BMJ Open

Frequencies and ethnic distribution of ABO and RhD blood groups in China: a population-based cross-sectional study

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To cite: Liu J, Zhang S, Wang Q, *et al*. Frequencies and ethnic distribution of ABO and RhD blood groups in China: a population-based cross-sectional study. *BMJ Open* 2017;**7**:e018476. doi:10.1136/bmjopen-2017-018476

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2017-018476).

Received 1 July 2017
Revised 22 October 2017
Accepted 31 October 2017

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ABSTRACT

Objectives ABO and RhD blood groups are key factors affecting blood transfusion safety. The distribution of ABO and RhD blood groups varies globally, but limited data exist for ethnic distributions of these blood groups in Asian populations. We aimed to evaluate the distribution of ABO and RhD blood groups among Chinese ethnic groups.

Design A population-based cross-sectional study.

Setting Data on ABO groups and ethnicities were obtained from the National Free Preconception Health Examination Project (NFPHEP) with participants from 220 counties of 31 provinces in China

Participants There were 3 832 034 participants aged 21–49 years who took part in the NFPHEP from January 2010 to December 2012 and were included in this study.

Outcome Measures The proportion of ABO and RhD blood groups among different ethnic groups was calculated.

Results ABO and RhD blood distribution was significantly different among nine ethnic groups (P<0.001). Compared with other ethnic groups, the Yi group had more A phenotypes (34.0%), and the Manchu (33.7%) and Mongolian (33.3%) ethnic groups had more B phenotypes. The Zhuang group had the greatest proportion of O phenotypes (41.8%), followed by the Miao group (37.7%). AB phenotypes were more frequent in the Uygur ethnic group (10.6%) but lower in the Zhuang group (5.5%). Meanwhile, RhD negativity (RhD–) was greater in the Uygur group (3.3%) than in the Mongolian (0.3%) and Manchu ethnic groups (0.4%). O RhD– blood groups were more frequent in the Uygur group (0.8%) than in the other ethnic groups (0.1%–0.4%, P<0.001).

Conclusion ABO and RhD blood phenotypes vary across different ethnic groups in China. The diversity in the distribution of the ABO and RhD blood groups in different ethnic groups should be considered when developing rational and evidence-based strategies for blood collection and management.

Strengths and limitations of this study

- To our knowledge, this is the largest population-based study of ABO and RhD blood type distribution in different ethnic groups among the general population in an Asian country.
- A major limitation of the study was that there was no further laboratory data on the subtypes of the ABO blood groups (eg, A1, A2, A3, Aw, Ax and Ael).
- We did not assess all of the 55 ethnic minority groups in China, but we assessed the seven ethnic minority groups with larger population sizes.
- Participants' willingness to donate and history of blood donation were not investigated, so we could not provide specific evidence on donor recruitment.

INTRODUCTION

ABO and RhD blood groups, the most well-known blood group systems, are of key importance for transfusion safety and clinical practice and are also thought to be linked with disease susceptibility.[1 2] The distribution of ABO and RhD blood groups varies throughout the world[3–5]; previous studies have found the percentage of blood group O to be 46.6% in the USA,[3] 34% in China,[4] 49.10% in Mauritania,[5] 38.9% in Sweden[6] and 42.3% in Denmark.[6] The proportion of those with RhD-negative (RhD–) blood has been reported to be 14.6% in the USA,[3] 17.9% in Sweden and Denmark[6] and between 0.4% and 1.0% in China[4]; this also varies among different races or ethnic populations.[3 5 7] In the USA, the percentage of group O varies from 39.8% in Asian donors to 56.5% in Hispanic donors, and the proportion of RhD– varies from 1.7% in Asian donors to 17.3% in White non-Hispanic donors.[3] Data regarding the distribution of ABO and RhD blood groups were primarily obtained from blood donors in previous studies, while little data came from the general population.

China comprises more than 20% of the world's population.[8] Social–economic development and increased healthcare coverage have increased the demand for blood and its products in China.[9] Despite steady increases in total blood collections and voluntary non-remunerated donors, China faces challenges to its blood donation system.[10] Nine per cent of Chinese donate blood, and more than 60% of donors are first-time donors.[10] Thus, data regarding the frequencies and ethnic distributions of ABO and RhD blood groups in the general population may help us to develop rational and evidence-based strategies for

blood collection and management. However, studies that focused on the frequency and ethnic distribution of ABO and RhD blood groups in the general population have been scarce in China.

Thus, we conducted a large population-based study to investigate the distribution of ABO and RhD blood groups in different ethnic groups in the general population in China to provide reliable data for better development of rational strategies for blood collection and management.

MATERIALS AND METHODS

Study design and data source

We performed a nationwide population-based, cross-sectional study using data from the National Free Preconception Health Examination Project (NFPHEP), which is a national health check-up programme that offers free preconception health examinations and counselling services for married couples preparing for pregnancy. It was launched by the Chinese National Health and Family Planning Commission and the Ministry of Finance in 2010. Project-related design and implementation were previously described.[11–14] This study was approved by the Institutional Review Board of the Chinese Association of Maternal and Child Health Studies. All participants were provided with written informed consent forms before enrolment.

From 1 January 2010 to 31 December 2012, there were 4 150 214 participants (2 120 131 women and 2 030 083 men) aged 21–49 years from 220 counties in 31 provinces enrolled in the NFPHEP, covering 86.1% of the target population.[15] A total of 318 180 (7.7%) participants who did not undergo ABO and RhD blood typing were excluded, yielding 3 832 034 enrolled participants who were included for analysis.

Questionnaire and laboratory testing

Basic information was collected by trained local health workers from all of the participants in the NFPHEP using a standardised questionnaire that inquired about gender, age, educational level, occupation, address of residence and ethnicity (Han, Uygur, Zhuang, Manchu, Miao, Yi, Mongolian, Hui or Others). Information on ethnicity was collected based on identification card of the participants to avoid recall bias. During the physical examination, trained local health workers collected blood samples from all of the participants and immediately sent them to local laboratories. Testing for both the ABO and RhD blood groupings was performed simultaneously with reagents (anti-A, anti-B, anti-AB and anti-D). The red blood cell agglutination method was used for blood type analysis. The National Center of Clinical Laboratories for Quality Inspection and Detection performed a biannual external quality assessment for quality control.

Statistical analysis

We used proportions to describe distributions of gender, age, ethnicity and other sociodemographic characteristics of the participants. We used χ^2 tests to compare proportions of A, B, AB and O blood groups across ethnicities. The proportion of RhD– and its 95% CI was calculated. The χ^2 test was also used to compare the proportion of RhD– blood groups across ethnicities. According to the ABO phenotypes (A, B, AB and O) and RhD phenotypes (RhD– and RhD+), we divided the participants into eight blood groups, namely A RhD+, A RhD–, B RhD+, B RhD–, AB RhD+, AB RhD–, O RhD +and O RhD–. We used the χ^2 test to compare distributions of ABO/RhD phenotypes across ethnicities. All of the analyses were done with SPSS V.18.0. Two-sided P<0.05 was considered to be statistically significant.

RESULTS

Demographic characteristics of the study population

Of the 3 832 034 participants included in the study, 48.8% were male, 36.3% were older than 30 years of age. There were 3 473 527 (90.6%) of the participants who were of the Han ethnicity. The proportions of the Uygur, Zhuang, Manchu, Miao, Yi, Mongolian and Hui ethnicities were 3.4%, 1.2%, 0.9%, 0.7%, 0.5%, 0.5% and 0.3%, respectively (table 1). The Manchu ethnic group (51.2%) had a significantly higher proportion of male proportion than other ethnicities (all P<0.001).

Distribution of ABO blood groups according to ethnicity

In the ABO blood system, blood group A (30.5%) appeared to be the most common phenotype, followed by O (30.4%), B (29.4%) and AB (9.7%). The proportions of the A, B, O and AB blood groups were significantly different among the nine ethnic groups (all P<0.001, table 2). Compared with the other ethnic groups, the Yi ethnic group had a significantly higher proportion of the A phenotype (34.0%), while Manchu (33.7%) and Mongolian (33.3%) ethnic groups had a significantly higher proportion of the B phenotype (all P<0.001). The Zhuang ethnic group had the highest proportion of the O phenotype (41.8%), followed by the Miao ethnic group (37.7%). The proportion of the AB phenotype was significantly higher in the Uygur ethnic group (10.6%) but lower in the Zhuang ethnic group (5.5%, all P<0.001).

Distribution of RhD blood groups according to ethnicity

In the Rh blood system, 1.02% (95% CI 1.01 to 1.03) of the 3 832 034 participants were RhD– (table 3). The proportion of the RhD– group was significantly different among the nine ethnic groups (χ^2=7413.07, P<0.001). Compared with other ethnic groups, the proportion of RhD– appeared to be significantly higher in the Uygur ethnic group (3.3%), while much lower in the Mongolian (0.3%) and Manchu ethnic groups (0.4%). The proportion of RhD– in the Yi (1.25%), Han (0.95%), and other ethnic groups (1.04%) was significantly different from each other (all P<0.01). Compared with the Han ethnic group, participants of Uygur ethnicity (OR=3.59; 95% CI, 3.48 to 3.71), Yi ethnicity (OR=1.32; 95% CI 1.16 to 1.49),

Table 1 Sociodemographic characteristics of the study population

Characteristic	Total (%)	Male (%)*	Female (%)*
Ethnicity			
Han	3 473 527 (90.6)	1 698 090 (48.9)	1 775 437 (51.1)
Uygur	1 29454 (3.4)	64 559 (49.9)	64 895 (50.1)
Zhuang	47305 (1.2)	22 735 (48.1)	24 570 (51.9)
Manchu	33182 (0.9)	16 988 (51.2)†	16 194 (48.8)
Miao	27637 (0.7)	12 212 (44.2)	15 425 (55.8)
Yi	19659 (0.5)	8839 (45.0)	10 820 (55.0)
Mongolian	18996 (0.5)	9148 (48.2)	9848 (51.8)
Hui	11471 (0.3)	5588 (48.7)	5883 (51.3)
Others	70803 (1.8)	32 276 (45.6)	38 527 (54.4)
Age (years)			
21–29	2 405 744 (62.8)	1 035 243 (43.0)	1 370 501 (57.0)
30–39	1 247 194 (32.5)	723 523 (58.0)	523 671 (42.0)
40–49	179 096 (4.7)	111 669 (62.4)	67 427 (37.6)
Region			
Eastern	857 763 (22.4)	416 191 (48.5)	441 572 (51.5)
Central	1 930 145 (50.4)	945 877 (49.0)	984 268 (51.0)
Western	1 044 126 (27.2)	508 367 (48.7)	535 759 (51.3)
Education			
Primary school or below	178 680 (4.7)	80 321 (45.0)	98 359 (55.0)
Junior high school	2 503 844 (65.3)	1 202 193 (48.0)	1 301 651 (52.0)
Senior high school	700 159 (18.3)	358 423 (51.2)	341 736 (48.8)
College or higher	449 351 (11.7)	229 498 (51.1)	219 853 (48.9)
Occupation			
Farmers	2 914 777 (76.1)	1 403 135 (48.1)	1 511 642 (51.9)
Factory workers	354 080 (9.2)	197 556 (55.8)	156 524 (44.2)
Others	563 177 (14.7)	269 744 (47.9)	293 433 (52.1)
Total	3 832 034 (100.0)	1 870 435 (48.8)	1 961 599 (51.2)

*The proportions of men and women in each ethnic group.
†Compared with the other ethnic groups, the proportions of men were significantly higher in the Manchu population (all P<0.001).

and others (OR=1.10; 95% CI 1.02 to 1.18) all had a significantly higher proportion of RhD–.

Distribution of ABO and RhD blood groups according to ethnicity

Compared with other ethnic groups, the Yi group had more A RhD+ phenotypes (33.6%), and the Uygur group had more A RhD– phenotypes (1.1%, all p<0.001). O RhD– blood groups were more frequent in the Uygur group (0.8%) than in the other ethnic groups (0.1%–0.4%, P<0.001). O RhD+ blood groups were frequent in the Zhuang group (41.7%) than in other ethnic groups (27.1%–37.5%, P<0.001). The proportions of AB RhD+ blood group (10.3%) and AB RhD– blood group (0.3%) were both higher in the Uygur than in other ethnic groups (all P<0.001). The distribution of ABO and RhD combination phenotypes across ethnicities is shown in table 4.

DISCUSSION

Similar with other developing countries, China has made progress on blood safety and availability through persistent efforts on blood screening and supply in the past decades.[16] China has 452 blood banks and 32 blood centres nationwide but still faces challenges in limited donors and blood shortage.[16] How ABO/RhD blood groups are distributed in the general population is of interest to improve blood services.

In this population-based study involving 3.8 million adults in China, we found that the A phenotype was the most common, followed by the O, B and AB phenotypes; O phenotype was more frequent in the Zhuang group and RhD– phenotype was more frequent in the Uygur group. Zu and colleagues[17] reported A, O, B and AB phenotypes to be 31.9%, 31.0%, 28.1% and 9.1%, respectively, in 19 247 patients without congenital heart disease in China,

Table 2 Distribution of ABO blood groups in the study population according to ethnicity

Ethnicity	Number	ABO phenotype (%)			
		A	B	AB	O
Han	3 473 527	1 065 599 (30.7)	1 021 051 (29.4)	338 230 (9.7)	1 048 647 (30.2)
Uygur	129 454	39 745 (30.7)	39 857 (30.8)	13 727 (10.6)*	36 125 (27.9)
Zhuang	47 305	11 917 (25.2)	13 006 (27.5)	2602 (5.5)	19 780 (41.8)*
Manchu	33 182	8438 (25.4)	11 180 (33.7)*	3132 (9.4)	10 432 (31.4)
Miao	27 637	7847 (28.4)	7435 (26.9)	1932 (7.0)	10 423 (37.7)*
Yi	19 659	6675 (34.0)*	5191 (26.4)	1778 (9.0)	6015 (30.6)
Mongolian	18 996	4983 (26.2)	6320 (33.3)*	1840 (9.7)	5853 (30.8)
Hui	11 471	3411 (29.7)	3429 (29.9)	1134 (9.9)	3497 (30.5)
Others	70 803	21 550 (30.4)	19 963 (28.2)	5887 (8.3)	23 403 (33.1)
Total	3 832 034	1 170 165 (30.5)	1 127 432 (29.4)	370 262 (9.7)	1 164 175 (30.4)

*Compared with the other ethnic groups, the proportions of group A (B, AB or O) were all significantly higher (P<0.001).

which were similar with our findings. This was a general population of patients without heart disease, therefore the data matches closely to our study conducted as there were likely to be all ethnicities present. In the Chinese blood donors, Guo and colleagues[4] reported that O phenotype was the most frequent (34.0%) and RhD– phenotype was 1.0% among 512 594 donations at five blood centres in China. Different characteristics between general population and blood donors might contribute to the discrepancy on ABO distribution, because it was found that Han donors were under-represented (86.2%) compared with the general population (>90%).[4] Li and colleagues[18] found that RhD– donors were more prevalent especially from the Uygur population (5%), which was consistent with the findings from the general population. However, these numbers are much lower than data (17.9% for RhD– phenotype) from Sweden and Denmark.[6] In the USA, Garratty and colleagues[3] demonstrated that percentages of group O were 39.8% in Asian donors, 56.5% in Hispanic donors and 54.6% in North American Indian donors. And they found that the proportions of RhD– was much lower in Asian donors (1.7%) than that in White non-Hispanic donors (17.3%) and North American Indian donors (9.7%).[3] The ABO and RhD blood phenotypes vary widely across races/ethnicities and geographical boundaries.[3 19] These findings highlight that it is necessary to consider ethnic diversity when developing recruitment strategies.

Table 3 Distribution of RhD blood groups in the study population according to ethnicity

Ethnicity	Total	RhD–	
		N	Proportion (%, 95% CI)
Han	3 473 527	33 003	0.95 (0.94 to 0.96)
Uygur	129 454	4309	3.33 (3.23 to 3.43)*
Zhuang	47 305	240	0.51 (0.44 to 0.57)
Manchu	33 182	121	0.36 (0.30 to 0.43)
Miao	27 637	191	0.69 (0.59 to 0.79)
Yi	19 659	245	1.25 (1.09 to 1.40)
Mongolian	18 996	65	0.34 (0.26 to 0.43)
Hui	11 471	92	0.80 (0.64 to 0.97)
Others	70 803	739	1.04 (0.97 to 1.12)
Total	3 832 034	39 005	1.02 (1.01 to 1.03)

*Compared with the other ethnic groups, the proportions of the RhD– group were significantly higher in the Uygur population (all P<0.001).
RhD–, RhD negative.

The majority of the population in China are of Han ethnicity (91.6%) and the minority of the population are of the other 55 ethnicities (8.4%), according to the Sixth National Population Census Report.[20] The Distribution of ethnic groups in our study was similar to this report. The Zhuang, Manchu, Uygur, Miao, Yi, Hui and Mongolian populations were assessed in our study; they are the top seven ethnic groups among the 55 minorities. In China, whole blood collection has increased rapidly over the past decade, from 6.75 million donations in 2006 to 12.32 million donations in 2011; however, it is still far from the ever-increasing demand.[9 21] Our findings on the ethnic diversity of blood group distribution would be helpful to design better recruitment strategies to prevent blood shortages.

Take group O RhD– for example, it is well known that group O RhD– is a precious resource that are often in short supply.[22] Studies have shown that supplying the 'universal' O RhD– blood group on time and on demand to hospitals is an ongoing challenge.[22–24] Hirani and colleagues[23] showed that, as patient blood management became more widespread, there was an international decline in the demand for red blood cell units with a 21% reduction between 2012 and 2015 in Australia.[23] On the contrary, the demand for the O RhD– blood group was in fact proportionally increasing.[23 24] A significant proportion of O RhD– blood units were transfused to compatible, non-identical recipients, although the frequency

Table 4 Distribution of ABO and RhD blood groups in the study population according to ethnicity

Ethnicity	Number	Phenotype (%)							
		A RhD+	**A RhD–**	**B RhD+**	**B RhD–**	**AB RhD+**	**AB RhD–**	**O RhD+**	**O RhD–**
Han	3 473 527	1 053 849 (30.3)	11 750 (0.3)	1 011 421 (29.1)	9630 (0.3)	335 237 (9.7)	2993 (0.1)	1 040 017 (29.9)	8630 (0.3)
Uygur	129 454	38 265 (29.6)	1480 (1.1)	38 529 (29.8)	1328 (1.0)	13 307 (10.3)	420 (0.3)	35 044 (27.1)	1081 (0.8)
Zhuang	47 305	11 821 (25.0)	96 (0.2)	12 938 (27.4)	68 (0.1)	2594 (5.5)	8 (0.02)	19 712 (41.7)	68 (0.1)
Manchu	33 182	8396 (25.3)	42 (0.1)	11 138 (33.6)	42 (0.1)	3123 (9.4)	9 (0.03)	10 404 (31.6)	28 (0.1)
Miao	27 637	7786 (28.2)	61 (0.2)	7372 (26.7)	63 (0.2)	1920 (7.0)	12 (0.04)	10 368 (37.5)	55 (0.2)
Yi	19 659	6601 (33.6)	74 (0.4)	5119 (26.0)	72 (0.4)	1755 (8.9)	23 (0.1)	5939 (30.2)	76 (0.4)
Mongolian	18 996	4968 (26.2)	15 (0.1)	6295 (33.1)	25 (0.1)	1834 (9.7)	6 (0.03)	5834 (30.7)	19 (0.1)
Hui	11 471	3381 (29.5)	30 (0.3)	3398 (29.6)	31 (0.3)	1124 (9.8)	10 (0.1)	3476 (30.3)	21 (0.2)
Others	70 803	21 320 (30.1)	230 (0.3)	19 731 (27.9)	232 (0.3)	5803 (8.2)	84 (0.1)	23 210 (32.8)	193 (0.3)
Total	3 832 034	1 156 387 (30.2)	13 778 (0.4)	1 115 941(29.1)	11 491 (0.3)	366 697 (9.6)	3565 (0.1)	1 154 004 (30.1)	10 171 (0.3)

RhD–, RhD negative; RhD+, RhD positive.

of this practice varied across sites from 0% to 33% in Australia.[22] The transfusion of group O RhD– blood to non-O RhD+ recipients can result in shortages of group O RhD– blood. Interestingly, we found that the majority of the population was RhD+ and only 0.3% were O RhD– blood in the Chinese general population. Given the high proportion of RhD+, the likelihood of emergency/trauma patients being RhD- and therefore susceptible to alloimmunisation are so remote that collections of O RhD+ might be more sensible. Studies have showed that transfusing emergency patients with unknown blood type with O RhD+ red blood cell concentrates has a low risk of inducing anti-D antibodies (3%–7%)).[25 26] RhD– blood types may not be as vitally required in China as in other countries with high proportion of RhD– blood. Information on the distribution of the O RhD+ and O RhD– blood groups in different ethnic groups is of importance for developing better rational strategies for blood collection and management in China, especially during blood shortages.

ABO and RhD blood groups are reported to be associated with many diseases.[1 2] Understanding the distribution of blood groups in the general population can provide information on the potential risk of diseases based on their blood groups. Zu and colleagues[17] evaluated the relationship between the ABO blood group and congenital heart disease in 39 042 consecutive inpatients in a 6-year cohort study and found that the A blood group demonstrated a decreased risk for isolated congenital heart disease (OR 0.82; 95% CI 0.78 to 0.87). Amundadottir and colleagues[27] conducted a two-stage genome-wide association study and identified an association between the ABO blood group gene and pancreatic cancer. Genetic traits might contribute to the link between ABO and RhD blood groups and disease susceptibility and contribute to the diverse distribution of ABO and RhD blood groups in different ethnic groups as well.

To our knowledge, this is the largest population-based study of ABO and RhD blood type distributions across ethnicities in China. However, there were several limitations in our study. First, information on the subtypes of the ABO blood groups (eg, A1, A2, A3, Aw, Ax and Ael) was not available in the NFPHEP, thus the distribution of those ABO subtypes could not further be assessed. Second, we did not assess all of the 55 ethnic minorities in China. Nevertheless, we assessed seven minorities with a large-sized population. Third, donor willingness and histories of blood donation were not investigated in the NFPHEP, so we could not provide specific evidence on donor recruitment.

In conclusion, ABO and RhD blood phenotypes varied across ethnicities in China. Diversity in the distribution of the ABO and RhD blood groups in different ethnic groups should be considered when developing rational and evidence-based strategies for blood collection and management. Our data should allow targeted donor management to increase the proportion of needed blood type products, especially for blood types that are high in demand but low in supply.

Acknowledgements We thank all the health workers in 220 counties of 31 provinces for their strong collaboration and great effects made in the NFPHEP. We thank Konglai Zhang for linguistic assistance.

Contributors JL and SZ searched the literature, designed the study, analyzed the data, interpreted the results, and drafted the manuscript. QW, HS and YZ collected the data and revised the manuscript. ML conceived the study, designed the study, supervised the study, interpreted the results, and revised the manuscript. All authors have read and approved the final manuscript. ML is the study guarantors. ML has the right to grant on behalf of all authors and does grant on behalf of all authors.

Funding This work was supported by grants from the Chinese Association of Maternal and Child Health Studies (AMCHS-2014-5).

Disclaimer The views expressed in the report are those of the authors and do not necessarily reflect the official policy or position of the Department of Maternal and Child Health of National Health and Family Planning Commission in China.

Competing interests None declared.

Patient consent Obtained.

Ethics approval This study was approved by the Institutional Review Board of the Chinese Association of Maternal and Child Health Studies.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Due to privacy and ethical concerns, supporting data cannot be made openly available. Please contact the authors for the access of the original data.

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