52**	

Values are presented as numbers and percentages (%). χ^2 is the Chi-square statistic. *Fischer exact test. **Chi-square test. Serological test results for human immunodeficiency virus (HIV), hepatitis B surface antigen (HBsAg), hepatitis B core antibody (HBcAb), malaria, human T-lymphotropic virus (HTLV), hepatitis C virus (HCV), and syphilis. Nucleic acid test (NAT) results for hepatitis B virus (HBV), HCV, and HIV.

Australia.[18-20] In our study, the number of female donors was low (0.7%). There may be a cultural stigma in some areas that discourages women from donating blood, due to beliefs that pregnancy and menstruation affect their somatic maturation and body composition.[15] Women are commonly reluctant to donate blood for a variety of reasons, so it is necessary to comprehend their specific problems, needs, and motivating factors. In general, females should be encouraged and educated on the importance and safety of blood donation.

In our blood group analysis, the most common blood group was O (55%) and the least common AB

Table 4 - Distribution of transfusion-transmissible infection markers among blood donors according to Rh-D blood type.

Markers	Rh-D positive	Rh-D negative	*P*-values
HIV			
Positive	13 (0.1)	1 (0.1)	X^2=0.1184,
Negative	9084 (99.9)	997 (99.9)	*p*=0.73**
HBsAg			
Positive	36 (0.4)	1 (0.1)	X^2=2.151,
Negative	9061 (99.6)	997 (99.9)	*p*=0.14**
HBcAb			
Positive	408 (4.5)	35 (3.5)	X^2=2.050,
Negative	8689 (95.5)	963 (96.5)	*p*=0.15**
Malaria			
Positive	5 (0.05)	0 (0.0)	*p*=0.99*
Negative	9092 (99.9)	998 (100)	
HTLV			
Positive	0 (0.0)	2 (0.2)	*p*=0.009*
Negative	9097 (100)	996 (99.8)	
HCV			
Positive	39 (0.4)	4 (0.4)	X^2=0.01652,
Negative	9058 (99.6)	994 (99.6)	*p*=0.89**
Syphilis			
Positive	39 (0.4)	6 (0.6)	X^2=0.6030,
Negative	9058 (99.6)	962 (99.4)	*p*=0.438**
HBV			
Positive	31 (0.34)	1 (0.1)	X^2=1.647,
Negative	9066 (99.7)	997 (99.9)	*p*=0.19**
HCV			
Positive	3 (0.03)	0 (0.0)	*p*=0.99*
Negative	9095 (99.97)	998 (100)	
HIV			
Positive	8 (0.1)	1 (0.1)	X^2=0.01517,
Negative	9089 (99.9)	997 (99.9)	*p*=0.90**

Values are presented as numbers and percentages (%). χ^2 is the Chi-square statistic. *Fischer exact test. **Chi-square test. Serological test results for human immunodeficiency virus (HIV), hepatitis B surface antigen (HBsAg), hepatitis B core antibody (HBcAb), malaria, human T-lymphotropic virus (HTLV), hepatitis C virus (HCV), and syphilis. Nucleic acid test (NAT) results for hepatitis B virus (HBV), HCV, and HIV.

Table 5 - Distribution of transfusion-transmissible infection markers among blood donors according to Kell blood type.

Markers	Kell positive	Kell negative	*P*-values
HIV			
Negative	78 (97.5)	945 (99.9)	X^2=14.5,
Positive	2 (2.5)	1 (0.1)	*p*=0.0001**
HBsAg			
Negative	79 (98.7)	929 (98.2)	X^2=0.1281,
Positive	1 (1.3)	17 (1.8)	*p*=0.720
HBcAb			
Negative	64 (80.0)	929 (98.2)	X^2=78.51,
Positive	16 (20.0)	17 (1.8)	*p*<0.0001**
Malaria			
Negative	80 (100)	946 (100)	*p*=0.99*
Positive	0 (0.0)	0 (0.0)	
HTLV			
Negative	80 (100)	946 (100)	*p*=0.99*
Positive	0 (0.0)	0 (0.0)	
HCV			
Negative	80 (100)	946 (100)	*p*=0.99*
Positive	0 (0.0)	0 (0.0)	
Syphilis			
Negative	77 (96.2)	945 (99.9)	X^2=25.225,
Positive	3 (3.8)	1 (0.1)	*p*=<0.00001**
HBV			
Negative	79 (98.7)	929 (98.2)	X^2=0.1281,
Positive	1 (1.3)	17 (1.8)	*p*=0.72**
HCV			
Negative	80 (100)	944 (99.8)	*p*=0.99*
Positive	0 (0.0)	2 (0.21)	
HIV			
Negative	79 (98.7)	944 (99.8)	X^2=2.729,
Positive	1 (1.3)	2 (0.21)	*p*=0.09**

Values are presented as numbers and percentages (%). χ^2 is the Chi-square statistic. *Fischer exact test. **Chi-square test. Serological test results for human immunodeficiency virus (HIV), hepatitis B surface antigen (HBsAg), hepatitis B core antibody (HBcAb), malaria, human T-lymphotropic virus (HTLV), hepatitis C virus (HCV), and syphilis. Nucleic acid test (NAT) results for hepatitis B virus (HBV), HCV, and HIV.

(2.6%). In addition, the majority of the participants were RhD +ve. These findings are in line with a previous report from the same region and with other studies from Saudi Arabia.[14,15,21] We also analyzed the prevalence of TTIs in the Asir region and found 6.3% of donors to at least one positive marker. This finding is likewise consistent with other studies in Saudi Arabia. The observed incidence of TTIs in blood donors from Najran was 5.66%.[13] Altayar et al[15] identified a TTI prevalence of 7.93% among donors from the Western region. In addition, a recent nationwide study reported the overall TTI prevalence among Saudi Arabian donors to be 8.7%.[22] However, other local studies in the country have documented lower frequencies of TTIs. For instance, a study from the Central region found 1.002% of donors to have TTIs.[14] As another point of contrast, studies from Nigeria (11.3%) and Sudan (20.1%) have reported higher overall TTI prevalence rates.[23,24] It is possible that differences in sample size and the utilization of nucleic acid technology may explain the relatively different prevalence in our study compared to these other studies. Finally, we found in the current study that male blood donors are more likely to contract TTIs than female blood donors, which is consistent with other reports.[4,15] However, this finding may also be attributable to the low number of female donors in our study. In the current study, HBcAb (70%) was the most prevalent TTI marker, followed by syphilis (7.1%),

while HTLV (0.3%) was the least prevalent. Prior studies from Saudi Arabia have identified HBV as the most common TTI.[13,15,22,25] In addition, studies from North India, Northwest Ethiopia, Jordan, Pakistan, and Turkey have all found HBV to be the predominantly observed TTI among participants.[4,8,11,17,26] Thus, our finding is consistent with previously published data.

In our blood group analysis, we observed donors with the O blood group to be at higher risk of contracting TTIs, followed by those with group A, B, and lastly AB. Asir donors with the O blood group may have a higher risk of TTIs simply due to the prevalence of that common group. Overall, the distribution of TTIs among participants in this study is similar to that among the local population. In addition, we observed a significant association of ABO blood group system with HBsAg positivity, consistent with previously published data from western regions of Saudi Arabia.[15] We also observed a significant association of HIV with blood group A, as well as of both HBsAg and HBV with blood group AB. The latter finding contrasts with a previous systemic review that reported individuals with the AB blood group to have decreased risk of HBV infection.[27] Finally, we observed a significant association between malaria and the A blood group. Researchers have reported a high incidence of malaria in individuals with blood types A, B, and AB, compared to those with blood type O.[28]

In general, previous studies regarding the relationship between ABO blood group status and TTI susceptibility have produced contradictory results. A group from Ethiopia reported O to be the most prevalent blood group in donors, but detected no relation of blood group with TTIs.[29] Among Jordanian donors, HBsAg has been reported the most common infection biomarker, with no link between ABO/Rh blood group and TTIs.[4] As a point of contrast, a previous systemic review reported a negative association of the B blood group with HBV.[27] Meanwhile, a study from South Africa reported a weak association between Rh-D positive and HIV, and no association of ABO blood type association with TTIs.[30] In a study carried out by Arif et al,[31] AB/Rh-positive blood group was associated with syphilis infection. Still others demonstrated no significant association between ABO and TTIs.[4]

Although TTI infection rates were higher in Rh-D +ve donors, we did not detect any significant association of Rh-D status with TTIs. In line with our findings, no association between Rh-D and TTIs has been reported in other studies.[4,29]

The prevalence of Kell blood system positivity in this study was 7.8%, lower than previously reported in Saudi Arabia; for example, the reported prevalence in Najran is 12.05% and that in Taif 22.1%.[13,32] A high level of variability is observed in other parts of the world. In North Nigeria, 21.7% of the population is Kell-positive; in Sudan, 5.6%; in Caucasian populations, 9%; and in North Indians, 4%.[13,33] Concerning the association of the Kell blood group system with TTIs in the present work, HBcAb was the most prevalent TTI among the Kell-positive donors, and we observed significant associations of Kell status with HBcAb, HIV, and syphilis. To our knowledge, few studies have investigated association of the Kell antigen with infections. Bhandari et al[12] recently reported an association between Kell negativity and susceptibility to COVID-19. There may be various reasons for this discrepancy, including differences in blood type frequency distribution among ethnic groups. In addition, the sample size as well as the demographic characteristics of the study participants should be considered.

Previous studies have demonstrated blood group to be of significance in infection. In particular, some bacteria, viruses, and parasites can use red blood cell antigens as receptors or coreceptors. Additionally, a number of blood group antigens are capable of adsorption, signal transduction, or membrane microdomain retention. Moreover, ABO antibodies are part of the innate immune system, and as such may have an impact on the infected organism.[9,27] Although no other reports exist concerning Kell antigens acting as receptors for disease-causing microbes, it has been reported that microorganisms such as *E. coli* and *Enterococcus faecalis* can trigger cross-reactive antibodies with anti-Kell activity.[34]

Ultimately, blood products are lifesaving resources, and therefore it is crucial to use them correctly. TTIs can be minimized by increasing public awareness, selecting appropriate donors, providing proper counseling, and medical assessments and testing. In addition, individuals should consider getting vaccinated against TTIs when available, the better to reduce the prevalence of these infections within the population. Several studies, including ours, have reported a correlation between blood group status and TTIs. To discover a definite association, random population studies will need to be carried out over longer periods. Additionally, further studies are needed to determine what mechanisms account for the higher susceptibility of particular blood group phenotypes to infections, specifically the Kell system. Researchers should investigate whether anti-Kell antibodies contribute to infection susceptibility.

Study limitations. The present study has several limitations due to its retrospective nature. The Kell blood

test was not available for many donors due to a shortage of tests in the blood bank. Donor nationalities were not reported due to that data having limited availability. The associations between blood groups and TTIs need to be validated using a larger cohort of donors and at multiple centers. Finally, the majority of the donors in this study were male; it would be beneficial to evaluate the prevalence of blood group systems and TTIs and assess their association among female donors.

In conclusion, this single-center observational study aimed to examine the association of ABO, Rh-D, and Kell blood groups with susceptibility to TTIs in the Asir region, Saudi Arabia. The most widespread TTI marker was HBcAb, followed by syphilis, and then HCV. We found donors with the O blood group to be at higher risk of contracting TTIs, followed by those of the A, B, and lastly AB groups. We also observed a significant association of HBcAb with ABO blood group. Most notably, we identified significant associations of HIV with group A, HBsAg with group AB, malaria with group A, and HBV-DNA with group AB. Finally, we reported significant associations of HBcAb, HIV, and syphilis with Kell status.

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