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Frequencies of ABO, Rh and Kell phenotypes in couples from Han, Kazak, Uyghur and Hui in Xinjiang: an inheritance simulation model for blood group incompatibility in new–born

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ABSTRACT

The Xinjiang region with residents from more than 13 minorities represents an area of many diverse ethnicities. This ethnic diversity in relation to their blood groups and immune status may have a consequential impact on the clinical status of married couples. To evaluate the risks of haemolytic disease in new–born infants, we investigated the rate of blood–group incompatibility among 487 married couples from four ethnic minorities, namely the Han, Hui, Uyghur and Kazak populations. Han minority married couples showed significantly different ABO, Rh and K phenotype frequencies between marital relationships, whereas there was no significant difference in ABO, Rh and K phenotypes between the Uyghur, Hui and Kazak couples. There was a significant difference between ABO blood types in Han married couples, in the Kazak Rh–C phenotype and in the Uyghur Rh–D phenotype. The Hui married couples only demonstrated ABO, Rh and K phenotypes. The Hui minority showed the highest incompat–ibility rate for Rh–C and Rh–E phenotypes between mothers and their new–born infants. The highest incompat–ibility rate for the ABO phenotype occurred in the Kazak group. These results particularly demonstrate the clinical issues relating to ABO and Rh incompatibility in the Kazak and Hui minorities, respectively.

Keywords: antigen frequency, ABO blood type, Rh blood type, Kell blood type

INTRODUCTION

Xinjiang is the one of the most diverse minority ar–eas in China with a population comprising of 13 long–dwelling nationalities (residing in various areas of the province) including Han, Hui, Uyghur, Manchu, Kirgiz, Tajik, Xib, Uzbek, Russian, Tatar, Mongo–lian, Kazakh, and Daur ethnic groups[1]. Also, owing to a national building policy in Xinjiang introduced in 1996, many Han people migrated to Xinjiang from other regions in China[2], and subsequently, the genetic mix in Xinjiang is rich and highly varied.

Recent studies have demonstrated a high diversity in the frequency of RBC allo–antibodies among the Han and Uyghur populations[3]. Moreover, it has been reported that the numbers of antibodies against Asian–specific low–frequency antigens, such as K antigen, are notably high in Xinjiang[3–4]. Although blood group frequencies, including ABO, Rh, Kidd, and MNS have previously been reported in Xinjiang[5–8], this study focused specifically on the estimated risks of transfu–sion among differing minorities in Xinjiang, while only few studies have evaluated marital relationship–induced risks for new–born haemolytic disease in Xinjiang.

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To evaluate the inheritance risks in Xinjiang, we investigated the frequencies of erythrocytic ABO, Rh and K antigens among the Han, Hui, Uyghur and Kazak minority groups. We calculated the risks of horizontal incompatibility through the identification of phenotypes in married couples using a simulation study in Xinjiang.

MATERIALS AND METHODS

Population data

The study participants were recruited from two medical centres, namely the Xinjiang Uyghur Autonomous People´s Hospital and the Traditional Chinese Medicine Hospital of Xinjiang Medical University between June and December 2016. Participants with a history of a blood transfusion in the previous three months or auto−controlled participants with reported positive specimens were excluded. In instances where participants had been admitted to either or both of the medical centres on several occasions during the study period, only data from the first clinical reports were recorded. Overall, 487 couples, comprising of 297 (60.1%) Han, 147 (30.2%) Uyghur, 29 (6.0%) Hui, and 14 (2.9%) Kazak were included in the study, and phenotyped for ABO, Rh and Kell blood group antigens. The mean age of the participants was (29.9 ±4.8) years. Ethical approval was given by the medical ethics committee of Xinjiang Uyghur Autonomous People´s Hospital. All the data of patient were collected according to the approval of the institutional review board and informed consent was obtained.

Phenotyping method

Three millilitres of peripheral venous blood was drawn from each participant and placed in EDTA−Na_2 tubes. The phenotyping method included a microbead test for forward and reverse ABO typing, and isolating Rh and K antigens (ABO typing, Rh/K blood group diagnostic reagent card, Ortho BioVue System, Ortho Clinical Diagnostics, UK). Tests were performed on an automated machine (ORTHO Workstation, AutoVue, Ortho Clinical Diagnostics, UK). In addition, the samples were incubated with monoclonal antibodies against the following erythrocyte antigens: anti−D, anti−C, anti−c, anti−E, anti−e (Shanghai Blood Biological Medicine Co Ltd, Shanghai, China), and anti−K (Sunquin GmbH, Switzerland). In brief, EDTA whole blood was centrifuged at 1,000 *g* for 5 min (KUBOTA KA−2200, Japan) and 1 mL of packed RBCs was pipetted and centrifuged at 800 *g* for 1 min (KUBOTA MC−450, Japan) and 1.5 mL 0.9% normal saline was added as washing buffer. This procedure was repeated three times. Ten microliters of washed packed RBCs was resolved into 1 mL of 0.9% normal saline at a concentration of 0.8% to 1.0%. The RBC suspension was examined with Rh/K microbead phenotyping kits (Rh/K blood group diagnostic reagent card, Ortho BioVue System, Ortho Clinical Diagnostics, UK). For the tube method of analysis, 3% of the washed RBCs were reacted with 100 μL of the monoclonal antibody, with incubation at room temperature for 10 min. A positive K phenotype was judged when the titre of any phenotype was lower than 3+. Other procedures, such as antibody screening, sample reception, report documentation, and report writing, were all based on regulations, protocols and standard procedures specified by the transfusion departments of the two medical centres.

Statistical analysis

To evaluate the risk of haemolytic disease in newborns through the incompatibility rate of the mother and new−born infant, we created a simulation model using the parent´s phenotype to infer the probability of the new−born´s phenotype, then multiplied the frequency of phenotype from the couple, based on the mother´s phenotype, to evaluate the risks of the stimulated alloantibody.

For the frequencies of ABO, Rh and K phenotyping results, the chi−squared test was used to determine the statistical significance among the four minority groups. Group differences with a two−sided P−value < 0.05 were considered statistically significant. All statistical analyses were conducted using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Frequencies of ABO, Rh and K phenotypes and alleles in four minorities

The frequencies of the ABO phenotype were as follows: 24.2% A, 31.5% B, 34.1% O, 10.1% AB in Han; 32.0% A, 27.9% B, 27.2% O, 12.9% AB in Uyghur; 25.9% A, 25.9% B, 34.5% O, 13.8% AB in Hui; and 39.3% A, 25.0% B, 21.4% O, 14.3% AB in Kazak, representing an insignificant difference (P = 0.148) among the four minorities ***(Table 1)***. The frequencies of Rh alleles were as follows: 0.9% ccDee, 0.2% ccdee, 4.5% ccDEe, 7.3% ccDEE, 0.2% Ccdee, 8.0% CcDee, 36.9% CcDEe, 0.7% CcDEE, 40.6% CCDee, 0.3% CCDEe, 0.3% CCDEE in Han; 4.4% ccDee, 2.7% ccdee, 7.1% ccDEe, 7.5% ccDEE, 21.8% CcDee, 30.6% CcDEe, 0.7% CcDEE, 24.8% CCDee, 0.3% CCDEE in Uyghur; 12.1% ccDEe, 5.2% ccDEE, 12.1% CcDee, 27.6% CcDEe, 43.1% CCDee, in

Table 1 **Frequencies of ABO, Rh and K alleles among four minorities**

[(*n*)%]

	Han (*n*=574)	Uyghur (*n*=294)	Hui (*n*=58)	Kazak (*n*=28)	*P*
A	139 (24. 2)	94 (32.0)	15 (25.9)	11 (39.3)	0.148
B	181 (31.5)	82 (27.9)	15 (25.9)	7 (25.0)	
O	196 (34.1)	80 (27.2)	20 (34.5)	6 (21.4)	
AB	58 (10.1)	38 (12.9)	8 (13.8)	4 (14.3)	
ccDee	5 (0.9)	13 (4.4)	0 (0.0)	0 (0.0)	<0.001
ccdee	1 (0.2)	8 (2.7)	0 (0.0)	1 (3.6)	
ccDEe	26 (4.5)	21 (7.1)	7 (12.1)	4 (14.3)	
ccDEE	42 (7.3)	22 (7.5)	3 (5.2)	2 (7.1)	
Ccdee	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	
CcDee	46 (8.0)	64 (21.8)	7 (12.1)	2 (7.1)	
CcDEe	233 (36.9)	90 (30.6)	16 (27.6)	8 (28.6)	
CcDEE	4 (0.7)	2 (0.7)	0 (0.0)	1 (3.6)	
CCDee	233 (40.6)	73 (24.8)	25 (43.1)	10 (35.7)	
CCDEe	2 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	
CCDEE	2 (0.3)	1 (0.3)	0 (0.0)	0 (0.0)	
K^+	1 (0.2)	10 (3.4)	0 (0.0)	0 (0.0)	0.997

Hui; 3.6% ccdee, 14.3% ccDEe, 7.1% ccDEE, 7.1% CcDee, 28.6% CcDEe, 3.6% CcDEE, 35.7% CCDee, in Kazak, representing a significant difference (*P* <0.001) among the four minorities ***(Table 1)***. The frequencies of the K phenotypes were 0.2% in Han and 3.4% in Uyghur, representing an insignificant difference (*P* =0.997) among the four minorities (***Table 1***).

Frequencies of ABO, Rh and K phenotypes in couples among four minorities

The married Han couples showed significantly different frequencies for ABO and Rh phenotypes, and the K phenotype, whereas the ABO, Rh and K phenotypes were not significantly different in married couples from the Uyghur, Hui and Kazak minority groups (***Table 2***).

Table 2 **Frequencies of ABO, Rh and K phenotypes in marital relationship between Uyghurs and Kazaks**

Phenotypes	Han			Uyghur			Hui			Kazak		[(*n*)%]
	wife (*n*=287)	husband (*n*=287)	*P*	wife (*n*=147)	husband (*n*=147)	*P*	wife (*n*=29)	husband (*n*=29)	*P*	wife (*n*=14)	husband (*n*=14)	*P*
A	59(20.6)	80 (27.9)	0.003	49(33.3)	45 (30.6)	0.192	5 (17.2)	10 (34.5)	0.847	4 (28.6)	7 (50)	0.551
B	82(28.6)	99 (34.5)		45(30.6)	37 (25.2)		8 (27.6)	7 (24.1)		5 (35.7)	2 (14.3)	
O	119(41.5)	77 (26.8)		40 27.2)	40 (27.2)		12 41.4)	8 (27.6)		3 (21.4)	3 (21.4)	
AB	27 (9.4)	31 (10.8)		13 (8.8)	25 (17.0)		4 (13.8)	4 (13.8)		2 (14.3)	2 (14.3)	
ccDee	0 (0.0)	5 (1.7)	0.018	2 (1.4)	11 (7.5)	0.134	0 (0.0)	0 (0.0)	0.424	0 (0.0)	0 (0.0)	0.791
ccdee	1 (0.3)	0 (0.0)		7 (4.8)	1 (0.7)		0 (0.0)	0 (0.0)		1 (7.1)	0 (0.0)	
ccDEe	14 (4.9)	12 (4.2)		11 (7.5)	10 (6.8)		4 (13.8)	3 (10.3)		1 (7.1)	3 (21.4)	
ccDEE	12 (4.2)	30 (10.5)		12 (8.2)	10 (6.8)		1 (3.4)	2 (6.9)		1 (7.1)	1 (7.1)	
Ccdee	0 (0.0)	1 (0.3)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
CcDee	29 10.1)	17 (5.9)		34(23.1)	30 (20.4)		4 (13.8)	3 (10.3)		1 (7.1)	1 (7.1)	
CcDEe	104 (36.2)	108 (37.6)		43 29.3)	47 (32.0)		5 (17.2)	11 (37.9)		5 (35.7)	3 (21.4)	
CcDEE	3 (1.0)	1 (0.3)		1 (0.7)	1 (0.7)		0 (0.0)	0 (0.0)		1 (7.1)	0 (0.0)	
CCDee	121 (42.2)	112 (39.0)		36 24.5)	37 (25.2)		15 51.7)	10 (34.5)		4 (28.6)	6 (42.9)	
CCDEe	1 (0.3)	1 (0.3)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
CCDEE	2 (0.7)	0 (0.0)		1 (0.7)	0 (0.0)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
K^+	1 (0.3)	0 (0.0)	0.317	6 (4.1)	4 (2.7)	0.520	0 (0.0)	0 (0.0)	1.000	0 (0.0)	0 (0.0)	1.000

Compatibility rate of ABO, Rh and K phenotypes in married couples of the four minorities

To evaluate the risks of haemolytic disease in new-born infants, we calculated incompatible major erythrocytic phenotypes between the couples. A significant difference in the couples was seen for the following: the ABO blood type in the Han minority group, the Rh-C phenotype in the Kazak minority group, and the Rh-D in the Uyghur minority group. The Hui couples only showed the ABO, Rh and K phenotypes (***Table 3***).

The estimated risks for incompatible ABO and Rh phenotypes between mothers and new-born infants

Within Hui minority couples, the highest estimated

Table 3 **Couple of ABO Rh and K phenotypes in Xinjiang four minorities**

[(*n*)%]

husband phenotype						husband phenotype					husband phenotype					husband phenotype					husband phenotype			
wife pheno–type	A	B	O	AB	*P*	wife pheno–type	cc	Cc	CC	*P*	wife pheno–type	ee	Ee	EE	*P*	wife pheno–type	d	D	*P*	wife pheno–type	K	k	*P*
Hans																							
A	16(5.6)	19(6.6)	17(5.9)	7(2.4)	0.004	cc	3(1.0)	12(4.2)	12(4.2)	0.837	ee	70(24.4)	63(22.0)	18(6.3)	0.942	d	0(0.0)	1(0.3)	0.953	K	1(0.3)	0(0.0)	–
B	17(5.9)	28(9.8)	29(10.1)	8(2.8)		Cc	23(8.0)	57(19.9)	56(19.5)		Ee	58(20.2)	50(17.4)	11(3.8)		D	1(0.3)	285(99.3)		k	286(99.6)	0(0.0)	
O	40(13.9)	46(16.0)	17(5.9)	16(5.6)		CC	21(7.3)	58(20.2)	45(15.7)		EE	7(2.4)	8(2.8)	2(0.7)									
AB	7(2.4)	6(2.1)	14(4.9)	0(0.0)																			
Kazak																							
A	0(0.0)	1(7.10)	2(14.30)	1(7.10)	0.298	cc	0(0.0)	2(14.3)	1(7.1)	0.001	ee	4(28.6)	2(14.3)	0(0.0)	0.695	d	0(0.0)	1(7.1)	–	K	0(0.0)	0(0.0)	–
B	4(28.6))	0(0.0)	0(0.0)	1(7.10)		Cc	4(28.6)	1(7.1)	2(14.3)		Ee	2(14.3)	3 (21.4)	1(7.1)		D	0(0.0)	13(92,9)		k	0(0.0)	14(100)	
O	2(14.30)	0(0.0)	1(7.10)	0(0.0)		CC	0(0.0)	1(7.1)	3(21.4)		EE	1(7.1)	1(7.1)	0(0.0)									
AB	1(7.10)	1(7.10)	0(0.0)	0(0.0)																			
Uyghur																							
A	20(13.6)	9(6.1)	12(8.2)	8(5.4)	0.535	cc	6(4.1)	21(14.3)	5(3.4)	0.230	ee	47(32.0)	28(19.0)	4(2.7)	0.454	d	1(0.7)	6(4.1)	<0.001	K	0(0.0)	6 (4.1)	0.676
B	12(8.2)	15(10.2)	10(6.8)	8(5.4)		Cc	21(14.3)	37(25.2)	20(13.6)		Ee	24(16.3)	24(16.3)	6(4.1)		D	0(0.0)	140(95.2)		k	4(2.7)	137 (93.2)	
O	11(7.5)	8(5.4)	14(9.5)	7(4.8)		CC	5(3.4)	20(13.6)	12(8.2)		EE	8(5.4)	5(3.4)	1(0.7)									
AB	2(1.4)	5(3.4)	4(2.7)	2(1.4)																			
Hui																							
A	0(0.0)	2(6.9)	2(6.9)	1(3.4)	0.504	cc	1(3.4)	4(13.8)	0(0.0)	0.326	Ee	9(31.0)	8(27.6)	2(6.9)	0.511	d	0(0.0)	0(0.0)	–	K	0(0.0)	0(0.0)	–
B	4(13.8)	3(10.3)	1(3.4)	0(0.0)		Cc	1(3.4)	3(10.3)	5(17.2)		Ee	3(10.3)	6(20.7)	0(0.0)		D	0(0.0)	29 (100)		k	0(0.0)	29 (100)	
O	5(17.2)	2(6.9)	3(10.3)	2(6.9)		CC	3(10.3)	7(24.1)	5(17.2)		EE	1(3.4)	0(0.0)	0(0.0)									
AB	1(3.4)	0(0.0)	2(6.9)	1(3.4)																			

incompatibility risk rate between mothers and new–born of Rh–C and Rh–E phenotype was found to be 29.3% Rh–C and 24.1% Rh–E, followed by 23.7% Rh–C and 21.1% Rh–E in Han; 20.8% Rh–C and 19.3% Rh–E in Uyghur, 17.8% Rh–C and 17.8% Rh–E in Kazak. The highest incompatibility rate of ABO phenotype occurred in the Kazak, Hui, Han and Uyghur minority groups with 44.6%, 42.2%, 40.0%, and 30.6%, respectively(***Table 4***).

DISCUSSION

This is the first study to determine the frequency of ABO, Rh and K phenotypes to analyze the incompati–

Table 4 **The incompatible rate between mother and newborn through inferred newborn allele and rate under parent´s phenotype**

		Inferred newborn allele and rate							Han		Kazak		Uyghur		Hui	
wife	husband	AA	AO	BB	BO	OO	AB	Incompat–ible rate	frequen–cy(%)	Incom–patible rate(%)	fre–quen–cy(%)	Incom–patible rate(%)	fre–quen–cy(%)	Incom–patible rate(%)	fre–quen–cy(%)	Incom–patible rate(%)
A	A	0.5	0.375	0.0	0.0	0.125	0.0	0.0	5.6	0.0	0.0	0.0	13.6	0.0	0.0	0.0
A	B	0.0	0.188	0.0	0.188	0.063	0.563	0.75	6.6	5.0	7.1	5.3	6.1	4.6	6.9	5.2
A	O	0.0	0.75	0.0	0.0	0.25	0.0	0.0	5.9	0.0	14.3	0.0	8.2	0.0	6.9	0.0
A	AB	0.375	0.125	0.0	0.125	0.0	0.375	0.5	2.4	1.2	7.1	3.6	5.4	2.7	3.4	1.7
B	A	0.0	0.188	0.0	0.188	0.063	0.563	0.75	5.9	4.4	28.6	21.5	8.2	6.2	13.8	10.4
B	B	0.0	0.0	0.5	0.375	0.125	0.0	0.0	9.8	0.0	0.0	0.0	10.2	0.0	10.3	0.0
B	O	0.0	0.0	0.0	0.75	0.25	0.0	0.0	10.1	0.0	0.0	0.0	6.8	0.0	3.4	0.0
B	AB	0.0	0.125	0.375	0.125	0.0	0.375	0.5	2.8	1.4	7.1	3.6	5.4	2.7	0.0	0.0
O	A	0.0	0.75	0.0	0.0	0.25	0.0	0.75	13.9	10.4	14.3	10.7	7.5	5.6	17.2	12.9
O	B	0.0	0.0	0.0	0.75	0.25	0.0	0.75	16.0	12.0	0.0	0.0	5.4	4.1	6.9	5.2
O	O	0.0	0.0	0.0	0.0	1.0	0.0	0.0	5.9	0.0	7.1	0.0	9.5	0.0	10.3	0.0
O	AB	0.0	0.5	0.0	0.5	0.0	0.0	1.0	5.6	5.6	0.0	0.0	4.8	4.8	6.9	6.9
AB	A	0.375	0.125	0.0	0.125	0.0	0.375	0.0	2.4	0.0	7.1	0.0	1.4	0.0	3.4	0.0
AB	B	0.0	0.125	0.375	0.125	0.0	0.375	0.0	2.1	0.0	7.1	0.0	3.4	0.0	0.0	0.0
AB	O	0.0	0.5	0.0	0.5	0.0	0.0	0.0	4.9	0.0	0.0	0.0	2.7	0.0	6.9	0.0
AB	AB	0.25	0.0	0.25	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.4	0.0	3.4	0.0
Total										40.0		44.6		30.6		42.2

		Inferred newborn allele and rate				Han		Kazak		Uyghur		Hui	
wife	husband	cc	Cc	CC	Incompat–ible rate	frequen–cy(%)	Incompat–ible rate(%)	frequen–cy(%)	Incompat–ible rate(%)	frequen–cy(%)	Incompat–ible rate(%)	frequen–cy(%)	Incompat–ible rate(%)
cc	cc	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	4.1	0.0	3.4	0.0
cc	Cc	0.5	0.5	0.0	0.5	4.2	2.1	14.3	7.2	14.3	7.2	13.8	6.9
cc	CC	0.0	1.0	0.0	1.0	4.2	4.2	7.1	7.1	3.4	3.4	0.0	0.0
Cc	cc	0.5	0.5	0.0	0.0	8.0	0.0	28.6	0.0	14.3	0.0	3.4	0.0
Cc	Cc	0.25	0.5	0.25	0.0	19.9	0.0	7.1	0.0	25.2	0.0	10.3	0.0
Cc	CC	0.0	0.5	0.5	0.0	19.5	0.0	14.3	0.0	13.6	0.0	17.2	0.0
CC	cc	0.0	1.0	0.0	1.0	7.3	7.3	0.0	0.0	3.4	3.4	10.3	10.3
CC	Cc	0.0	0.5	0.5	0.5	20.2	10.1	7.1	3.6	13.6	6.8	24.1	12.1
CC	CC	0.0	0.0	1.0	0.0	15.7	0.0	21.4	0.0	8.2	0.0	17.2	0.0
Total							23.7		17.8		20.8		29.3

		Inferred newborn allele and rate				Han		Kazak		Uyghur		Hui	
wife	husband	ee	Ee	EE	Incompat–ible rate	frequen–cy(%)	Incompat–ible rate(%)	frequen–cy(%)	Incompat–ible rate(%)	frequen–cy(%)	Incompat–ible rate(%)	frequen–cy(%)	Incompat–ible rate(%)
ee	ee	1.0	0.0	0.0	0.0	24.4	0.0	28.6	0.0	32.0	0.0	31.0	0.0
ee	Ee	0.5	0.5	0.0	0.5	22.0	11.0	14.3	7.2	19.0	9.5	27.6	13.8
ee	EE	0.0	1.0	0.0	1.0	6.3	6.3	0.0	0.0	2.7	2.7	6.9	6.9
Ee	ee	0.5	0.5	0.0	0.0	20.2	0.0	14.3	0.0	16.3	0.0	10.3	0.0
Ee	Ee	0.25	0.5	0.25	0.0	17.4	0.0	21.4	0.0	16.30	0.0	20.7	0.0
Ee	EE	0.0	0.5	0.5	0.0	3.8	0.0	7.1	0.0	4.1	0.0	0.0	0.0
EE	ee	0.0	1.0	0.0	1.0	2.4	2.4	7.1	7.1	5.4	5.4	3.4	3.4
EE	Ee	0.0	0.5	0.5	0.5	2.8	1.4	7.1	3.6	3.4	1.7	0.0	0.0
EE	EE	0.0	0.0	1.0	0.0	0.7	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Total							21.1		17.8		19.3		24.1

bility rate among minority married couples with respect to ABO, Rh, and K phenotype matching for evaluating the risk of haemolytic disease in new−born infants.

Xinjiang is an area of rich ethnic diversity, and due to a national building policy throughout Xinjiang, first introduced in 1996 and which resulted in further inward migration, the impact on the frequencies of erythrocytic phenotypes among four minorities including Han, Hui, Kazak and Uyghur has become more apparent. Our present study indicated that, in estimating the transfusion risks in Xinjiang, it would be advisable to perform K and Rh−matched transfusion due to the higher frequency of K antigen in this region, compared to other regions in China[2−8]. This result has also shown that the frequencies of ABO and Rh phenotypes in the Han minority group were significantly different, which may have been due to the Han migration from various other areas, as a consequence of the national Xinjiang building policy. The Hui showed a conservative result for Rh−C and RH−E which may have resulted from closer ethnic inter−marriage.

There was no absolute association between erythrocytic antibodies and haemolytic disease in new−borns. Anti−A, anti−B, anti−C, anti−E, anti−D, anti−c, anti−e and anti−K have all been previously reported to be erythrocytic alloantibodies inducing haemolytic disease. Furthermore, anti−Rh and anti−K have also been reported in foetal hydrops[9−11]. Therefore, the simulated model used to evaluate the incompatibility rate among the married couples and the mother−child relationship was able to calculate the risk in new−born infants, due to hereditary depending on marial relationship. Our study noted that the Hui minority group in Xinjiang should be made aware of Rh−induced haemolytic disease in their new−born infants, especially when allo−antibodies against the Rh antigen were identified in the maternal plasma. Several factors influence immunization, such as the HLA−DRB1 gene, transfusion, and pregnancy history. Furthermore, horizontal cross−minority marital relationships, and haemolytic disease in new−born, due to the incompatibility of ABO, Rh, and K, require further study.

According to the simulated model, attention should be paid to the ABO and Rh incompatibility problem clinically in the horizontal status of the Kazak and Hui minority groups, respectively. Within the Uyghur minority group in Xinjiang, K antigen should be phenotyped due to its higher frequency in this region, compared to other minorities in other districts in China.

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