Population-based projections of blood supply and demand, 
China, 2017–2036

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Abstract

Objective To estimate the long-term effect of the changing demography in China on blood supply and demand.

Methods We developed a predictive model to estimate blood supply and demand during 2017–2036 in mainland China and in 31 provinces. Model parameters were obtained from World Population Prospects, China statistical yearbook 2016, China’s report on blood safety and records from a large tertiary hospital. Our main assumptions were stable age-specific per capita blood supply and demand over time.

Findings We estimated that the change in demographic structure between 2016 (baseline year) and 2036 would result in a 16.0% decrease in blood supply (from 43.2 million units of 200 mL to 36.3 million units) and a 33.1% increase in demand.
(from 43.2 million units to 57.5 million units). In 2036, there would be an estimated shortage of 21.2 million units. An annual increase in supply between 0.9% and 1.8% is required to maintain a balance in blood supply and demand. This increase is not enough for every region as regional differences will increase, e.g. a blood demand/supply ratio ≥ 1.45 by 2036 is predicted in regions with large populations older than 65 years. Sensitivity analyses showed that increasing donations by 4.0% annually by people aged 18–34 years or decreasing the overall blood discard rate from 5.0% to 2.0% would not offset but help reduce the blood shortage.

**Conclusion** Multidimensional strategies and tailored, coordinated actions are needed to deal with growing pressures on blood services because of China’s ageing population.

**Introduction**

Maintaining a safe and adequate supply of blood for health services is an important responsibility of every World Health Organization Member State. Demographic changes are a threat to the balance of blood demand and supply in blood services because both blood consumption and donation patterns vary by age, as has been shown in countries such as the United Kingdom of Great Britain and Northern Ireland, Germany, Canada and Japan. The challenge is even greater in China, which is the most populous country and is shifting towards an aged society. The proportion of the Chinese population aged 65 years or older is projected to double from 10% (142 million people) in 2016 to 22% (309 million) in 2036. The driving forces for this change are the birth boom (242 million births) during the 1960s and the sharp decrease in births in later generations because of the birth control policies that began in the 1970s and lasted more than 40 years. Although a universal two-child policy was started in 2016, China is facing rapid depopulation. As a result, shortages in blood supply will grow over at least the next 20 years.

Blood shortages are already common in China because of low blood donation rate – 10.5 donors per 1000 population in 2016. Despite a growth in the total volume of blood donation over 20 consecutive years in China, this rate is well below the world average of 30–40 donors per 1000 population. Regional variations in China’s population further add to difficulties in developing and coordinating blood services nationwide.
affluent eastern part of China has long faced an ageing population. In underdeveloped and sparsely populated western China, which has 71% of China’s land area but only 28% of its population, life expectancy is below the national average of 76 years. A national survey in 2012–2014 also reported large regional variations in the ability of blood banks to supply blood.

The objectives of our study therefore were to: (i) estimate the differences between supply and demand of blood as a result of the changing demography in China by year and region and (ii) propose strategies to reduce these differences to ensure an adequate supply of blood for the needs of the Chinese population.

Methods

Data sources

We estimated the annual supply of and demand for blood in mainland China between 2017 and 2036. We obtained the population sizes of different age groups in these years from World Population Prospects. We used the China statistical yearbook for 2016 to extract age structure data of 31 provincial-level regions (22 provinces, five autonomous regions and four province-level municipalities) in the baseline year 2016.

We obtained data from China’s report on blood safety 2016 on the overall supply and use of blood, age composition of blood donors, clinical use among specialties (e.g. surgery, obstetrics and gynaecology and intensive care), and rate of discarding blood (e.g. for physical reasons such as blood bag breakage, incomplete collection and haemolysed blood, disqualification because of positive test results for infections such as human immunodeficiency virus and hepatitis B and C, and expiry). This report includes detailed data of blood services for the whole country as well as the 31 province-level regions. We supplemented patient data on age, clinical specialty and blood use included in our previous study during 2015–2016 with data from Peking Union Medical College Hospital, to estimate the age- and specialty-specific usage rate of blood. This hospital is a large tertiary facility and leading centre in blood transfusion therapy in China.
Predictive model

The age criterion for donating blood in China is 18–59 years, and we divided this interval into five age groups (n) for the analysis: 18–24, 25–34, 35–44, 45–54 and 55–59 years. Similarly, we divided the population of potential blood users into nine age groups of 10-year spans (m): 0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, and ≥ 80 years. We used a calculation method (Box 1) to predict blood supply and demand by examining age-specific data on blood services and population projections, using the following formula.

Total blood supply in year t is

\[ S(t) = \sum_{i=1}^{n} N_i(t) \times S_i \] (1)

where \( N_i(t) \) is the population size of the \( i \)th age group in year \( t \) and \( S_i \) is the per capita blood supply of the \( i \)th age group in the baseline year (2016), calculated as: \( S_i = (A \times R_i)/N_i(2016) \), where \( A \) is the overall blood supply in 2016 and \( R_i \) is the proportion of blood supply of the \( i \)th age group in 2016.

Similarly, total blood demand in year t is

\[ D(t) = \sum_{j=1}^{m} P_j(t) \times D_j \] (2)

where \( P_j(t) \) is the population size of the \( j \)th age group in year \( t \) and \( D_j \) is the per capita blood demand of the \( j \)th age group in 2016 calculated as: \( D_j = (A \times Q_j)/P_j(2016) \) where \( A \) is the overall blood supply in 2016 and \( Q_j \) is the proportion of blood demand of the \( j \)th age group in 2016. These proportions were estimated by weighting the age structure of blood use in the Peking Union Medical College Hospital with the nationwide proportions of blood used by different specialties. No hospital can serve as a representative sample of blood use, therefore we validated this estimate using data from another report.

Assumptions

In a base-case scenario, we assumed that the supply and demand of blood per capita in each age group remains stable during the forecasted 20 years (2017–2036), as in the baseline year 2016.
As the actual need for blood cannot be determined,\textsuperscript{23,24} we assumed that blood demand in the baseline year was equal to supply (43.2 million units of 200 mL, including all blood components),\textsuperscript{13} even though China already has a long-term shortage of blood.\textsuperscript{12}

By also assuming that the age-specific population growth ratios in each region were identical to national levels, we predicted the blood supply and demand for each of the 31 province-level regions.

**Sensitivity analysis**

We carried out the following sensitivity analyses to explore the effect of changing certain variables on blood supply. First, we lowered the current (2016) discard rate of blood of 5.0% to 2.0% throughout the country. The 2.0% rate was considered a reasonable forecast based on present achievable levels.\textsuperscript{12} Second, we increased the combined annual per capita blood donation from young people aged 18–24 and 25–34 years by 2.0% and by 4.0%. We selected these age groups because they are more physically fit for donation than older people, although few currently donate blood. Finally, we increased the overall annual blood supply for all age groups by 1.0% and 1.5%. We selected 1.0% and 1.5% based on actual annual growth rates of overall blood supply during 2012–2016.\textsuperscript{13}

We used MATLAB R2018a (MathWorks\textsuperscript{®} Inc., Beijing, China) to analyse the data.

**Results**

**Baseline blood supply and demand**

Fig. 1 shows the average amounts of blood (units per 1000 people) donated in 2016 for the different age groups. The youngest donation group (age 18–24 years) donated the most blood per 1000 people (91.8 units), followed by the age group 35–44 years (53.2 units) and the age group 25–34 years (49.9 units). The age group 55 years or older donated the smallest amount of blood (5.4 units). In contrast, the consumption of blood increased by age group (Fig. 2), from 1.0 unit per 1000 people in those aged 0–9 years to 43.9 units per 1000 people in those aged 50–59 years, and to as high as 115.3 units per 1000 people in those older than 79 years.
Base-case predictions

The overall blood supply and demand predicted in the next 20 years, based on 2016 data (43.2 million units), are shown in Fig. 3. We estimated that blood supply would decrease after 2016, more than 5% by 2021 (to 40.9 million units) and reaching 10% by 2027 (to 38.9 million units). In contrast, the overall demand for blood increased sharply against the 2016 baseline, with an increase of about 10% by 2021 (to 47.2 million units) and 20% by 2027 (to 51.8 million units). By 2036, we estimated the blood supply would be 36.3 million units (a decline of 16.0% from 2016) and blood demand would be 57.5 million units (an increase of 33.1%), indicating a potential shortage of 21.2 million units (36.9% of the demand).

The most substantial decrease in supply (32.3%) will occur in the age group 25–34 years, from about 11.8 million units in 2016 to 8.0 million units in 2036. This decrease roughly corresponds to the sharp decrease in the size of this age group, from those born in the 1980s (236 million) to those born in the 1990s (172 million) and 2000s (160 million). Although the blood supply in the age group 55–59 years is estimated to grow by 9.9% (43,962/445,073) from 2016 to 2036 because of the 1960s birth boom, its effect on the overall supply trend is very small because the absolute increase is small (from 445,073 to 489,036 units; Fig. 3).

There are two divergent trends of age-specific blood demand (Fig. 3). Blood demand in all age groups younger than 50 years is expected to fall from 2016 to 2036, by between 4.9% (92,492/1,899,179) and 25.5% (1,012,390/3,972,959). However, demand in all groups aged 50 years or older will increase in the next 20 years, especially in those aged 70–79 years (from 5,379,852 to 12,150,15 units, a 125.8% increase) and 80 years or more (from 2,836,230 to 7,059,161 units, a 148.9% increase).

Fig. 4 shows the increase in the overall blood supply needed to maintain a balance with demand during 2017–2036. The required increase in supply declined steadily over time, from 1.8% in 2017 to 1.5% in 2026 and to 0.9% in 2036, which is about half the increase in rate needed at the beginning of the period.
Regional variations

We predicted large variation between regions in the level of blood shortages projected for 2036 (Fig. 5). Regions with the highest demand/supply ratios ($\geq 1.45$) were Chongqing (a municipality in the south-west of the country), Sichuan (neighbouring Chongqing, whose population became older before achieving economic prosperity) and Jiangsu (the most affluent eastern province); these regions have the biggest proportions of older people ($\geq 65$ years). Regions with the lowest demand/supply ratios ($\leq 1.30$) were Guangdong (on the south-east coast, the most populous and one of the richest areas in China), Xinjiang (in the north-west), Qinghai (next to Xinjiang and one of the least developed regions) and Tibet (west of Qinghai).

Sensitivity analysis

When we reduced the blood discard rate from 5% to 2% the overall supply–demand balance did not change greatly; however, we estimated that an additional 24.8 million units of blood would be available for clinical use over the next 20 years (Fig. 6).

A 2.0% annual increase in per capita blood donation in people aged 18–34 years would still be inadequate and would result in a shortage of 12.1 million units by 2036. An annual increase of 4.0% in this group alone would still be insufficient to reach a balance in supply and demand until 2035 and later (Fig. 6).

Increasing the blood supply, regardless of age group, seems to be the most effective approach. Maintaining an annual increase in blood supply of 1.0% would greatly reduce (though not offset) the imbalance with demand (a shortage of 4.8 million units by 2036). A 1.5% annual increase in supply would achieve a balance with demand by 2033, with a supply shortage of no more than 1.0 million units before this time. Between 2033 and 2036, supply would exceed demand by no more than 0.7 million units (Fig. 6).

Discussion

China has the highest annual blood collection and number of volunteer donors in the world. Nonetheless, because of demographic changes, we predict a decline in the blood supply and...
an increase in demand by 2036, relative to 2016. To maintain a nationwide balance in supply and demand for blood, a high, though decreasing, annual growth rate in supply is required. Moreover, regional variation is estimated to grow and regions with large proportions of older people, will have an even greater demand than supply in 2036. These findings suggest a growing imbalance between blood supply and demand, and between regions, which requires immediate, strategic and ongoing action.

Our study results are based on population data from the World Population Prospects,\textsuperscript{10} and blood service data of the whole country.\textsuperscript{13} The use of world population data facilitates comparison of our results with those of other countries. For example, a shortage in blood supply of 25–40\% in about 2035 has also been predicted in Canada,\textsuperscript{5} Iceland,\textsuperscript{26} Japan,\textsuperscript{6} and Switzerland,\textsuperscript{27} despite differences in modelling parameters and approach. To a certain extent, the regional variation shown in our study is representative of the situation worldwide. Therefore, sharing information and experiences between countries will help deal with problems with blood supply arising from ageing populations worldwide.

The study has limitations. The assumption of constant age-specific blood donation and transfusion frequencies over time is common in many demographic models\textsuperscript{3–5} but may not reflect the complex reality.\textsuperscript{28} For instance, overall blood donation did not decrease but continued to rise during 2016–2018, as a response to the substantial efforts made in China to encourage blood donation.\textsuperscript{29} The value of this assumption is to inform investment in such efforts by estimating the potential influence of demographic shifts (a key predictable factor); we did not intend to model every possible scenario that is vulnerable to change and less quantifiable. For the same reason, we did not analyse potential changes in donation policy (e.g. expanding the eligible donor age\textsuperscript{30,31} and donation frequency,\textsuperscript{32} as adopted or considered in developed countries but not yet in most regions of China). Currently, the donation policy in most places in China allows a donation of 200, 300 or 400 mL of blood at one time, and an interval between donations of not less than 6 months for whole blood donations and not less than 28 days for platelet donation.
Blood demand may have been underestimated because we assumed it to be equal to blood supply in 2016 and is expected to be affected by future medical advances.\cite{28,33}

Data on time trends in the blood supply,\cite{27,34} transition probabilities between donation frequencies in succeeding years,\cite{6} and retention rates of donors\cite{34} can be used to construct more sophisticated (and perhaps more precise) prediction models; however, such data were unavailable in our study. The effects of specialty hospitals (6642 hospitals in 2016),\cite{35} minority ethnic groups (120 million people, with low reported donation rates because of cultural beliefs),\cite{36} and sex differences in blood donation and consumption (e.g. more women in their 30s and 40s having a second child and higher risk of maternal haemorrhage with more births as a result of the new birth policy)\cite{11} were also not analysed in this study.

**Recommendations**

Blood shortage is a problem requiring multidimensional solutions and close collaboration between researchers, blood bank staff, policy-makers and all of society. We can learn from efforts in developed countries,\cite{37} and as new solutions to sustain the blood supply continue to emerge.\cite{38,39} Instead of a discussion of specific solutions, we suggest the following overall strategies, which we consider of great importance to the future of blood service management and the supply of and demand for blood in China.

**Strategy I. Education**

A voluntary, unpaid donation-based blood system in China is still in its early stages.\cite{40} Therefore, professional, public and early education should be strengthened across the country to encourage blood donation. In contrast to the more than 30 years’ experience in education on transfusion medicine in the USA,\cite{41} transfusion medicine only became a separate specialty in China in 2016.\cite{13} Only seven of over 2500 universities nationwide now offer undergraduate education in transfusion medicine. Accelerating professional education and developing qualified blood service teams are important, especially to train personnel on assuring the quality, safety and appropriate use of blood.\cite{42} In addition, increasing public awareness and helping more eligible adults to understand the importance of blood donation\cite{43,44} could greatly
increase the number of blood donors and hence the blood supply. This strategy could be particularly useful given China’s current low blood dependency ratio, which is projected to still be low even after two decades. Furthermore, the current blood donation rate among young people is much lower in China (30 donors per 1000 population) than in developed countries (e.g. 116 per 1000 in Poland). With long-term problems in blood donation and an ageing population similar to China, Japan has set several good examples, especially early education of schoolchildren, the main blood donors of the future.

**Strategy II. Tailored methods**

The large regional variation in blood supply and demand in China is a unique challenge; thus, strategies to tackle the issue should vary accordingly. For example, given the very high predicted blood demand/supply ratios in Sichuan because of an ageing population (because of the low birth rate since the 1970s), the age limit of healthy donors was increased from 59 to 65 years in 2019, with the governor leading voluntary blood donation. More than 10% of blood collected in Sichuan was discarded in 2016, so benchmarking this rate with eastern areas (e.g. a discard rate of 1% in Jiangsu) and setting goals to reach a 1% discard rate would also improve blood supply in this region. In other regions of western China, despite less pressure from ageing populations because family planning is not required among ethnic minority groups, the rapidly growing per capita blood demand because of economic growth calls for preparedness of blood services in equipment, facilities, staff, organization as well as technical support from the eastern regions of China as needed. Sentinel hospitals (as in the Republic of Korea) should be established in sparsely populated areas to better understand and cater to the needs of residents for blood services.

**Strategy III. Multilevel coordination**

China has considerable experience in network and systems construction, which could be used to improve coordination of blood services. First, cross-sectoral coordination: given the large blood shortage according to our projection, mechanisms should be established to strengthen transparency and communication between blood banks, hospitals and communities to match patient needs. Second, cross-regional coordination: even though 98.6% (8709/8831 units) of
blood products were reallocated within provinces in 2016, increasing the movement of blood products across provincial borders may offset urgent shortages, especially in regions predicted to not be self-sufficient in future. Third, urban–rural coordination: population ageing in rural China is twice that in urban areas. As can be inferred from our sensitivity analyses on people aged 18–34 years, these young adults relocating to work in cities would create greater difficulties for blood services in rural areas and for their parents and the children left behind. Fourth, short-term coordination: although average predicted blood shortages are not high in provinces with high levels of imported labour (e.g. Guangdong), reliance on university students and migrant workers results in seasonal blood shortages during summer holidays and the annual celebration of the Chinese New Year, which is a special challenge requiring more flexible and coordinated solutions.

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None declared.

References


Box 1. Calculations for estimating blood supply and demand in China for 2017 to 2036

**Prediction of supply**

1. Total blood supply in China in 2016 × Proportions of blood supply in different age groups in 2016 = Blood supply in different age groups in 2016
2. Blood supply in different age groups in 2016 ÷ Population in different age groups in 2016 = Per capita blood supply in different age groups
3. Per capita blood supply in different age groups × Population in different age groups in the forecast year = Blood supply in different age groups in the forecast year
4. The sum of blood supply in different age groups in the forecast year equals the total blood supply in the forecast year.

**Prediction of demand**

2. Blood demand in different age groups in 2016 ÷ Population in different age groups in 2016 = Per capita blood demand in different age groups
3. Per capita blood demand in different age groups × Population in different age groups in the forecast year = Blood demand in different age groups in the forecast year
4. The sum of blood demand in different age groups in the forecast year equals the total blood demand in the forecast year.
Fig. 1. **Blood supply in different age groups in China in 2016, the baseline year**

![Blood supply in different age groups](image)

Note: One unit equals 200 mL blood.
Fig. 2. **Blood demand in different age groups in China in 2016, the baseline year**

![Blood demand graph](image)

Note: One unit equals 200 mL blood.
Fig. 3. Predicted overall and age-specific blood supply and demand in China, 2016–2036

Notes: In the two panels showing data for different age groups, the percentages are the difference between 2036 and 2016 (baseline year). Percentage change in demand is not shown for the age group 0–9 years (−21.8%). One unit equals 200 mL blood.
Fig. 4. **Predicted annual increase in blood supply needed to maintain a balance with demand in China, 2017–2036**
Fig. 5. Predicted ratios of blood demand to supply in different regions of China in 2036
Fig. 6. Sensitivity analysis of different assumptions of blood supply and demand in China, 2016–2036

Note: One unit equals 200 mL blood.