Research paper

A Cross-Sectional Nationwide Study on Accessibility and Availability of Neonatal care Resources in Hospitals of China: Current Situation, Mortality and Regional Differences

Neonatal Care Resources and Newborn Mortality in China

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Background: To investigate the current situation of neonatal care resources (NCR), newborn mortality rates (NMR), regional differences and existing challenges in China.

Methods: By using a self-designed questionnaire form and the cross-sectional method, we conducted a survey of all hospitals equipped with neonatal facilities in China from March 2019 to March 2020 with respect to the level and nature of these hospitals, the number of newborn beds and NICU beds, the number of neonatal pediatricians, and the development of therapeutic techniques. The data about the newborn births and deaths were retrieved from the annual statistics of the health commissions of the related provinces, autonomous regions and municipalities.

Finding: Included in this nationwide survey were 3,020 hospitals from all 22 provinces, 5 autonomous regions and 4 municipalities directly under the Central Government of Mainland China, with a 100% response rate. They included 1,183 (39.2%) level-3 (L3) hospitals, 1,629 (53.9%) L-2 hospitals and 208 (6.9%) L-1 hospitals. Geographically, 848 (31.4%) hospitals were distributed in Central China, 983 (32.5%) hospitals in East China, and 1,089 (36.1%) in West China. The 3,020 included hospitals were altogether equipped with 75,679 newborn beds, with a median of 20 (2-350) beds, of which 2,286 hospitals (75.7%) were equipped with neonatal intensive care units (NICU), totaling 28,076 NICU beds with a median of 5 (1-160) beds. There were altogether 27,698 neonatal pediatricians in these hospitals, with an overall doctor-bed ratio of 0.366. There were 48.18 newborn beds and 17.87 NICU beds per 10,000 new births in China. In East, Central and West China, the number of neonatal beds, NICU beds, neonatal pediatricians, and attending pediatricians or pediatricians with higher professional titles per 10,000 newborns were 42.57, 48.64 and 55.67; 17.07, 18.66 and 18.17; 16.26, 16.51 and 20.14; and 10.69, 10.81 and 11.29, respectively. However, when the population and area are taken into consideration and according to the health resources density index (HRDI), the number of newborn beds, NICU beds and neonatal pediatricians in West China was significantly lower than that in Central and East China. In addition, only 10.64% of the neonatal pediatricians in West China possessed the Master or higher degrees, vs. 31.7% in East China and 20.14% in Central China. On the contrary, the number of neonatal pediatricians with a lower than Bachelor degree in West China was significantly higher than that in Central and East China (13.28% vs. 7.36% and 4.28%). Technically, the application rate of continuous positive airway pressure (CPAP) and conventional mechanical ventilation (CMV) in L-1 hospitals of West China was lower than that in Central and East China. According to the statistics in 2018, the newborn mortality rate (NMR) in West China was significantly higher than that in Central and East China.

Interpretation: China has already possessed relatively good resources for neonatal care and treatment, which is the primary reason for the rapid decrease in the NMR in China. However, there are still substantial regional differences. The density of health resources, the level of technical development and educational background of neonatal pediatricians in West China still lag behind those in other regions of China and need to be further improved and upgraded.

Funding: This research work was funded by National Natural Science Foundation of China (81671504) and United Nations International Children’s Emergency Fund (CHINA-UNICEF501MCH).

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1. Introduction

Neonatal care resources (NCR) are of primary importance in reducing the newborn mortality rate (NMR) [1,2]. China has the largest population in the world and annual birth population in China is only next to India [3]. The total population of China by the end of 2019 was 1,400.5 million, with 14.65 million people born in 2019 [4]. It is a huge challenge to provide such as large newborn population with good medical care services. In recent 30 years, China has made rapid progress in neonatal medical treatment; for instance, the NMR decreased from 33.1‰ in 1991 to 3.9‰ in 2018 [5-6]. This is attributed not only to the rapid socioeconomic development in China but directly benefits from the improvement in NCR supplies. A nationwide survey made in 2011 [7] showed that problems such as personnel and equipment shortages and regional differences still existed despite the rapid development in the specialty of neonatology. But as the sample size of that survey is relatively small and mainly involved 1-3 hospitals, it is unable to represent the overall situation of NCR in China, especially in recent 10 years during which China has made very rapid progress in neonatal specialties. Therefore, there lack sufficient data to reflect the current situation of NCR in China, including the number of newborn beds and neonatal pediatricians, and regional differences, knowing that all these changes are related to the NMR.

In 2015, China began implementing the “Comprehensive Two-Child Policy” [8-9]. The birth rate is 12.95‰ in 2016 and 12.43‰ in 2017 [6], giving birth to 17.86 and 17.23 million new babies, and increasing the mean number of new births by 1.42 and 0.79 million respectively as compared that from 2011 to 2015 before the new “Two-Child Policy”. Among these increased births, “second children” account for about 50% [10-11]. Affected by the size of childbearing-age women, the number of births declined slightly in 2018, but the proportion of “second children” still accounts for about 50% of the new births [11-12]. With the increased number of elderly “second-child” pregnant women, the number of high-risk and premature babies is also increased, which brings about substantial pressure on the neonatal care systems [13-14]. To gain a better understanding about the comprehensive situation of NCR after the “Two-Child Policy” in China and provide evidence-based data for formulating medical and health care policies, we conducted a cross-sectional nationwide survey from March 2019 to March 2020 by laying the emphasis on the relationship between NCR and the NMR in different regions of China for the sake of formulating targeted policies to further update the neonatal care systems in China.

2. Methods

2.1. Research subjects

This survey was sponsored and implemented by the Chinese Neonatologist Association (CNA) from March 2019 to March 2020 by using the national consensus method. It was a cross-sectional nationwide survey on NCR in all hospitals equipped with newborn beds and having the basic neonatal care abilities in all 22 provinces, 5 autonomous regions and 4 municipalities directly under the Central Government of mainland China. There were altogether 33,009 hospitals in mainland China in 2018, of which 3,020 (9.15%) were found to be equipped with newborn beds.

2.2. Questionnaire survey

The questionnaire survey protocol was ascertained by the hospital management experts, epidemiologists and senior neonatal specialists after repeated discussions. The research project was conducted in a stratified responsibility manner by appointing a responsible person in each province, city or autonomous region, who then appointed a responsible person in each city under the jurisdiction of the province, city or autonomous region to take in charge of the survey in their areas. All responsible persons in each province, city or autonomous region received standardized training in conference form the CNA, including the purpose, content and method of the survey, as well as distribution, recovery and recording of the questionnaire forms. Then, they trained the responsible persons in each city under the jurisdiction of the province, city or autonomous region through the Internet. All the questionnaire forms were distributed through the Questionnaires app and filled out personally by the directors of the pediatrics or neonatology departments. The questionnaire contained mixed closed-ended and open-ended questions as well as response formats. The responsible persons of each province collected the questionnaire of their province and assigned two experts to check the survey data, and then sent it back to the CNA. Should there be any question or uncompleted item, the experts would make follow-up visits to the person concerned by telephone to make corrections or replenishment. The questionnaire form mainly included the following three aspects.

The basic profile of the hospital, including its location, province (city or autonomous region), nature (public or private), level (1, 2 or 3), and type (general, pediatrics or maternal and child health care). According to the division of China’s administrative regions, all the hospitals were divided as East, Central and West for comparative analysis. East China is the most economically developed area, while West China is the most under-developed area in China. As the area of West China is by far larger than that of Central and East China, we made use of the health resources density index (HRDI) [15-16] in the present study to objectively reflect the density of health resource distribution, knowing that HRDI is a resource allocation model based on the balanced distribution of health resources by population and area. The HRDI mathemati- cal model is based on the geometric average of health human resources per thousand people and per square kilometer as follows:

\[ HRDI = \left( \frac{\text{human resource capacity per 1,000 people}}{\text{human resource capacity per km}^2} \right)^{\frac{1}{2}} \]

NCR, including the total number of newborn beds and NICU beds, and the number, professional tile and academic background of the neonatal pediatricians. As we have no perfect neonatal specialist training system in China at present, the term “neonatal pediatrician” is not equal to “neonatologists” in developed countries; rather it refers to pediatricians who were working in the neonatal words during the period of the present survey. Professionally, they were stratified as senior experts (full-senior or associate-senior doctors), attending doctors and residents, and academically they were divided as postgraduates (with Master or PhD degree), under-graduates (with Bachelor degree), and three-year college under-graduates or technical secondary school students (below Bachelor degree).

The workload of neonatal care in 2018, including the total number of hospitalized newborns, and premature, very low birth weight (VLBW) newborns and extremely low birth weight (VLBW) newborns who were hospitalized.

2.3. NMR analysis

Data about NMR in 2018 were retrieved from the annual statistics of the health commissions of the related provinces [17-26].
NMR is defined as the ratio of the number of deaths in the first 28 days of life to the number of live births occurring in the same population during the same period.

2.4. Statistical analysis

Data obtained from the recovered questionnaire forms were input into EpiData Software, cleaned by exporting the EXCEL format, and analyzed by SPSS 20.0. Qualitative data are expressed by number (%), and quantitative data are expressed as the mean ± standard deviation (SD).

2.5. Role of the funding source

The funder played no role in the study design, data collection, data analysis, data interpretation, or preparation of the manuscript. The corresponding authors had full access to all the data in the study and had the final responsibility of the decision to submit the manuscript for publication.

3. Results

3.1. General description of the included hospitals

Of the 3,020 hospitals included in the survey, 2,298 (76.1%) were general hospitals, 655 (21.7%) were maternal & child health hospitals, and only 67 (2.2%) were children’s hospitals. There were altogether 75,679 newborn beds, with a median of 20 (2-350) beds per hospital, and 2,286 (75.7%) hospitals were equipped with NICU beds, totaling 28,076 beds with a median of 5 (1-160) beds per hospital. Hospitals with the neonatal care abilities in China in 2018 are shown in Figure 1 and Table 1. L3 Hospitals, neonatal pediatricians, neonatal beds and NICU beds were more concentrated in East China (Table 4).

3.2. NCR distribution and case volumes in different areas in China

About 94.3% of the newborn beds and 94.9% of the NICU beds were distributed in L-2 and L3 hospitals. The total number of newborn and NICU beds, the number of newborn and NICU beds in L-3 hospitals and the number of neonatal pediatricians in East China were all higher than those in Central and West China. In addition, the overall educational background of the neonatal pediatricians in East China was higher than that in West China (Table 1). Geographically, the academic background of neonatal pediatricians in Shanghai, Beijing, Tianjin and other big cities in East China was the strongest (Figure 2).

In 2018, a total of 2.63 million newborns were admitted in China, accounting for 16.75% of total births, including 645000 premature births, which accounted for 24.51% of total admissions and 4.11% of total births. There were 127300 VLBWI babies, accounting for 4.83% of total admissions and 0.81% of total births. In 2018, the case volume per bed and case volume per doctor in East China were both lower than those in Central and West China (Table 1).

3.3. NCR per 10,000 new births and after HRDI correction in different areas

A summary of the data from the provinces, cities and autonomous regions concerned showed that 15.71 million new babies were born in 2018, with 48.18 newborn beds and 17.87 NICU beds per 10,000 new births. The number of newborn beds per 10,000 new births in Each, Central and West China was 42.57, 48.64 and 55.67 respectively, including 17.07, 18.66 and 18.17 NICU beds. However, these figures in West China, after HRDI calculation, were by far lower than those in Central and East China (Table 2). As calculated by HRDI by province, the number of newborn beds and NICU beds in Tibet, Qinghai and Xinjiang in West China was by far lower than that in Shanghai and Beijing in East China (Figure 3, 5).
There were altogether 27,698 neonatal pediatricians in China, with an overall doctor-bed ratio of 0.37, and 17.64 neonatal pediatricians per 10,000 newborns. The number of neonatal pediatricians per 10,000 newborns in East, Central and West China was 16.26, 16.51 and 20.81 respectively. But when the population and area were taken into consideration according to the HRDI model, the number of both neonatal pediatricians and attending doctors and doctors with higher ranks in West China significantly lagged behind (Table 2). Data concerning the neonatal pediatricians in each province, city and autonomous region are shown in Figure 4 and Figure 5, indicating that figures related neonatal pediatricians in Beijing and Shanghai in East China were significantly higher than those in Tibet and Qinghai in West China after HRDI adjustment.
3.4. Technical development of neonatal care in different areas

The results of the survey showed significant differences in technical development of neonatal care between different areas of China. Although continuous positive airway pressure (CPAP), conventional mechanical ventilation (CMV) and pulmonary surfactant (PS) replacement therapy had been applied clinically in most hospitals under survey, the practice rate of high frequency ventilation (HFV) and bedside ultrasound examination was relatively low, much less the practice rate of neonatal surgery, mild hypothermia, iNO and ECMO. Only about a quarter of the hospitals investigated carried out newborn transport, demonstrating a very low transport popularity rate in China. The higher the level of the hospitals, the more complete the technical equipment. There were relatively small differences in technical development between L-2 and L-3 hospitals in West China and those in Central and East China, but there were substantial differences in this aspect between L-1 hospitals in West China and those in Central and East China (Table 3).

3.5. Differences in NMR between different areas in 2018 and the trend of change in recent years

Geographically, the NMR in East, Central and West China in 2018 was 2.09‰, 2.56‰ and 3.88‰ respectively, the highest being in West China. In 2018, the NMR was the highest in Tibet (7.12‰) followed by Xinjiang (7.06‰), and the lowest was in Zhejiang (1.16‰) followed by Beijing (1.26‰) (Figure 3, 4). It was found that there was a significant negative correlation between the NMR and the number of newborn beds, the number of doctors and other factors related to NCR density (Figure 3, 4).

4. Discussion

There is a close correlation between the NMR and NCR supplies [27]. The neonatal care system in China has made considerable progress in recent 30 years, and the NMR has continued to decrease rapidly from 33.1% in 1991 to 3.9% in 2018 [5,6]. According to the recent report of the United Nations International Children’s Emergency Fund (UNICEF), the NMR of decline in China was 3.6 times higher than the global average during the period from 1990 to 2019, which is very close to that in North America and Europe in 2019 [28]. These achievements are mainly attributed to China’s investment in NCR [5].

The present study is the first cross-sectional nationwide general survey on NCR in China. The results showed that the number of NICU beds per 10,000 newborns was 17.87, which is significantly lower than that reported by the United States (33.7 per 10000 newborns) [1] and South Korea (28.2 per 10000 newborns) [29]. NICU beds need to consume large amounts of resources. Some researchers believe that 11 NICU beds per 10,000 newborns is the appropriate number, but on the other hand more NICU are required if VLBWI survival is to be further improved [30]. It was found in our study that the number of hospitalized VLBWI newborns in China is about 127300 in 2018, accounting for 0.81% of the total new births, which is significantly lower than that in the USA [2]. Since implementation of the “Comprehensive Two-Child Policy” in China in 2016, the number of “second children” has occupied about 50% of the total number of new births [10-12], and
Table 1
Neonatal care resources and hospitalization in hospitals of different regions and levels in China in 2018.

| Regions      | Hospital level | Hospitals with neonatal beds (n) | Newborns (n) | NICU beds (n) | Neonatal pediatricians (n) | Attending pediatricians and higher professional titles (n) | Postgraduate degree (%) | Bachelor degree (%) | Junior college and polytechnic school (%) | Newborns admitted in 2018 (10,000) | Newborns admitted in 2018 (10,000) | Average admissions number per beds in 2018 (n) | Preterm babies admitted in 2018 (n) | VLBWI admitted in 2018 (n) | Average admissions number per doctor (n) |
|--------------|----------------|---------------------------------|--------------|--------------|---------------------------|-----------------------------------------------------------|--------------------------|---------------------|------------------------------------------|---------------------------------|---------------------------------|-----------------------------------------|---------------------------------|---------------------------------|------------------------------------------|
| East China   | L3             | 470                             | 18120        | 7706         | 6060                      | 4239                                                       | 2866 (47.3)              | 3128 (51.6)         | 66 (1.1)                                                | 1328 (81.7)                     | 335 (8.8)                      | 23.0                                    | 29.8                            | 4.4                             | 0.8                                      |
|              | L2             | 453                             | 7726         | 2689         | 3798                      | 2225                                                       | 361 (9.5)                | 3102 (81.7)         | 33 (8.8)                                                | 3128 (81.7)                     | 51 (8.8)                       | 4.4                                      | 4.4                             | 0.8                             | 0.8                                      |
|              | L1             | 60                              | 1256         | 472          | 495                        | 340                                                        | 55 (11.1)                | 398 (80.4)          | 42 (8.5)                                                | 42 (8.5)                        | 42 (8.5)                      | 4.2                                      | 4.2                             | 0.8                             | 0.8                                      |
| Subtotal     | L3             | 313                             | 11238        | 4638         | 3501                      | 2438                                                       | 1415 (40.4)              | 2002 (57.2)         | 84 (2.4)                                                | 3128 (51.6)                     | 335 (8.8)                      | 23.0                                    | 29.8                            | 4.4                             | 0.8                                      |
| Central China| L2             | 551                             | 10556        | 3759         | 3974                      | 2489                                                       | 166 (4.2)                | 3368 (84.8)         | 440 (11.1)                                              | 3368 (84.8)                     | 440 (11.1)                    | 35.7                                    | 35.7                            | 5.8                             | 0.8                                      |
|              | L1             | 84                              | 1862         | 678          | 552                        | 330                                                        | 36 (6.5)                 | 449 (81.3)          | 67 (12.1)                                               | 449 (81.3)                      | 67 (12.1)                    | 5.8                                      | 31.3                            | 0.9                             | 0.2                                      |
| Subtotal     | L3             | 948                             | 23656        | 9075         | 8027                      | 5257                                                       | 1617 (20.1)              | 5819 (72.5)         | 591 (7.4)                                               | 5819 (72.5)                     | 591 (7.4)                    | 84.7                                    | 84.7                            | 19.2                            | 3.6                                      |
| West China   | L2             | 400                             | 13488        | 5378         | 4420                      | 2689                                                       | 809 (19.7)               | 3426 (77.5)         | 125 (2.8)                                               | 3426 (77.5)                     | 125 (2.8)                    | 48.6                                    | 48.6                            | 13.7                            | 3.2                                      |
|              | L1             | 625                             | 10214        | 2466         | 4402                      | 2160                                                       | 106 (2.4)                | 3371 (76.6)         | 925 (21.0)                                              | 3371 (76.6)                     | 925 (21.0)                   | 35.2                                    | 35.2                            | 5.3                             | 1.1                                      |
| Subtotal     | L3             | 64                              | 1219         | 290          | 496                        | 206                                                        | 16 (3.2)                 | 293 (59.1)          | 187 (37.7)                                              | 293 (59.1)                      | 187 (37.7)                   | 3.5                                      | 3.5                             | 0.6                             | 0.1                                      |
| Total        |                | 1089                            | 24921        | 8134         | 9318                       | 5055                                                       | 991 (10.6)               | 7090 (76.1)         | 1237 (13.3)                                             | 7090 (76.1)                     | 1237 (13.3)                  | 87.3                                    | 87.3                            | 19.6                            | 4.4                                      |
|              |                | 13488                           | 28076        | 27098        | 17116                      | 5890 (21.3)                                               | 2271 (8.2)               | 2631 (9.8)          | 2071 (7.2)                                               | 2631 (9.8)                      | 2071 (7.2)                   | 34.8                                    | 34.8                            | 12.7                            | 4.4                                      |

Table 2
Distribution of neonatal care resources corrected by HRDI model in different areas.

| Region      | Newborns born in 2018 (10,000) | Newborns admitted in 2018 (10,000) | Neonatal pediatricians per 10,000 newborn(n) | Neonatal pediatricians after HRDI correction(n) | Attending doctors or above title per 10,000 newborns(n) | Attending doctors or above title after HRDI correction(n) | Newborn beds per 10000 newborns(n) | Newborn beds after HRDI correction(n) | NICU beds per 10000 newborns(n) | NICU beds after HRDI correction(n) |
|-------------|---------------------------------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------|-----------------------------------|---------------------------------|-----------------------------------|
| East China  | 636.6                           | 91.1                                | 16.3                                          | 0.15                                          | 10.7                                                    | 0.09                                                    | 42.6                             | 4.0                               | 17.1                            | 1.7                               |
| Central China| 486.3                           | 84.7                                | 16.5                                          | 0.09                                          | 10.8                                                    | 0.06                                                    | 48.6                             | 2.6                               | 18.7                            | 1.0                               |
| West China  | 447.7                           | 87.3                                | 20.8                                          | 0.08                                          | 11.3                                                    | 0.04                                                    | 55.7                             | 2.0                               | 18.2                            | 0.7                               |
| Total       | 1570.6                          | 263.1                               | 17.6                                          | 0.10                                          | 10.9                                                    | 0.06                                                    | 48.2                             | 2.9                               | 17.9                            | 1.1                               |
therefore there is an increasing tendency in high-risk pregnancies, especially in the increased proportion of multiple and premature births. Along with such an increase, the proportion of VLBW infants will also increase in China. For this reason, it is still necessary to increase the number of NICU beds for the sake of reducing the death rate.

There is also a close correlation between the number of neonatal pediatricians and the NMR [1, 31]. An investigation from the USA [1] shows that the NMR in areas with 4.3 neonatal experts per 10,000 births is lower than that in areas with 2.7 neonatal experts per 10,000 births (OR 0.93 95% CI 0.88-0.99) after adjustment for factors from the newborns and mothers. In our study, we found 17.63 neonatal pediatricians per 10,000 new births in China. This figure is by far larger than that of South Korea, the USA and other developed countries [1, 29]. Our study also found that the NMR in provinces with more neonatal pediatricians is relatively low. However, we found that the so-called neonatal pediatricians in China are actually pediatricians who are working in the neonatal wards, not neonotologists in those developed countries, mainly because China has not established a perfect neonotologists training system so far. About 8.2% neonatal pediatricians only had three-year college educational backgrounds. Even so, the shortage of neonatal pediatricians in China is not so serious as imagined purely in terms of quantity, which is inconsistent with previous reports on the shortage of pediatricians in China [32-33]. A nationwide survey on pediatricians in China made in 2019 [34] shows that there is only 0.4 pediatrician per 1,000 children, which is by far lower than 0.93 in Japan [35] and 1.9 in the USA [2]. In addition, our survey showed that the 27,698 neonatal pediatricians were concentrated in 3,020 hospitals, most of which are L2 and L3 hospitals. This finding also indicates that neonatal pediatricians are more concentrated in higher-level hospitals, and the occupation of neonatology may be more attractive than general pediatrics. It was found in our study that the educational background of neonatal pediatricians is also significantly higher than general pediatricians in China. More than 90% neonatal pediatricians had an educational background of Bachelor degree or higher ranks, about 20% were postgraduates, and about 33% general pediatricians only had three-year college educational backgrounds [34]. According to the national standards established in 2018[36], one neonatal pediatrician is required for every two NICU beds, and one neonatal pediatrician is required for every five general neonatal beds. China needs 23,597 neonatal pediatricians vs. 27,698 at present, which is already a surplus. In the past two years, China’s birth population has shown a significant decline, and therefore China should pay more attention to improving the training quality of neonotologists, rather than the number of them.

The regional differences in NCR distribution are closely correlated with the NMR [27]. Although the NMR has decreased astonishingly over the past 30 years in China, regional differences still exist. The NMR is 3.88 in West China in 2018, which is 1.9 fold that in East China. The NMR is the highest in Tibet, reaching 7.12‰ vs. 1.16‰ in Zhejiang of East China. It is very important to find out the causes underlying such differences. It was found in our study that there were significant regional differences in medical resource density, which is known to be closely related to the NMR. West China covers a vast area, where the area per capita is by far larger than that of Central and East China. The result of HRDI model analysis showed that both the number and newborn beds and the number of neonatal pediatricians lag far behind. In addition, analysis of the educational structure also showed that the neonatal pediatrician training in West China also lags far behind that in Central and East China. The number of neonatal pediatricians with Master or higher degrees in East and Central China is 3- and 2-fold that in West China respectively, suggesting that increasing the investment in health resources in West China and intensifying neonatal pedi-

| Region | East | Central | West |
|--------|------|---------|------|
| L2     | 40   | 71      | 48   |
| L3     | 293  | 401     | 293  |
| Total  | 333  | 472     | 341  |

Table 3: Technical development of neonatal care in different areas.
Table 4
Characteristics of Neonatal Pediatricians and Hospitals with Newborn Care Services in China.

| Region | Hospitals, n (%) | General Hospitals | Children's Hospitals | Public | L1 | L2 | L3 | Private | L1 | L2 | L3 | Public | L1 | L2 | L3 | Private | L1 | L2 | L3 | Total | L1 | L2 | L3 |
|--------|------------------|-------------------|----------------------|--------|----|----|----|---------|----|----|----|---------|----|----|----|---------|----|----|----|-------|----|----|----|
| Eastern| 39.4 (1157) 34.0 (257) 36.1 (83) | 15 (7.0) 40 (27.2) 16 (38.8) | 19 (16.4) 6 (10.9) 2 (16.7) 5 (41.7) | 5 (41.7) 151 (36.8) 126 (22.4) | 0 (0) 7 (7.0) 3 (30.0) | 1065 (38.3) 1534 (55.1) | 185 (6.6) | 118 (9.5) 23 (9.7) |
| Central | 34.4 (1157) 30.9 (154) 32.8 (83) | 60 (27.2) 25 (13.5) 22 (40.2) | 23.5 (33.2) 33.3 (16.7) 50.0 (20.0) | 20.0 (20.0) 22.5 (14.3) 24.7 (14.3) | 14.3 (14.3) 0.0 (0.0) 5.0 (5.0) | 1189 (37.2) 1189 (37.2) | 544 (18.3) | 524 (17.3) 32 (11.3) |
| Western | 26.2 (257) 19.1 (154) 16.9 (83) | 0.0 (0.0) 16.9 (13.5) 33.3 (16.7) | 50.0 (20.0) 20.0 (20.0) 80.0 (40.0) | 22.5 (14.3) 24.7 (14.3) 14.3 (14.3) | 14.3 (14.3) 5.0 (5.0) 25.6 (25.6) | 1195 (37.2) 1195 (37.2) | 449 (15.3) | 449 (15.3) 449 (15.3) |
| Neonatal Pediatricians, n (%) | 22.3 (257) 15.9 (154) 15.9 (83) | 82.9 (44.4) 1195 (5.8) 29 (22.7) | 88.0 (31.5) 1195 (38.3) 47.8 (13.8) | 65.5 (36.5) 44.7 (14.7) 5.4 (5.4) | 44.7 (14.7) 44.7 (14.7) 44.7 (14.7) | 1195 (37.2) 1195 (37.2) | 449 (15.3) | 449 (15.3) 449 (15.3) |

*Note:* The table provides a detailed breakdown of the number of pediatricians, hospitals, and hospital beds in different regions of China, categorized by public and private sectors. The data includes the proportion of hospitals and pediatricians in each category, as well as specific numbers for general hospitals, children's hospitals, and neonatal intensive care units (NICUs). The table also mentions the percentage of neonatal pediatricians within the regional population.
training to improve their occupational abilities are the key to reducing the NMR in future.

In addition to education and training, the technological development of neonatal care in root-level hospitals in West China also lags behind that in East and Central China. Although there are not significant differences in this respect between L-3 and L2 hospitals in West, East and Central China, the differences are significantly large between L-1 hospitals in West China and those in Central and East China, not only due to the small number of L-1 hospitals that have the capability and technical proficiency to undertake neonatal care services in West China. As West China covers a vast area with a sparse population, which brings about much difficulty with transport and referral, it is primarily important to emphasize the neonatal care construction of L-1 hospitals in West China, especially in primary care of newborns. Now China is undertaking a program of constructing neonatal critical care centers at provincial, city and county levels [36], and the main task of this program is to strengthen the neonatal care abilities of the root-level hospitals and establish referral networks between different levels of hospitals, which will certainly upgrade the level of neonatal care of the root-level hospitals, especially those in West China.

This is a cross-sectional nationwide survey in China. Although we have spent a lot of time and resources, there are still some unavoidable limitations. First, as this is a mandatory government survey and implemented through neonatal experts in the provinces, cities and counties involved, it was possible to have missed individual hospitals. In addition, although the questionnaire forms were filled out by the directors of the pediatrics or neonatology departments of the hospitals involved, some data may not be accurate enough due to various reasons. Finally, the NMR data provided by the provinces, cities and autonomous regions involved were based on the death rate of the registered population. But as China has a very large mobile population, it is very difficult to provide a very accurate statistical NMR. We also found that the statistical NMR in East, Central and West China obtained in this study are lower than the national death rate. Nevertheless, the data obtained in this study are of great significance in upgrading the level of neonatal care in China with a population of 1.4 billion, despite the above-mentioned limitations.

In summary, China has made substantial progress in the development of NCR and at the technical level, but regional differences remain remarkable. The future work should lay emphasis on the investment of health resources in underdeveloped areas in West China, raise the NCR density, and improve the neonatal care abilities of the root-level hospitals by raising the educational level of the neonatal pediatricians and intensifying their professional and technical training, which are the crux to further reduce the overall NMR in China.

Contributors
ZF, YS, QL conceptualized and designed this study. QZ, YZ, YS, Lg L, XC, BY, JM, CC, SH, Li I, LZ, XL, ZL, JZ, XC, SX, YL, SY, CY, XM L, ZW, JT, YW, DZ, LM, YC, ML, HM, KL, LY, XW, HW were responsible for training the data collectors, and collecting and treating the data. QL and Xg L were responsible for analyzing the data and preparing the first draft of the manuscript. All authors were involved in data interpretation and review of the final manuscript.

Declaration of Competing Interest
None declared.

Acknowledgements
This study was founded by National Natural Science Foundation of China (81671504) and United Nations International Children’s Emergency Fund (CHINA-UNICEF501MCH). We also thank Mr. Jintao Liu (Mabwell Bioscience Co., Ltd.) for his kind help in statistical analysis.

Supplementary materials
Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lanwpc.2021.100212.

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