

BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open

The analysis for the neonatal mortality and leading causes of deaths in China from 2014 to 2018

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042654
Article Type:	Original research
Date Submitted by the Author:	04-Aug-2020
Complete List of Authors:	<p>Liu, Yuxi; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Kang, Leni; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China He, Chunhua; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Miao, Lei; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Qiu, Xiaoqiong; Pidu district people's hospital, Chengdu, Sichuan Xia, Weipeng; Second People's Hospital of Zhaotong, Zhaotong, Yunnan, Department of Pediatrics Zhu, Jun; Sichuan University West China Second University Hospital, Key Laboratory of Birth Defects and Related Diseases of Women and Children of the Ministry of Education, West China Second University Hospital, Sichuan University, Chengdu, China; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Liang, Juan; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Li, Qi; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Wang, Yanping; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Liu, Min; Sichuan University West China Second University Hospital, Department of Pediatrics</p>
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, NEONATOLOGY

SCHOLARONE™
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3
4 **The analysis for the neonatal mortality and leading causes of deaths in China from**
5
6 **2014 to 2018**
7
8
9

10
11
12
13
14 Yuxi Liu, MIPH, MHM^a; Leni Kang, PhD^a; Chunhua He, MD^a; Lei Miao, MD^a; Xiaoqiong
15
16 Qiu, MD^d; Weipeng Xia, MD^e; Jun Zhu, MD^{a,c}; Juan Liang, MD^a; Qi Li, MD^a; Yanping
17
18 Wang, MD^{a,▲}; Hanmin Liu, PhD^{b,c,▲}.
19
20
21

22
23
24
25 ^a National Office for Maternal and Child Health Surveillance of China, West China Second
26
27 University Hospital, Sichuan University, Chengdu, Sichuan, China
28

29
30 ^b Department of Pediatrics, West China Second University Hospital, Sichuan University,
31
32 Chengdu, China
33

34
35 ^c Key Laboratory of Birth Defects and Related Diseases of Women and Children of the
36
37 Ministry of Education, West China Second University Hospital, Sichuan University,
38
39 Chengdu, China
40
41

42
43 ^d Pidu district people's hospital, Chengdu, Sichuan, China
44

45
46 ^e Department of Pediatrics, Second People's Hospital of Zhaotong, Zhaotong, Yunnan,
47
48 China
49

50
51
52
53
54
55
56 ▲ These authors contributed equally to this work.

1
2
3
4
5
6
7 **Corresponding authors:** Yanping Wang, National Office for Maternal and Child Health
8
9 Surveillance of China, West China Second University Hospital, Sichuan University,
10
11 Chengdu, Sichuan, China, email: wyxianping@163.com; and Hanmin Liu; Department of
12
13 Pediatrics, West China Second University Hospital, Sichuan University, Chengdu, China,
14
15 email: hanmin@vip.163.com
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract

Objective: The present study estimated the national and urban-rural levels and causes of neonatal deaths in China annually between 2014 and 2018 to provide data support for the further end of preventable neonatal deaths for China and other low-and middle-income countries.

Methods: The study was based on data from the National Maternal and Child Health Surveillance System (NMCHSS). All neonates of surveillance districts (gestational week ≥ 28 weeks) who died after delivery have been involved in the study. The mortality rate and the leading causes of death for neonates were analyzed.

Results: The NMR of China has steadily decreased from 5.9 deaths per 1000 live births in 2014 to 3.9 deaths per 1000 live births in 2018. The NMR in 2018 of urban and rural areas was 2.2 deaths per 1000 live births and 4.7 deaths per 1000 live births, respectively. The leading preventable death causes of neonatal deaths in 2018 were preterm birth (106.6 deaths per 100,000 live births), intrapartum complications (84.6 deaths per 100,000 live births), and pneumonia (35.0 deaths per 100,000 live births). Mortality rates of these three causes fell significantly between 2014 and 2018, but contributed to a higher proportion of deaths in rural areas than urban areas. The proportion of preventable deaths accounted for 73.9% in 2018.

Conclusions: The NMR of China has decreased steadily from 2014 to 2018. However, the inequality between urban and rural areas still exists. The goal of government interventions

1
2
3
4 should be to reduce the health inequality of neonates and further take targeted measures to
5
6 eliminate the preventable neonatal death.
7
8

9
10 **Keywords:** neonatal mortality, leading cause, Surveillance, inequality, China
11
12

13 14 15 **Strengths and limitations of this study** 16

- 17
18 • The study covers the most geographically extensive newborn population in mainland
19
20 China, the data are from 334 National Maternal and Child Health Surveillance Districts.
21
22
 - 23
24 • The study provides describes the status of neonatal deaths in China from 2014 to 2018.
25
26
 - 27
28 • The study has not covered pre-natal assessment due to system design limitation.
29
30
- 31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Introduction

In 2015, the United Nations (UN) summit on sustainable development formally adopted the 2030 agenda for sustainable development. The UN has proposed 17 sustainable development goals (SDG) from three key economic, social, and environmental dimensions.

In SDG3, the goal is to end preventable neonatal and under-five children deaths by 2030^[1], with all countries aiming to reduce neonatal mortality to at least as low as 12 deaths per 1,000 live births and under-five mortality to at least as low as 25 deaths per 1,000 live births. The importance of newborn health issues has received global attention. The Chinese government has always attached great importance to the survival, protection, and development of children, and has made great achievements in reducing child mortality.

The MDG4 (Millennium Development Goal 4) was achieved eight years ahead of schedule in 2007^[2-7], and it is also rated by the World Health Organization as a country with "high performance in maternal and child health". In 2018, the mortality rate of children under five (U5MR) in China was 8.4‰, which was lower than 25 per 1000 live births by 2030^[8].

The biggest challenge for China in the face of the SDGs is to eliminate preventable neonatal and children under 5 deaths. This study will analyze neonatal mortality trends and its mortality of major causes of death in China from 2014 to 2018 to provide data support for the further elimination of key preventable diseases that can cause neonatal deaths.

Materials and Methods

Study subjects

The study covered all the 334 districts of National Maternal and Child Health Surveillance Districts (with 124 urban districts and 210 rural districts) in 31 provinces, autonomous regions, and municipalities of China. Further details about the National Maternal and Child Health Surveillance System (NMCHSS) have been described elsewhere^[9].

All neonates of surveillance districts (gestational week ≥ 28 weeks) who died after delivery, and had one of the four vital signs would be involved in surveillance subject, including heartbeat, breath, umbilical cord pulsation, and voluntary muscle contraction. The surveillance subject also includes adoption children and children of non-local household residents whose mothers have living in the surveillance districts for more than one year.

Data collection and quality control

After each child died in the surveillance districts, the local village doctor (or community doctor) needs to report to the local township health centers (or community health service centers) within 10 days. Local township health centers (or community health service centers) need to be verified within 7 days after reporting and fill the Child Death Report Card based on the hospital's death diagnosis. If the child died at home or on the way to the health facilities, infer the cause of death would base on 2016 WHO Verbal Autopsy

1
2
3
4 Standards^[10] and then fill the Child Death Report Card. The classification of diseases
5
6 according to the international classification of diseases-10 (ICD-10).
7
8
9

10
11
12
13 The children's mortality data was reported level by level, and the data is timely reported
14
15 through the network direct reporting system. Technical personnel responsible for
16
17 monitoring work are set up at all levels to complete the collection, review, and operation
18
19 of surveillance data. The completed child death data would send to the county (or district)
20
21 level maternal and child health institutions each season. The county (or district) level
22
23 maternal and child health institutions would report the local child deaths status to
24
25 prefecture-level and province-level maternal and child health institutions each season, the
26
27 National Office of Maternal and Child Health would summarize and analyzes the data
28
29 finally.
30
31
32
33
34
35
36
37
38
39

40 For quality control, we have used the regular level-by-level on-site quality control system.
41
42 At the county (district), city, and provincial levels, following the requirements of the
43
44 Chinese Maternal and Child Health Surveillance Work Manual, a multi-source data cross-
45
46 check method is used to complete the on-site quality control work in sampling surveillance
47
48 districts. The National Office of Maternal and Child Health will select 18 districts in 6
49
50 provinces each year for quality inspection^[9,11].
51
52
53
54
55
56

Statistical analysis

Results were collected in Microsoft Excel and analyzed using SPSS 22.0 (IBM, Armonk, NY, USA). The neonatal mortality rates (NMR) of different regions and the main cause-specific mortality rates were corrected using the average underreporting rate of the national-level surveillance data quality checks in the past three years. The national NMR and the main cause-specific mortality rate were weighted calculated according to the proportion of the urban and rural population in the census. The diagnostic level composition ratio of the neonate is calculated based on the reported Child Death Report Card, excluding children who died of accidental injuries^[11].

The Poisson regression model was used to calculate the average annual rate of decline of NMR, cause-of-death mortality, and its 95% confidence interval in the country, urban and rural areas, respectively. Linear by the linear association in the chi-square test using SPSS software was used to test whether there was a linear downward trend in different regions and causes of death.

Ethics approval and consent to participate

1
2
3
4 This study was approved by the Ethics Committee of West China Second University
5
6 Hospital, Sichuan University, China.
7
8
9
10
11
12

13 *Patient and public involvement*

14
15
16 Patients and members of the public were not involved in the design of this study.
17
18
19
20
21
22

23 *Data Availability Statement*

24
25
26 This study used data from the NMCHSS. This system is co-established by the National
27
28 Health and Family Planning Commission of the People Republic of China and Sichuan
29
30 University, and finally owned by National Health and Family Planning Commission of the
31
32 People Republic of China. The researchers did not obtain consent to publicly share data.
33
34
35
36 The de-identified data set is available upon request to interested researchers. For data
37
38 requests, please contact the Department of Science and Technology of West China Second
39
40 University Hospital, Sichuan University, at:fu2yuankjb@163.com. This department is in
41
42 charge of all the programs in the hospital, including the data management. One staff from
43
44
45
46 the department (named Xian He) monitors this email.
47
48
49
50
51
52

53 **Result**

1. *The NMR of China from 2014 to 2018*

At the national level, the NMR of China has steadily decreased from 5.9 deaths per 1000 live births in 2014 to 3.9 deaths per 1000 live births in 2018 ($p<0.001$), the average annual rate of decline was 10.7%. The NMR of urban and rural areas have both showed a declining trend in the same period ($p<0.001$). The mortality rate of urban areas decreased from 3.5 deaths per 1000 live births to 2.2 deaths per 1000 live births, with the average annual rate of decline was 13.0%. In rural areas, the NMR decreased significantly from 2014 to 2018 (6.9 deaths per 1000 live births to 4.7 deaths per 1000 live births, the average annual rate of decline was 10.6%, $p<0.001$). The absolute difference between NMR of urban and rural areas has reduced from 3.4 deaths per 1000 live births to 2.5 deaths per 1000 live births, but the relative difference has increased from 2.0 to 2.2. (See **Figure 1**)

2. *Cause of neonates mortality in China from 2014 to 2018*

Nationwide, compared with 2014, the neonatal deaths caused due to preterm birth, intrapartum complication, and pneumonia in 2018 have sharply decreased. Among the particular diseases, the intrapartum complications have the highest average annual decline rate (AADR) from 2014 to 2018 (with 13.5%, $p<0.001$). The smallest AADR belonged to Tetanus (with 0.8%, $p<0.05$). In any given year, preterm birth, intrapartum complication, and pneumonia were the top three leading causes of neonatal death in China, total

accounting for nearly 60%. (See **Table 1**) In 2018, all deaths causes have been divided into preventable diseases and unpreventable diseases to analyses the proportion. The proportion of preventable diseases reached 73.9%. Moreover, the top three diseases at the national level were preterm birth, intrapartum complications, and congenital malformations. (See **Figure 2A**)

Table 1. Leading causes of death in neonates in China from 2014 to 2018

Causes of death	Cause-specific mortality (per 100,000 livebirths)							Proportion (%)				
	2014	2015	2016	2017	2018	Average annual decline rate (%)	P value	2014	2015	2016	2017	2018
National wide												
Preterm birth	170.7	167.2	139.8	144.4	106.6	9.7 (7.4, 11.9)	<0.001	29.1	30.8	28.7	32.2	27.3
Intrapartum complications	141.7	138.5	103.9	92.5	84.6	13.5 (11.0, 15.9)	<0.001	24.2	25.5	21.4	20.6	21.7
Pneumonia	66.1	46.7	55.7	49.1	35.0	11.0 (7.1, 14.7)	<0.001	11.3	8.6	11.4	11.1	9.9
Diarrhea	2.2	2.8	1.4	0.2	1.7	20.1 (-2.0, 37.4)	>0.05	0.4	0.5	0.3	0.0	0.4
Tetanus	0.8	0	0	0	0	N/A	<0.05	0.1	0	0	0	0
HIV	0	0	0	0	0	N/A		0	0	0	0	0
Neonatal sepsis/meningitis	14.5	14.3	19.3	15	19.6	-6.5 (-14.7, 1.2)	>0.05	2.5	2.6	4	3.3	5
Other infectious diseases	1.8	1.1	1.4	0.9	0	33.1 (7.9, 51.4)	<0.05	0.3	0.2	0.3	0.2	0
Congenital malformations	101.7	82.3	91.9	82.8	78.5	5.1 (2.0, 8.1)	<0.01	17.4	15.2	18.9	18.5	20.2
Other diseases	86.1	90	73	63.4	63.8	9.2 (5.9, 12.3)	<0.001	14.7	16.6	15	14.2	16.4
Urban area												
Preterm birth	111.2	92.9	74.5	84.3	63.3	11.4 (7.1, 15.5)	<0.001	31.4	28.6	25.5	31.8	28.8

Intrapartum complications	92	80.2	63.6	61.4	41.2	16.4 (11.8, 20.7)	<0.001	25.9	24.6	21.8	23.2	18.7
Pneumonia	28.8	26.1	34.9	22.9	13.5	12.4 (4.5, 19.7)	<0.01	8.1	8	12	8.6	6.1
Diarrhea	0.6	0.7	0	0.5	0.6	2.7 (-96.6, 51.8)	>0.05	0.2	0.2	0	0.2	0.3
Tetanus	0	0	0	0	0	N/A	N/A	0	0	0	0	0
HIV	0	0	0	0	0	N/A	N/A	0	0	0	0	0
Neonatal sepsis/meningitis	10.2	12.7	16.6	17.5	20.9	2.7 (-96.6, 51.8)	<0.01	2.9	3.9	5.7	6.6	9.5
Other infectious diseases	1.9	2	1.7	1.5	0	25.2 (-7.7, 48.1)	>0.05	0.5	0.6	0.6	0.5	0
Congenital malformations	72.9	64.2	57.3	46.3	41.2	13.6 (8.4, 18.5)	<0.001	20.5	19.7	19.6	17.5	18.7
Other diseases	37.1	46.8	43.5	30.7	39.3	3.2 (-3.7, 9.7)	>0.05	10.5	14.4	14.9	11.6	17.9
Rural area												
Preterm birth	197.2	200.3	168.9	171.3	125.9	9.2 (6.3, 12.1)	<0.001	28.6	31.3	29.5	32.3	27
Intrapartum complications	163.8	164.5	121.9	106.5	104	12.8 (9.5, 15.9)	<0.001	23.8	25.7	21.3	20.1	22.3
Pneumonia	82.8	55.9	64.9	60.8	44.7	10.8 (5.9, 15.5)	<0.001	12	8.7	11.3	11.5	9.6
Diarrhea	2.9	3.8	2	0	2.2	25.5 (-0.3, 44.6)	<0.05	0.4	0.6	0.3	0	0.5
Tetanus	1.2	0	0	0	0	N/A	<0.05	0.2	0	0	0	0
HIV	0	0	0	0	0	N/A	N/A	0	0	0	0	0
Neonatal sepsis/meningitis	16.4	15.1	20.5	13.9	19	-2.3 (-13.2, 7.7)	>0.05	2.4	2.4	3.6	2.6	4.1
Other infectious diseases	1.8	0.6	1.3	0.7	0	29.7 (-13.7, 56.6)	>0.05	0.3	0.1	0.2	0.1	0
Congenital malformations	114.5	90.4	107.3	99.2	95.2	3.0 (-1.2, 6.9)	>0.05	16.6	14.1	18.7	18.7	20.4
Other diseases	108	109.3	86.1	78	74.7	10.3 (6.3, 14.2)	<0.001	15.7	17.1	15	14.7	16.1

The death cause distribution and AADR were also significantly different among regions.

1
2
3
4 In urban areas, preterm birth, intrapartum complication, and congenital anomalies also
5
6 accounting the largest proportion of all deaths cause from 2014 to 2018. Moreover, the
7
8 AADR of preterm birth, intrapartum complications, pneumonia, and congenital
9
10 malformations in urban areas were all larger than that of the national level. In rural areas,
11
12 the mortality rate of preterm birth, intrapartum complication, and congenital anomalies
13
14 significantly decreased. Additionally, the NMR of diarrhea have sharply decreased, with
15
16 AADR was 25.5% ($p < 0.001$). (See **Table 1**)
17
18
19
20
21
22

23 In contrast, the urban-rural gap still existed. The contribution of tetanus among neonates in
24
25 urban areas remains zero during the study period, while the rate in rural areas has
26
27 eliminated until 2015. (See Table 1) In the disease proportion aspect, the proportion of
28
29 intrapartum complications and pneumonia in rural areas significantly higher than that of
30
31 urban areas. (See Figure 2B&C) According to the data analysis, causes of neonatal death
32
33 varied between urban and rural areas ($P < 0.05$), but the correlation between neonatal
34
35 mortality and whether the newborn lived in urban or rural areas was weak (Cramer's
36
37 $V = 0.129$).
38
39
40
41
42
43
44
45
46

47 *3. Neonate Diagnosis Facilities Level in China between 2014 and 2018*

48
49

50 The children's diagnosis facilities level has also be included in surveillance. Nationwide,
51
52 from 2014 to 2018, the proportion of neonate diagnosis at the provincial (or municipal)
53
54 level health facilities has significantly increased, and the proportion of the district (or
55
56
57
58
59
60

1
2
3
4 county) level has decreased. Moreover, the proportion of township level and village level
5
6 have both fluctuating declined during this period. In 2018, the proportion of neonate who
7
8 has not to seek any medical care has minimized, which declined to 3.9% in 2018. (See
9
10
11 **Figure 3**)

12
13
14
15
16
17
18 In an urban aspect, from 2014 to 2018, the majority of children (accounted for over 80%)
19
20 in urban areas have been diagnosed at provincial (or municipal) level medical facilities.
21
22 The proportion of the district (or county) level and township -level both have a slight rise
23
24 between 2014 and 2018. As a result, the percentage of children who have not to seek
25
26 medical has declined, with 1.9% in 2014 and 1.1% in 2018. (See **Figure 3**)
27
28
29
30

31
32
33
34
35 On the contract, the diagnosis contribution figure of rural areas was different. Although the
36
37 proportion of provincial (or municipal) level have shown growth trend from 2014 to 2018,
38
39 the proportion in rural areas have only half of that in urban areas. Moreover, the proportion
40
41 of street-level diagnoses in the urban area is reduced to 1.4% in 2018, while this proportion
42
43 in rural areas fluctuated and remained at 3.7% in the same year. Another significant
44
45 contributor is the proportion of children who have not sought medical care. The proportion
46
47 of neonate who has not to seek medical care has decreased, and still, 5.5% of children have
48
49 not sought any medical advice. (See **Figure 3**)
50
51
52
53
54
55
56
57
58
59
60

Discussion

Globally, there were 5.3 million deaths occurred on children under 5 in 2018, 47% of them died during their first month of life. The vast majority of neonatal deaths occur in low - and middle-income countries. Approximately 73,000 neonates died in China in 2018, accounting for about 3.0% of the total newborn deaths worldwide, ranking sixth in the world^[12]. Moreover, the global decline in neonatal mortality rate (NMR) has been slower than the decline in the under-five mortality rate (U5MR)^[6]. Global U5MR declined from 93 per 1,000 live births in 1990 to 39 per 1,000 live births in 2018, while that of NMR only declined from 37 per 1,000 live births to 18 per 1,000 live births during the same time period. Additionally, a great many studies have shown that neonatal deaths amounting a large proportion of total mortality of children under 5^[13-15]. Furthermore, SDGs (Sustainable Development Goals) have targeted specifically for reducing neonatal mortality and eliminating preventable child deaths in 2015^[1].

The results of this study show that the NMR in urban and rural areas of China have decreased significantly between 2014 and 2018. According to the NMR data from World Bank in 2018^[14], although Chinese NMR (3.9 deaths per 1000 live births in 2018) is at a low level in developing countries (such as the NMR in Brazil was 8.1 deaths per 1000 live births, and Thailand was 5.0 deaths per 1000 live births), it still lags behind that in

1
2
3
4 developed countries (such as the NMR in Australia was 2.3 deaths per 1000 live births, and
5
6 Germany was 2.2 deaths per 1000 live births). In order to further shorten the gap with
7
8 developed countries, there is still room for improvement in neonatal deaths in China. In
9
10 addition, there were significant differences in NMR between urban and rural areas, which
11
12 were consistent with significant differences in NMR between countries and regions
13
14 globally^[16,17].
15
16
17
18
19
20
21
22

23 From 2014 to 2018, Chinese NMR continued to decline, and it was dropped quickly. This
24
25 is closely related to the rapid growth of China's economy^[18], the continuous improvement
26
27 of transportation, and the improvement of the educational level of women at reproductive
28
29 age^[19]. Moreover, it also benefits from the improvement of medical treatment at all levels
30
31 of health facilities, and all levels of government attached great importance to strengthen
32
33 the construction of the pediatric institution, raise pediatricians' payment, and continue to
34
35 implement neonatal asphyxia recovery training program^[20]. As a result, neonatal deaths
36
37 from pneumonia and infectious diseases, intrapartum complications, and premature
38
39 delivery were significantly reduced.
40
41
42
43
44
45
46
47
48
49

50 China has implemented the Safe Maternal Initiative and the National Program to Reduce
51
52 Maternal Mortality and Eliminate Tetanus, China has officially eliminated neonatal tetanus
53
54 in 2012^[21], and from 2015 to 2018, the NMR of neonatal tetanus remained 0. Moreover,
55
56
57
58
59
60

1
2
3
4 through the success of the Prevention of Mother-to-child Transmission of HIV, Syphilis,
5
6 and Hepatitis B Program, the HIV/AIDS mortality rate has also been 0 from 2014 to
7
8 2018^[22,23]. In 2018 the national neonatal mortality, although already less than 12 deaths per
9
10 1000 live births, but the preventable deaths still accounted for 73.9%. Among those
11
12 preventable diseases, mainly pneumonia, intrapartum complication, premature birth.
13
14 Among these diseases, the proportion of preterm birth was highest in both nationwide,
15
16 urban areas, and rural areas. In the recent two decades, the prevalence of preterm birth has
17
18 significantly increased^[9], especially after the Two-child Policy^[24] was implemented In
19
20 China. The mortality rate among preterm birth infants was apparently higher than the full-
21
22 term infant, and the risk of mortality increases proportionally with decreasing gestational
23
24 age^[25]. Furthermore, with the widespread development of assisted reproductive technique
25
26 (ART), the incidence of monozygotic twins has increased significantly^[26]. The risk of
27
28 premature birth is significantly higher in ART infants than in infants conceived naturally^[27],
29
30 and the NMR of twins is several times higher than that of singletons^[28].

31
32
33
34
35
36
37
38
39
40
41
42
43
44 Addressing the issue of preterm birth may require different priorities in rural and urban
45
46 areas. Because of the good management of many curable neonatal complications (such as
47
48 pneumonia), the proportion of preterm birth in urban areas is obviously larger than that of
49
50 rural areas^[29]. Hence, for urban areas, it is suggested that urban areas need to pay more
51
52 attention to the prevention of the death of premature infants less than 32 weeks age. For
53
54
55
56

1
2
3
4 rural areas, the local government needs to focus on the prevention of premature infants at
5
6 32-36 weeks and continue to invest in medical services to improve medical services
7
8 accessibility for women and children in rural areas.
9

10
11
12
13
14
15 In addition, the neonatal mortality rate of preterm birth, intrapartum complication, and
16
17 pneumonia in rural areas were over doubled than urban areas. Hence, the government
18
19 needs to implement the interventions in preterm birth, intrapartum complications, and root,
20
21 especially in rural areas.
22
23
24
25
26
27
28

29 For neonates, surviving from preterm birth, intrapartum complication and pneumonia are
30
31 close linking to accessibility to health care, local hospitals' obstetrics and neonates
32
33 departments' treatment level, and rescue skills^[30,31]. Therefore, the issue can be addressed
34
35 from the following four aspects.
36
37
38
39
40
41
42
43

44 Firstly, the local governments need to strengthen the construction of RNTN (Regional
45
46 Neonatal Transport Network), carry out the transport plan according to the Guidelines for
47
48 the Construction and Management of Critical Neonatal Treatment Center^[32], and ensure
49
50 the applying of professional medical staff and newborn rescue equipment for neonatal
51
52 transport. Secondly, one study in Japan has pointed out that the medical care resources
53
54
55
56
57
58
59
60

1
2
3
4 (including Neonatal Intensive Care Unit (NICU), midwives, emergency physicians, and
5
6 emergency medical care centers) would impact on the NMR decline^[33]. Therefore, the local
7
8 governments may base on the Administration guide (proposal) of the Neonatal Physician
9
10 Branch of the Chinese Physician Association^[34] to grading neonatal wards, and
11
12 establishing NICU after analyses local medical establishment plan and newborn medical
13
14 treatment needs. Thirdly, local health departments can regularly organize multi-level ,
15
16 especially provincial, prefecture-level and district-level) newborn health training programs.
17
18 In rural areas, with the policies support of the New Rural Construction and the Targeted
19
20 Poverty Alleviation^[35,36], the improved rural transport and higher incomes have prompted
21
22 the enhanced accessibility of health services in rural areas, and the proportion of rural
23
24 children receiving medical treatment in provincial and municipal hospitals has significantly
25
26 increased. The proportion of rural neonate diagnosis at the provincial (or municipal) level
27
28 health facilities has significantly increased from 39.2% to 47.6% from 2014 to 2018. Set
29
30 training objectives for medical staff in health facilities of different levels, and strengthen
31
32 the newborn treatment technology in each level of health facilities. Especially for the health
33
34 workers in rural areas, the newborn resuscitation training needs to be specifically
35
36 strengthened. Fourthly, the local communities can strengthen publicity to encourage
37
38 caregivers to take children to attend to the health facilities for treatment. As for poor
39
40 households, local governments can set up special subsidies for them to reduce the economic
41
42 cost of medical treatment.
43
44
45
46
47
48
49
50
51
52
53
54

Conclusion

With the joint efforts of the economic development and the governmental policies and strategies, the neonatal mortality rate of China has significantly decreased from 2014 to 2018. The gap between neonatal mortality and cause-of-death distribution still existed between urban and rural areas. The goal of government interventions should be to narrow the urban-rural gap, reduce the health inequality of neonates, and further take targeted measures to eliminate the preventable death of neonates, especially premature births, so as to achieve the SDGs goal.

Acknowledgments

We thank the institutions and staff of the National Maternal and Child Health Surveillance System for data collection, data provided, and case investigation.

Funding

This study was supported by the Ministry of Health, China (grants QT2003-009 and 05wsb-02) and UNICEF (grant YH601-11-1141).

Author contributions

Data analysis: Yuxi Liu

1
2
3
4 Methodology: Hanmin Liu and Yanping Wang, Leni Kang
5

6 Data curation: Jun Zhu, Juan Liang, Lei Miao, Xiaoqiong Qiu, Weipeng Xia
7

8
9 Software: Chunhua He, Leni Kang and Qi Li
10

11 Writing – original draft: Yuxi Liu
12

13
14 Writing – review, and editing: Yuxi Liu, Hanmin Liu, and Yanping Wang
15
16
17
18

19 **Conflicts of interest**

20
21
22 The authors declare no conflicts of interest.
23
24
25
26
27

28 **References**

29
30
31 [1] UN (2015). Sustainable Development Goals.
32

33
34 <https://sustainabledevelopment.un.org/?menu=1300>. Accessed 12th Mar 2020.
35

36 [2] National Working Committee on Children and Women under State Council.
37

38 National Program for Women and Child Development.
39

40
41 http://www.nwccw.gov.cn/node_2427.htm. Accessed 12th Mar 2020.
42
43

44 [3] UN (2000). Millennium Development Goal.
45

46
47 <http://www.un.org/zh/millenniumgoals/getinvolved.shtml>. Accessed 12th Mar
48

49 2020.
50

51
52 [4] Wang Y, Li X, Zhou M, et al. Under-5 mortality in 2851 Chinese counties, 1996-
53

54 2012: a subnational assessment of achieving MDG 4 goals in China. Lancet.
55
56

- 2016;387(10015):273-283.
- [5] National Bureau of Statistics of China (2016). China statistical yearbook 2016. <http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm>. Accessed 12th Mar 2020.
- [6] Ministry of Foreign Affairs of China & UN China (2015). Report on China's Implementation of the Millennium Development Goals (2000-2015). http://cn.chinagate.cn/reports/2015-07/28/content_36164105.htm. Accessed 12th Mar 2020.
- [7] Kuruvilla S, Schweitzer J, Bishai D, et al. Success factors for reducing maternal and child mortality. Bull World Health Organ. 2014;92(7):533-544b.
- [8] The development of China's Health Care and inhabitant's health status (2018) China Public Health Statistical Yearbook 2018. Peking Union Medical College Publishing House.
- [9] Lu R, Li X, Guo S, et al. Neonatal mortality in the urban and rural China between 1996 and 2013: a retrospective study. Pediatr Res. 2016;79(5):689-696.
- [10] Nichols EK, Byass P, Chandramohan D, et al. The WHO 2016 verbal autopsy instrument: An international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. PLoS Med. 2018;15(1):e1002486.
- [11] He C, Liu L, Chu Y, et al. National and subnational all-cause and cause-specific child mortality in China, 1996-2015: a systematic analysis with implications for the Sustainable Development Goals. Lancet Glob Health. 2017;5(2):e186-e197.
- [12] WHO, UNICEF, UN & World Bank Group (2019). Levels & Trends in Child

- 1
2
3
4 Mortality-Report 2019.
5
6
7 [13] Zhang. CL. (2015) Analysis of surveillance results of 4074 children under 5 years
8
9 old. Maternal and Child Health Care of China.30:5095-5098.
10
11
12 [14] WHO (2019). Newborns: reducing mortality. [https://www.who.int/news-](https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality)
13
14 [room/fact-sheets/detail/newborns-reducing-mortality](https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality). Accessed 12th Mar 2020.
15
16
17 [15] Health Ministry of China. Health Statistical Yearbook of China, 1st edn. Beijing,
18
19 China: Peking Union Medical College Press, 2013:201.
20
21
22 [16] Yaya S, Uthman OA, Okonofua F, et al. Decomposing the rural-urban gap in the
23
24 factors of under-five mortality in sub-Saharan Africa? Evidence from 35
25
26 countries. BMC Public Health. 2019;19(1):616.
27
28
29
30 [17] Saikia, N., Singh, A., Jasilionis, D., et al. Explaining the rural-urban gap in infant
31
32 mortality in India. Demographic Research, 29(18), 473-506.
33
34
35 [18] The World Bank Group. GDP (current US\$) – China.
36
37 [https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2018&locations=](https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2018&locations=CN&start=1960)
38
39 [CN&start=1960](https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2018&locations=CN&start=1960). Accessed 2nd May 2020.
40
41
42
43 [19] National Bureau of Statistics of China. A series of reports on the economic and
44
45 social achievements of the 70th anniversary of the founding of the People's
46
47 Republic of China.
48
49
50 http://www.stats.gov.cn/tjsj/zxfb/201907/t20190701_1673407.html. Accessed 3rd
51
52 May 2020.
53
54
55
56 [20] National health commission, National Development, and reform commission, the

- 1
2
3
4 Ministry of Education, the Ministry of Finance, the Ministry of human resources
5
6 and social security & National Administration of Traditional Chinese Medicine
7
8 (NATCM) (2016). Circular on the issuance of opinions on strengthening the
9
10 reform and development of children's medical and health services.
11
12
13
14 <http://www.mohrss.gov.cn/SYrlzyhshbzb/shehuibaozhang/zcwj/yiliao/201606/t20>
15
16 [160601_241098.html](http://www.mohrss.gov.cn/SYrlzyhshbzb/shehuibaozhang/zcwj/yiliao/201606/t20160601_241098.html). Accessed 2nd May 2020.
17
18
19 [21] UNICEF (2012). Maternal and neonatal tetanus eliminated in China.
20
21
22 <https://www.unicef.cn/en/press-releases/maternal-and-neonatal-tetanus->
23
24 [eliminated-china](https://www.unicef.cn/en/press-releases/maternal-and-neonatal-tetanus-). Accessed 2nd May 2020.
25
26
27 [22] Wang AL, Qiao YP, Wang LH, et al. Integrated prevention of mother-to-child
28
29 transmission for human immunodeficiency virus, syphilis and hepatitis B virus in
30
31 China. Bull World Health Organ. 2015;93(1):52-56.
32
33
34
35 [23] China CDC (2011) . Prevention of mother-to-child transmission of HIV, syphilis
36
37 and hepatitis b (2011-2013).
38
39
40 http://www.chinacdc.cn/gswsxx/fyzx/201107/t20110704_48397.html. Accessed
41
42 2nd May 2020.
43
44
45 [24] Institute of party history and literature of the CPC central committee (2019).
46
47 Memorabilia of the People's Republic of China (October 1949 -- September 2019)
48
49
50
51 <http://cpc.people.com.cn/n1/2019/0928/c419242-31378078.html>. Accessed 3rd May
52
53 2020.
54
55
56 [25] Boghossian NS, Geraci M, Edwards EM, et al. Morbidity and Mortality in Small
57
58
59
60

- 1
2
3
4 for Gestational Age Infants at 22 to 29 Weeks' Gestation. *Pediatrics*. 2018;141(2).
5
6 [26] Gee RE, Dickey RP, Xiong X, et al. Impact of monozygotic twinning on multiple
7
8 births resulting from in vitro fertilization in the United States, 2006-2010. *Am J*
9
10 *Obstet Gynecol*. 2014;210(5):468.e461-466.
11
12
13
14 [27] He L LY, Li Y, et al. Analysis of perinatal and neonatal outcomes in 1 237
15
16 pregnancies through in vitro fertilization. *Journal of Third Military Medical*
17
18 *University*, 2016, 38(23): 2516-2521.
19
20
21
22 [28] Imaizumi Y, Hayakawa K. Infant mortality among singletons and twins in Japan
23
24 during 1999-2008 on the basis of risk factors. *Twin Res Hum Genet*.
25
26 2013;16(2):639-644.
27
28
29
30 [29] Liang J, Mao M, Dai L, et al. Neonatal mortality due to preterm birth at 28-36
31
32 weeks' gestation in China, 2003-2008. *Paediatr Perinat Epidemiol*.
33
34 2011;25(6):593-600.
35
36
37
38 [30] World Health Organization, Dept. of Reproductive Health and Research; United
39
40 Nations Population Fund; UNICEF (2003). *Managing newborn problems: A*
41
42 *guide for doctors, nurses and midwives*. In.
43
44
45
46 [31] Bryce J, Boschi-Pinto C, Shibuya K, et al. WHO estimates of the causes of death in
47
48 children. *Lancet*. 2005;365(9465):1147-1152.
49
50
51 [32] The National Health Commission of China (2017). *Guidelines for the*
52
53 *Construction and Management of Critical Neonatal Treatment Center*.
54
55 <http://www.nhc.gov.cn/fys/s3581/201801/1048948966a44067974a44187c6a8912>.

- 1
2
3
4 [shtml](#). Accessed 28th Apr 2020.
5
6
7 [33] Matsumoto Y, Nakai A, Nishijima Y, et al. Absence of neonatal intensive care units
8
9 in secondary medical care zones is an independent risk factor of high perinatal
10
11 mortality in Japan. *J Obstet Gynaecol Res*. 2016;42(10):1304-1309.
12
13
14 [34] Neonatal Physician Branch of Chinese Physician Association (2013). Guidelines
15
16 for graded construction and management of neonatal wards in China (proposal).
17
18 *Chin J Appl Clin Pediatr*, February, 28(3). 231-239. In.
19
20
21 [35] Office of the central leading group for financial and economic affairs of China
22
23 (2006). Five mechanisms of the new socialist countryside.
24
25
26 <http://finance.people.com.cn/GB/1037/4132493.html>. Accessed 2nd May 2020.
27
28
29 [36] Zhou Y, Guo, Y., Liu, Y, et al. Targeted poverty alleviation and land policy
30
31 innovation: Some practice and policy implications from China. *Land Use Policy*,
32
33 74(74), 53-65.
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7 Figure 1. The national and urban-rural neonatal mortality rates (per 1,000 live births) in
8
9
10 China between 2014 and 2018

11
12
13 Figure 2A. The proportion of cause-specific neonatal diseases of China in 2018

14
15
16 Figure 2B. The proportion of cause-specific neonatal diseases of urban China in 2018

17
18
19 Figure 2C. The proportion of cause-specific neonatal diseases of rural China in 2018

20
21
22 Figure 3. The proportion of neonatal diagnose level in China from 2014 to 2018
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 1. The national and urban–rural neonatal mortality rates (per 1,000 live births) in China between 2014 and 2018

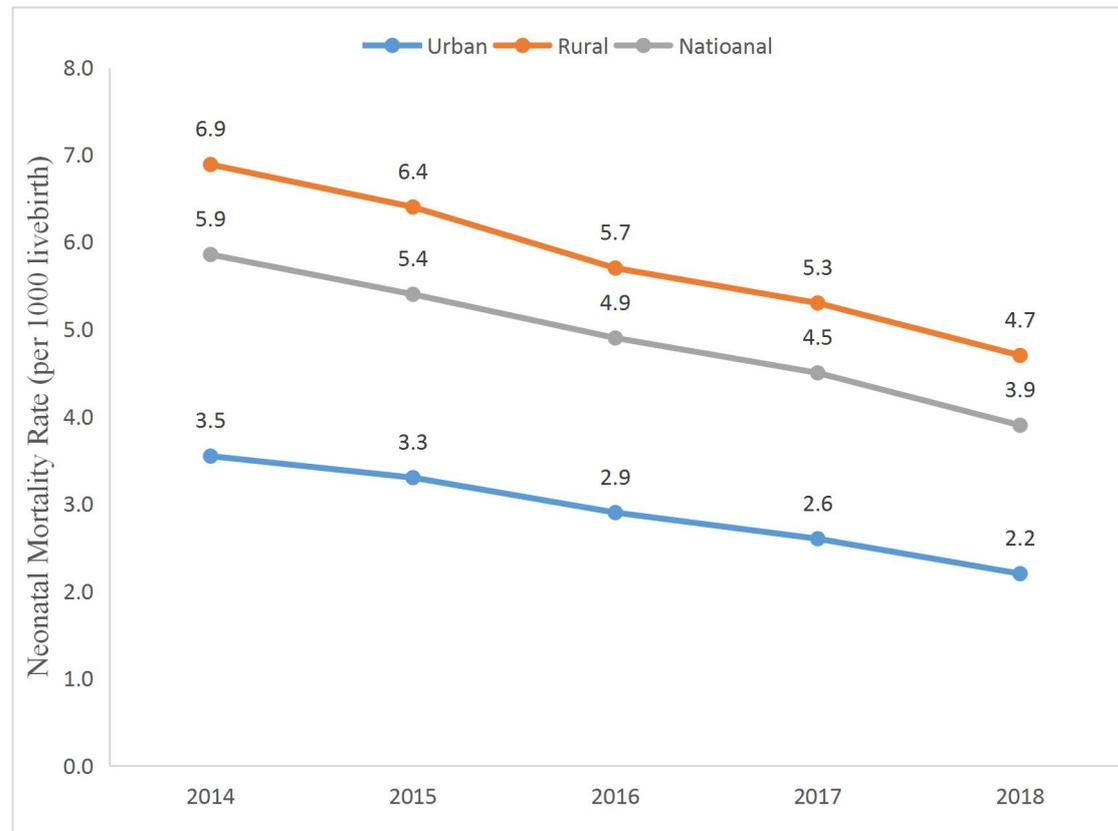


Figure 2A. The proportion of cause-specific neonatal diseases of China in 2018

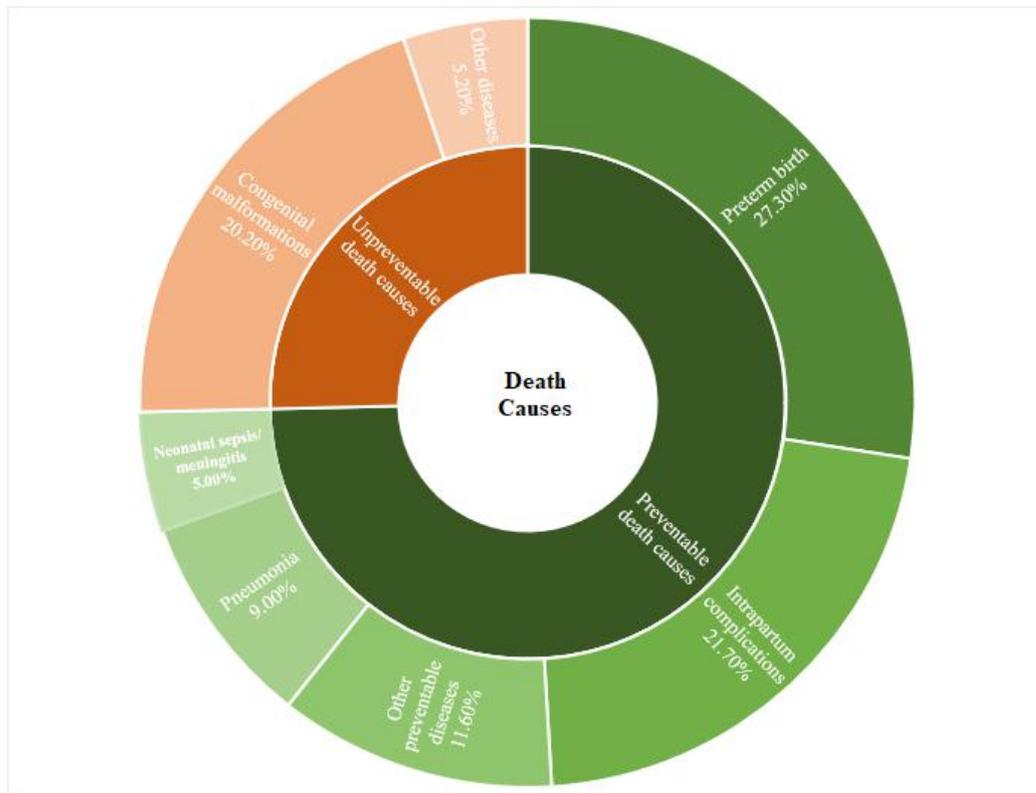
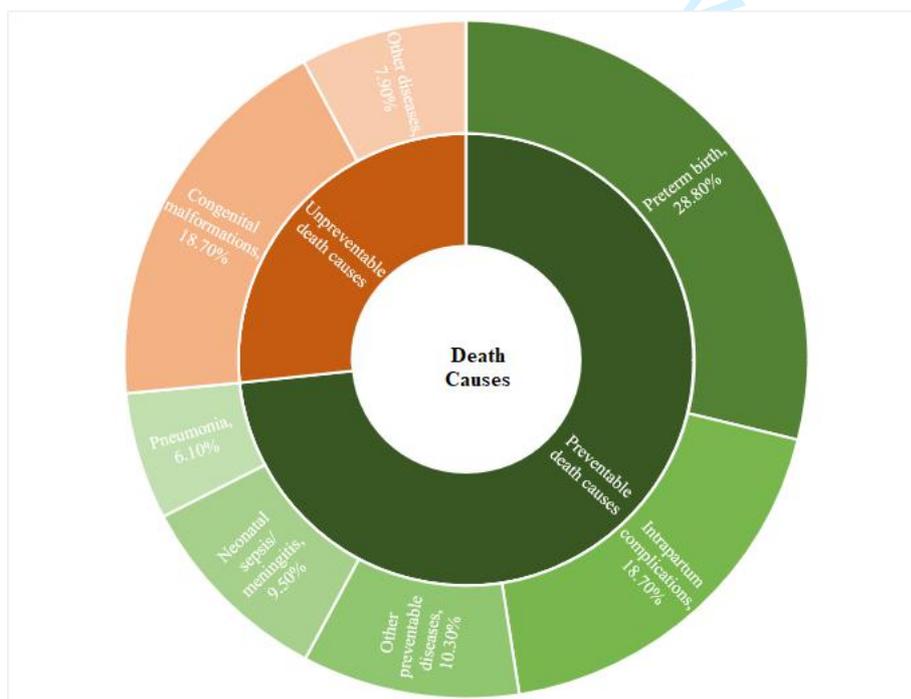
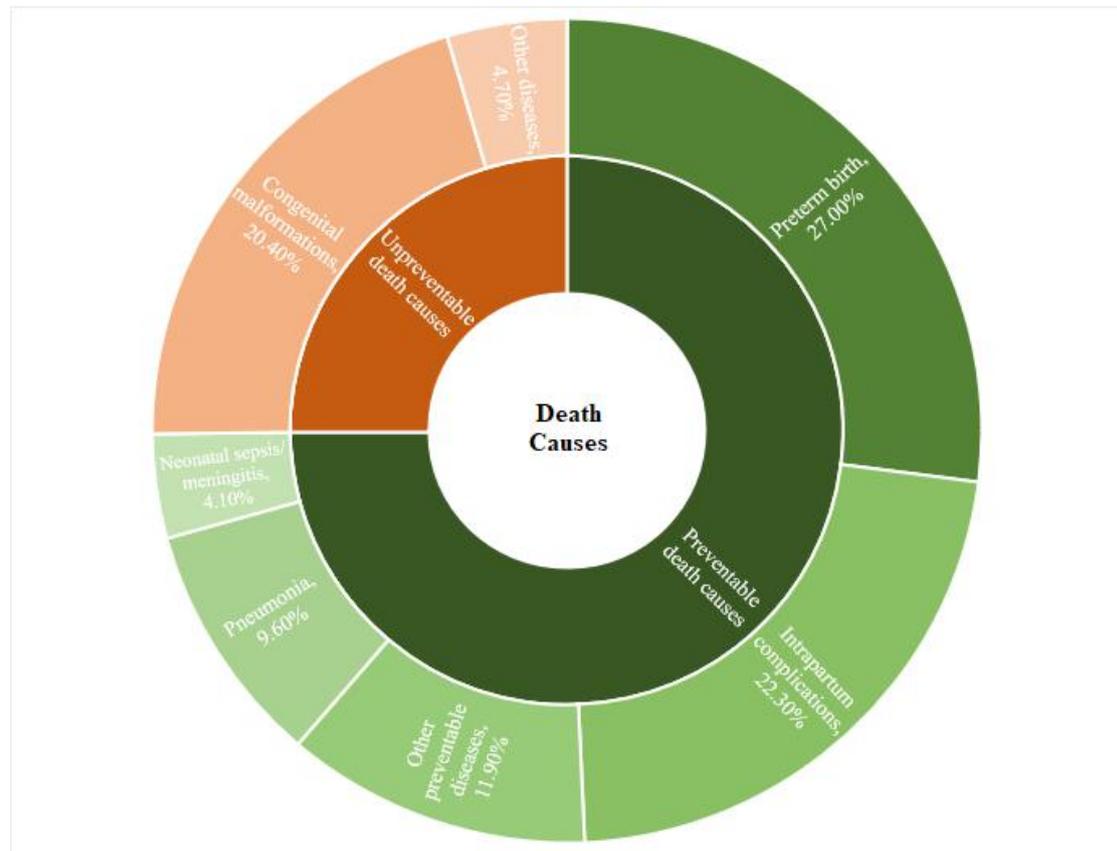


Figure 2B. The proportion of cause-specific neonatal diseases of urban China in 2018



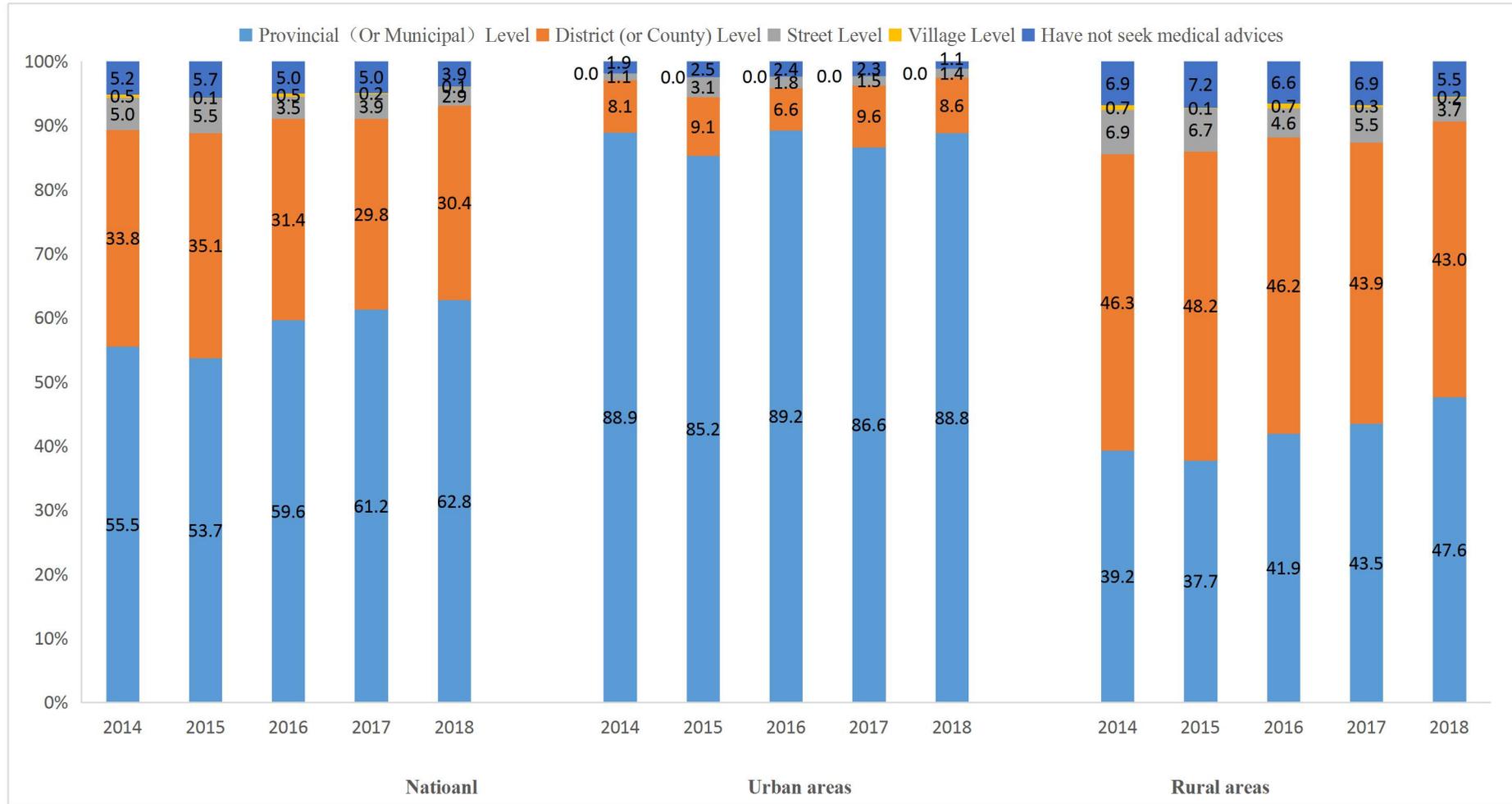
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 2C. The proportion of cause-specific neonatal diseases of rural China in 2018



view only

Figure 3. The proportion of neonatal diagnose level in China from 2014 to 2018



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1	a descriptive study
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3	The present study estimated the national and urban-rural levels and causes of neonatal deaths in China annually between 2014 and 2018. The Poisson regression model was used to calculate the average annual rate of decline of NMR, cause-of-death mortality, and its 95% confidence interval in the country, urban and rural areas, respectively. The neonatal mortality rate in China has significantly decreased from 2014 to 2018. The gap between neonatal mortality and cause-of-death distribution still existed between urban and rural areas. The further goal of government interventions need to focus on be to narrow the urban-rural gap and reduce the health inequality of neonates.
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5	Paragraphs 1 to 2 in the introduction
Objectives	3	State specific objectives, including any prespecified hypotheses	5	Paragraphs 2 in the introduction
Methods				
Study design	4	Present key elements of study design early in the paper	6	The data in this study were extracted from National Maternal and Child Health Surveillance System (NMCHSS). (first paragraph in Study subjects section)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6	Data used in this study were obtained from NMCHSS, a well-established population-based under-5 child death registry system. The 334 surveillance districts covering 124 urban districts and 210 rural districts in 31 provinces, autonomous regions, and municipalities of China. According to the women’s residence, the surveillance sites can be classified into urban areas or rural areas. More details about data collection and quality control have been described elsewhere. (Study subjects section)
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and	6-7	After each child died in the surveillance districts, the local village doctor (or community doctor) needs to report to the local township health centers (or community health service centers) within 10 days. Local township health centers (or community health service centers) need to be verified within 7 days after reporting and fill the Child Death Report Card based on the hospital's death diagnosis. The classification of diseases according to the international classification of diseases-10 (ICD-10). (Data collection and quality control section)

		the sources and methods of selection of participants		
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed		
		<i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case		
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6	All neonates of surveillance districts (gestational week \geq 28weeks) who died after delivery, and had one of the four vital signs would be involved in surveillance subject, including heartbeat, breath, umbilical cord pulsation, and voluntary muscle contraction. (Study subjects section)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6	The data in this study were extracted from National Maternal and Child Health Surveillance System (NMCHSS). (First paragraph in Study subjects section)
Bias	9	Describe any efforts to address potential sources of bias	-	-
Study size	10	Explain how the study size was arrived at	6	The data in this study were extracted from National Maternal and Child Health Surveillance System (NMCHSS). (First paragraph in Study subjects section)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	-	-
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding		
		(b) Describe any methods used to examine subgroups and interactions	8	Statistical analysis section
		(c) Explain how missing data were addressed		
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed		
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed		
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy		
		(e) Describe any sensitivity analyses		
Continued on next page				
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg	10	During 2014 to 2018, the NMR of China has steadily decreased from 5.9 deaths per 1000 live births in 2014 to 3.9 deaths per 1000 live births in 2018 ($p < 0.001$), the

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed

average annual rate of decline was 10.7%. The mortality rate of urban areas decreased from 3.5 deaths per 1000 live births to 2.2 deaths per 1000 live births, with the average annual rate of decline was 13.0%. In rural areas, the NMR decreased significantly from 2014 to 2018 (6.9 deaths per 1000 live births to 4.7 deaths per 1000 live births, the average annual rate of decline was 10.6%, p<0.001). **(the first paragraph in The NMR of China from 2014 to 2018 section)**

(b) Give reasons for non-participation at each stage

-

-

(c) Consider use of a flow diagram

-

-

Descriptive data

14*

(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders

10

Results section

(b) Indicate number of participants with missing data for each variable of interest

-

-

(c) Cohort study—Summarise follow-up time (eg, average and total amount)

-

-

Outcome data

15*

Cohort study—Report numbers of outcome events or summary measures over time

Case-control study—Report numbers in each exposure category, or summary measures of exposure

Cross-sectional study—Report numbers of outcome events or summary measures

10-14

Results section

Main results

16

(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included

10-14

Results section

(b) Report category boundaries when continuous variables were categorized

-

-

(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

-

-

Other analyses

17

Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

-

-

Discussion

Key results

18

Summarise key results with reference to study objectives

15

Discussion section

Limitations

19

Discuss limitations of the study, taking into account sources of

-

-

		potential bias or imprecision. Discuss both direction and magnitude of any potential bias		
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-19	Discussion section
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-19	Discussion section
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20	This study was supported by the Department of Women and Children of the National Health Commission of China, and UNICEF.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Neonatal mortality and leading causes of deaths: a descriptive study in China, 2014-2018

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042654.R1
Article Type:	Original research
Date Submitted by the Author:	30-Dec-2020
Complete List of Authors:	<p>Liu, Yuxi; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Kang, Leni; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China He, Chunhua; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Miao, Lei; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Qiu, Xiaoqiong; Pidun district people's hospital, Chengdu, Sichuan Xia, Weipeng; Second People's Hospital of Zhaotong, Zhaotong, Yunnan, Department of Pediatrics Zhu, Jun; Sichuan University West China Second University Hospital, Key Laboratory of Birth Defects and Related Diseases of Women and Children of the Ministry of Education, West China Second University Hospital, Sichuan University, Chengdu, China; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Liang, Juan; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Li, Qi; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Wang, Yanping; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Liu, Min; Sichuan University West China Second University Hospital, Department of Pediatrics</p>
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, NEONATOLOGY

SCHOLARONE™
Manuscripts

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3
4 1 **Neonatal mortality and leading causes of deaths: a descriptive study in China, 2014-**
5
6 2 **2018**
7
8
9 3

10
11 4 Yuxi Liu, MIPH, MHM^a; Leni Kang, PhD^a; Chunhua He, MD^a; Lei Miao, MD^a; Xiaoqiong
12 5 Qiu, MD^d; Weipeng Xia, MD^e; Jun Zhu, MD^{a,c}; Juan Liang, MD^a; Qi Li, MD^a; Yanping
13 6 Wang, MD^{a,▲}; Hanmin Liu, PhD^{b,c,▲}.
14
15
16
17
18
19
20
21

22 8 ^a National Office for Maternal and Child Health Surveillance of China, West China Second
23 9 University Hospital, Sichuan University, Chengdu, Sichuan, China
24
25
26

27 10 ^b Department of Pediatrics, West China Second University Hospital, Sichuan University,
28 11 Chengdu, China
29
30
31

32 12 ^c Key Laboratory of Birth Defects and Related Diseases of Women and Children of the
33 13 Ministry of Education, West China Second University Hospital, Sichuan University,
34 14 Chengdu, China
35
36
37
38
39

40 15 ^d Pidu district people's hospital, Chengdu, Sichuan, China
41
42

43 16 ^e Department of Pediatrics, Second People's Hospital of Zhaotong, Zhaotong, Yunnan,
44 17 China
45
46
47

48 18
49
50
51 19
52
53 20 ▲ These authors contributed equally to this work.
54
55
56 21

1
2
3
4 22 **Corresponding authors:** Yanping Wang, National Office for Maternal and Child Health
5
6 23 Surveillance of China, West China Second University Hospital, Sichuan University,
7
8
9 24 Chengdu, Sichuan, China, email: wyxianping@163.com; and Hanmin Liu; Department of
10
11 25 Pediatrics, West China Second University Hospital, Sichuan University, Chengdu, China,
12
13
14 26 email: hanmin@vip.163.com
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4 43 **Abstract**

5
6 44 **Objective:** The present study estimated the national and urban-rural levels and causes of
7
8
9 45 neonatal deaths in China annually between 2014 and 2018 to provide data support for the
10
11
12 46 further end of preventable neonatal deaths for China and other low-and middle-income
13
14
15 47 countries.

16
17 48 **Methods:** The study was based on data from the National Maternal and Child Health
18
19 49 Surveillance System (NMCHSS). All neonates of surveillance districts (gestational week
20
21 50 ≥ 28 weeks) who died after delivery have been involved in the study. The mortality rate and
22
23
24 51 the leading causes of death for neonates were analyzed.

25
26
27 52 **Results:** The NMR of China has steadily decreased from 5.9 deaths per 1000 live births in
28
29 53 2014 to 3.9 deaths per 1000 live births in 2018. The NMR in 2018 of urban and rural areas
30
31
32 54 was 2.2 deaths per 1000 live births and 4.7 deaths per 1000 live births, respectively. The
33
34
35 55 leading preventable causes of neonatal deaths are the same in the urban and rural areas
36
37 56 were same, which were preterm birth, intrapartum complications, and pneumonia.
38
39
40 57 Mortality rates of these three causes fell significantly between 2014 and 2018 but
41
42
43 58 contributed to a higher proportion of deaths in rural areas than urban areas. The proportion
44
45 59 of preventable deaths accounted for 73.9% in 2018.

46
47
48 60 **Conclusions:** The NMR of China has decreased steadily from 2014 to 2018. However, the
49
50
51 61 inequality between urban and rural areas still exists. The goal of government interventions

1
2
3
4 62 should be to reduce the health inequality of neonates and further take targeted measures to
5
6
7 63 eliminate preventable neonatal death.
8
9

10 64 **Keywords:** neonatal mortality, leading cause, Surveillance, inequality, China
11
12
13 65
14
15

16 66 **Strengths and limitations of this study**

17
18

- 19 67 • This is the first study to show the status of neonatal deaths in China from 2014 to 2018.
20
21
22 68 • The study covers the most geographically extensive newborn population in mainland
23
24
25 69 China.
26
27
28 70 • The data from the National Maternal and Child Health Surveillance System used in this
29
30
31 71 study have been shown to be representative of mainland China and to be of high quality
32
33 72 for the recording of death causes of children under 5.
34
35
36 73 • The system has not covered the pre-natal assessment due to design limitations.
37
38
39
40 74
41
42
43 75
44
45
46 76
47
48
49 77
50
51
52 78
53
54
55 79
56
57 80
58
59
60

81 **Introduction**

82 In 2015, the United Nations (UN) summit on sustainable development formally adopted
83 the 2030 agenda for sustainable development. In SDG3, the goal is to end preventable
84 neonatal and under-five child deaths by 2030¹, with all countries aiming to reduce neonatal
85 mortality to at least as low as 12 deaths per 1,000 live births and under-five mortality to at
86 least as low as 25 deaths per 1,000 live births. The importance of newborn health issues
87 has received global attention. The Chinese government has always attached great
88 importance to the survival, protection, and development of children, and has made great
89 achievements in reducing child mortality. Professional institutions for maternal and child
90 health care began to be established in 1950². Moreover, the Chinese government has taken
91 U5MR, IMR, and other indicators of children's health as assessment targets for provincial
92 governments, and has promulgated the National Program of Action for Child Development
93 in China every decade since 1990s^{2,3}.

94
95 Globally, there were 5.3 million deaths occurred on children under 5 in 2018, 47% of them
96 died during their first month of life. The vast majority of neonatal deaths occur in low -
97 and middle-income countries. Approximately 73,000 neonates died in China in 2018,
98 accounting for about 3.0% of the total newborn deaths worldwide, ranking sixth in the
99 world⁴. Moreover, the global decline in neonatal mortality rate (NMR) has been slower
100 than the decline in the under-five mortality rate (U5MR)⁶. Global U5MR declined from 93
101 per 1,000 live births in 1990 to 39 per 1,000 live births in 2018, while that of NMR only

1
2
3
4 102 declined from 37 per 1,000 live births to 18 per 1,000 live births during the same period.
5

6 103 Additionally, a great many studies have shown that neonatal deaths amounting to a large
7

8
9 104 proportion of total mortality of children under 5⁵⁻⁷. Therefore, reducing preventable
10

11 105 neonatal deaths is important to further reduce the U5MR.
12

13
14 106
15

16
17 107 China has achieved the MDG4 (Millennium Development Goal 4) eight years ahead of
18

19 108 schedule in 2007⁸⁻¹³, and it is also rated by the World Health Organization as a country
20

21 109 with "high performance in maternal and child health". In 2018, the NMR of China was 3.9
22

23 110 deaths per 1000 live births, which was lower than the target of SDG3¹⁴. However,
24

25 111 according to the NMR data from World Bank in 2018, the NMR of China is at a low level
26

27 112 in developing countries (such as the NMR in Brazil was 8.1 deaths per 1000 live births,
28

29 113 and Thailand was 5.0 deaths per 1000 live births), it still lags behind that in developed
30

31 114 countries (such as the NMR in Australia was 2.3 deaths per 1000 live births, and Germany
32

33 115 was 2.2 deaths per 1000 live births)¹⁵. Moreover, since urban areas generally have better
34

35 116 economic development than rural areas, resulting in better health service infrastructure and
36

37 117 health service infrastructures¹⁶, there is an urban-rural inequity in neonatal mortality in
38

39 118 China¹⁷. To further shorten the gap with developed countries, and reduce the difference in
40

41 119 neonatal mortality between urban and rural areas, there is still room for improvement in
42

43 120 neonatal deaths in China. This study will analyze neonatal mortality trends and its mortality
44

45 121 of major causes of death in China from 2014 to 2018 to provide data support for the further
46

47 122 elimination of key preventable diseases that can cause neonatal deaths.
48

1
2
3
4 123
56 124 **Materials and Methods**7
8
9 125 *Study subjects*
10
11
12 126

13
14 127 The study covered all the 327 districts of the National Maternal and Child Health
15
16
17 128 Surveillance Districts (with 124 urban districts and 203 rural districts) in 31 provinces,
18
19
20 129 autonomous regions, and municipalities of China. Further details about the National
21
22 130 Maternal and Child Health Surveillance System (NMCHSS) have been described
23
24
25 131 elsewhere¹⁸.
26

27 132

28
29
30 133 All neonates of surveillance districts (gestational week ≥ 28 weeks) who died after delivery,
31
32 134 and had one of the four vital signs would be involved in surveillance subject, including
33
34
35 135 heartbeat, breath, umbilical cord pulsation, and voluntary muscle contraction. The
36
37
38 136 surveillance subject also includes adoption children and children of non-local household
39
40
41 137 residents whose mothers have living in the surveillance districts for more than one year.
42

43 138

44
45 139 *Data collection and quality control*
46

47
48
49 140 After each child died in the surveillance districts, the local village doctor (or community
50
51
52 141 doctor) needs to report to the local township health centers (or community health service
53
54 142 centers) within 10 days. Local township health centers (or community health service
55

1
2
3
4 143 centers) need to be verified within 7 days after reporting and fill the Child Death Report
5
6 144 Card based on the hospital's death diagnosis. If the child died at home or on the way to the
7
8
9 145 health facilities, infer the cause of death would base on the 2016 WHO Verbal Autopsy
10
11
12 146 Standards¹⁹ and then fill the Child Death Report Card. The classification of diseases
13
14
15 147 according to the international classification of diseases-10 (ICD-10).
16
17
18 148

19
20
21 149 The children's mortality data was reported level by level, and the data is timely reported
22
23
24 150 through the network direct reporting system. Technical personnel responsible for
25
26
27 151 monitoring work are set up at all levels to complete the collection, review, and operation
28
29
30 152 of surveillance data. The completed child death data would send to the county (or district)
31
32
33 153 level maternal and child health institutions each season. The county (or district) level
34
35
36 154 maternal and child health institutions would report the local child deaths status to
37
38
39 155 prefecture-level and province-level maternal and child health institutions each season, the
40
41
42 156 National Office of Maternal and Child Health would summarize and analyzes the data
43
44
45 157 finally.
46
47
48 158

49
50
51 159 For quality control, we have used the regular level-by-level on-site quality control system.
52
53
54 160 At the county (district), city, and provincial levels, following the requirements of the
55
56
57 161 Chinese Maternal and Child Health Surveillance Work Manual, a multi-source data cross-
58
59
60 162 check method is used to complete the on-site quality control work in sampling surveillance

1
2
3
4 163 districts. The National Office of Maternal and Child Health will select 18 districts in 6
5
6 164 provinces each year for quality inspection^{17,18}.

7
8
9
10 165

11
12
13 166 *Statistical analysis*

14
15
16 167 Results were collected in Microsoft Excel and analyzed using SPSS 22.0 (IBM, Armonk,
17
18 168 NY, USA). The neonatal mortality rates (NMR) of different areas (urban areas & rural
19
20 169 areas) and stages (early neonates & late neonates), and the main cause-specific mortality
21
22 170 rates were corrected using the average underreporting rate of the national-level surveillance
23
24 171 data quality checks in the past three years. The national NMR and the main cause-specific
25
26 172 mortality rate were weighted calculated according to the proportion of the urban and rural
27
28 173 population in the census. The diagnostic level composition ratio of the neonate is calculated
29
30 174 based on the reported Child Death Report Card, excluding children who died of accidental
31
32 175 injuries¹⁷.

33
34
35
36
37
38
39
40 176

41
42
43 177 The Poisson regression model was used to calculate the average annual rate of decline of
44
45 178 NMR, cause-of-death mortality, and its 95% confidence interval in the country, urban and
46
47 179 rural areas, and its 95% confidence interval in early and late neonates, respectively. Linear
48
49 180 by the linear association in the chi-square test using SPSS software was used to test whether
50
51
52 181 there was a linear downward trend in different regions and causes of death.
53
54
55

1
2
3
4 182
5
6

7 183 *Ethics approval and consent to participate*
8
9

10 184 This study was approved by the Ethics Committee of West China Second University
11
12
13 185 Hospital, Sichuan University, China.
14
15

16 186
17
18

19 187 *Patient and public involvement*
20
21

22 188 Patients and members of the public were not involved in the design of this study.
23
24
25

26 189
27
28

29 190 **Result**

30
31

32 191 *1. The NMR of China from 2014 to 2018*
33
34
35

36 192 At the national level, the NMR of China has steadily decreased from 5.9 deaths per 1000
37
38 193 live births in 2014 to 3.9 deaths per 1000 live births in 2018 ($p<0.001$), the average
39
40
41 194 annual rate of decline was 10.7%. The NMR of urban and rural areas have both showed a
42
43 195 declining trend in the same period ($p<0.001$). The mortality rate of urban areas
44
45 196 decreased from 3.5 deaths per 1000 live births to 2.2 deaths per 1000 live births, with the
46
47 197 average annual rate of decline was 13.0%. In rural areas, the NMR decreased significantly
48
49 198 from 2014 to 2018 (6.9 deaths per 1000 live births to 4.7 deaths per 1000 live births, the
50
51 199 average annual rate of decline was 10.6%, $p<0.001$). The absolute difference between
52
53
54
55
56
57
58
59
60

1
2
3
4 200 NMR of urban and rural areas has reduced from 3.4 deaths per 1000 live births to 2.5 deaths
5
6
7 201 per 1000 live births, but the relative difference has increased from 2.0 to 2.2. (See **Figure**
8
9 202 **1**)

10
11
12 203

13 14 15 204 *2. Cause of neonates mortality in China from 2014 to 2018*

16
17
18
19 205 Nationwide, compared with 2014, the neonatal deaths caused due to preterm birth,
20
21
22 206 intrapartum complication, and pneumonia in 2018 have sharply decreased. Among the
23
24
25 207 particular diseases, the intrapartum complications have the highest average annual decline
26
27 208 rate (AADR) from 2014 to 2018 (with 13.5%, $p<0.001$). The smallest AADR belonged to
28
29
30 209 Tetanus (with 0.8%, $p<0.05$). In any given year, preterm birth, intrapartum complication,
31
32
33 210 and pneumonia were the top three leading causes of neonatal death in China, total
34
35 211 accounting for nearly 60%. (See **Table 1**) In 2018, all deaths causes have been divided into
36
37
38 212 preventable diseases and unpreventable diseases to analyze the proportion. The proportion
39
40
41 213 of preventable diseases reached 73.9%. Moreover, the top three diseases at the national
42
43
44 214 level were preterm birth, intrapartum complications, and congenital malformations. (See
45 215 **Figure 2A**)

216 Table 1. The proportion of cause-specific neonatal mortality in China from 2014 to 2018

Causes of death	0-6 days					7-28 days					0-28 days				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Nationalwide															
Preterm birth	32.3	33.1	32.0	36.2	26.7	19	24.2	19.9	22.3	28.8	29.1	30.8	28.7	32.2	27.3
Intrapartum complications	29.0	31.9	27.0	26.4	28.5	8.4	7.1	6	6.2	5.6	24.2	25.5	21.4	20.6	21.7
Pneumonia	9.5	6.9	9.0	8.0	7.9	17.3	13.5	18	18.2	11.5	11.3	8.6	11.4	11	9
Diarrhea	0.1	0.0	0.0	0.0	0.2	1.3	2	1.1	0.2	1	0.4	0.5	0.3	0	0.4
Tetanus	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.1	0	0	0	0
HIV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Neonatal sepsis/meningitis	1.6	2.1	2.7	2.4	3.0	5.3	4.3	7.5	5.8	9.8	2.5	2.6	4	3.3	5
Other infectious diseases	0.3	0.3	0.2	0.3	0.0	0.3	0.0	0.4	0.0	0.0	0.3	0.2	0.3	0.2	0
Congenital malformations	15.5	12.5	16.1	16.7	19.0	23.4	22.8	26.4	22.7	22.8	17.4	15.2	18.9	18.5	20.2
Other diseases	11.7	13.2	12.9	9.9	14.7	24.4	26.1	20.7	24.6	20.5	14.7	16.6	15	14.2	16.4
Urban area															
Preterm birth	35.5	30	26.6	36.5	29.1	15.5	24.6	22.8	19.8	27.9	31.4	28.6	25.5	31.8	28.8
Intrapartum complications	28	30	28.2	27.8	24.3	18.1	10.4	5.5	11.2	6.4	25.9	24.6	21.8	23.2	18.7
Pneumonia	7.3	7.9	10.7	6.4	5.3	11.3	8.2	15.1	14.5	8.1	8.1	8	12	8.6	6.1
Diarrhea	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.0	0.7	0.9	0.2	0.2	0	0.2	0.3
Tetanus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
HIV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

Neonatal sepsis/meningitis	2.7	2.5	4.7	4.3	8.1	3.4	7.5	8.3	12.4	12.6	2.9	3.9	5.7	6.6	9.5
Other infectious diseases	0.7	0.9	0.5	0.8	0.0	0.0	0.0	0.7	0.0	0	0.5	0.6	0.6	0.5	0
Congenital malformations	17.3	16.4	17.8	16.3	15.4	32.8	28.4	24.2	20.4	26.2	20.5	19.7	19.6	17.5	18.7
Other diseases	8.4	12.2	11.5	7.9	17.8	18.1	20.1	23.4	21.0	17.9	10.5	14.4	14.9	11.6	17.9
Rural area															
Preterm birth	31.5	33.7	33.2	36.1	26.2	19.6	24.1	19.1	22.9	29	28.6	31.3	29.5	32.3	27
Intrapartum complications	29.2	32.3	26.8	26.1	29.3	6.4	6.2	6.1	5.2	5.4	23.8	25.7	21.3	20.1	22.3
Pneumonia	10.0	6.7	8.7	8.4	8.4	18.6	14.8	18.7	18.9	12.4	12	8.7	11.3	11.5	9.6
Diarrhea	0.1	0.0	0.0	0.0	0.2	1.4	2.4	1.3	0.0	1.1	0.4	0.6	0.3	0	0.5
Tetanus	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.2	0	0	0	0
HIV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Neonatal sepsis/meningitis	1.3	2.0	2.2	1.9	2.0	5.7	3.5	7.4	4.3	9.1	2.4	2.4	3.6	2.6	4.1
Other infectious diseases	0.2	0.1	0.2	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.3	0.1	0.2	0.1	0
Congenital malformations	15.1	11.7	15.7	16.8	19.8	21.4	21.4	27.0	23.3	22.0	16.6	14.1	18.7	18.7	20.4
Other diseases	12.5	13.5	13.2	10.4	14.0	25.7	27.6	20.0	25.4	21.0	15.7	17.1	15	14.7	16.1

217
218
219
220
221

222 Table 2. Leading causes of death in neonates in China from 2014 to 2018

Causes of death	Cause-specific mortality (per 100,000livebirths)																	
	0-6 (<7) days newborns						7-27 days newborns						0-27 (<28) days newborns					
	2014	2015	2016	2017	2018	Average annual decline rate (%)	2014	2015	2016	2017	2018	Average annual decline rate (%)	2014	2015	2016	2017	2018	Average annual decline rate (%)
Nationalwide																		
Preterm birth	144.8	133.5	113.8	115.7	73.4	12.7 (15.1,10.2) **	25.9	33.7	26.0	28.7	33.2	-3.2 (2.4,-9.1) △	170.7	167.2	139.8	144.4	106.6	9.7 (7.4, 11.9)**
Intrapartum complications	130.2	128.7	96.1	84.5	78.2	13.5 (16.1,10.9) **	11.5	9.8	7.8	8.0	6.4	12.7 (21.3,3.3)**	141.7	138.5	103.9	92.5	84.6	13.5 (11.0, 15.9)**
Pneumonia	42.4	27.9	32.1	25.7	21.7	13.6 (18.3,8.7)**	23.7	18.8	23.6	23.4	13.3	7.2 (13.1,0.8) *	66.1	46.7	55.7	49.1	35	11.0 (7.1, 14.7)**
Diarrhea	0.4	0.0	0.0	0.0	0.5	-	1.8	2.8	1.4	0.2	1.2	24.5 (41.7,2.1) △	2.2	2.8	1.4	0.2	1.7	20.1 (-2.0, 37.4) △
Tetanus	0.0	0.0	0.0	0.0	0.0	-	0.8	0.0	0.0	0.0	0.0	-	0.8	0	0	0	0	-
HIV	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-
Neonatal sepsis/meningitis	7.2	8.4	9.4	7.6	8.3	-2 (8.2,-13.3) △	7.3	5.9	9.9	7.4	11.3	-12.1 (-0.9,-24.5)*	14.5	14.3	19.3	15	19.6	-6.5 (-14.7, 1.2) △
Other infectious	1.4	1.1	0.8	0.9	0.0	30.1	0.4	0.0	0.6	0.0	0.0	35.6 (68,-	1.8	1.1	1.4	0.9	0	33.1

diseases						(51,0.3) Δ						29.5) Δ						(7.9, 51.4) *	
Congenital malformations	69.8	50.6	57.3	53.5	52.3	5.6 (9.3,1.8) **	31.9	31.7	34.6	29.3	26.2	4.3 (9.4,-1) Δ	101.7	82.3	91.9	82.8	78.5	5.1 (2.0, 8.1) **	
Other diseases	52.8	53.6	45.9	31.6	40.2	10.4 (14.3,6.2) **	33.3	36.4	27.1	31.8	23.6	7.4 (12.3,2.2) **	86.1	90	73	63.4	63.8	9.2 (5.9, 12.3) **	
Urban area																			
Preterm birth	99.7	70.9	55.6	69.6	44.2	15 (19.4,10.4) **	11.5	22.0	18.9	14.7	19.1	-4.2 (6.2,-15.7) Δ	111.2	92.9	74.5	84.3	63.3	11.4 (7.1, 15.5) **	
Intrapartum complications	78.6	70.9	59.0	53.1	36.9	15.8 (20.5,10.9) **	13.4	9.3	4.6	8.3	4.3	21.2 (32.7,7.9) *	92	80.2	63.6	61.4	41.2	16.4 (11.8, 20.7) **	
Pneumonia	20.4	18.7	22.3	12.2	8.0	18 (26.5,8.5) **	8.4	7.4	12.6	10.7	5.5	2.7 (15.8,-12.4) Δ	28.8	26.1	34.9	22.9	13.5	12.4 (4.5, 19.7) **	
Diarrhea	0.0	0.0	0.0	0.0	0.0	-	0.6	0.7	0.0	0.5	0.6	2.7 (51.8,-96.6) Δ	0.6	0.7	0	0.5	0.6	2.7 (-96.6, 51.8) Δ	
Tetanus	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-	
HIV	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-	
Neonatal sepsis/meningitis	7.7	6.0	9.7	8.3	12.3	-13.8 (1.9,-32.1) Δ	2.5	6.7	6.9	9.2	8.6	-25.5 (-5.7,-49.1) **	10.2	12.7	16.6	17.5	20.9	2.7 (-96.6, 51.8) **	
Other infectious diseases	1.9	2.0	1.1	1.5	0.0	33 (56,-1.9) Δ	0.0	0.0	0.6	0.0	0.0	2.7 (76.2,-297.1) Δ	1.9	2	1.7	1.5	0	25.2 (-7.7, 48.1) Δ	

Congenital malformations	48.6	38.8	37.2	31.2	23.3	14.9 (20.9,8.4)**	24.3	25.4	20.1	15.1	17.9	10.8 (19.1,8)*	72.9	64.2	57.3	46.3	41.2	13.6 (8.4, 18.5)**	
Other diseases	23.6	28.7	24.1	15.1	27.0	3.5 (11.8,- 5.5) [△]	13.5	18.1	19.4	15.6	12.3	3.3 (13.3,- 7.8) [△]	37.1	46.8	43.5	30.7	39.3	3.2 (- 3.7, 9.7) △	
Rural area																			
Preterm birth	165.0	161.4	139.8	136.2	86.4	12 (15.2,8.8)**	32.2	38.9	29.1	35.1	39.5	-4.1 (2.9,- 11.7) [△]	197.2	200.3	168.9	171.3	125.9	9.2 (6.3, 12.1)**	
Intrapartum complications	153.2	154.5	112.6	98.5	96.6	13.1 (16.3,9.7)**	10.6	10.0	9.3	8.0	7.4	8.2 (20.2,- 5.5) [△]	163.8	164.5	121.9	106.5	104	12.8 (9.5, 15.9)**	
Pneumonia	52.3	32.0	36.4	31.7	27.8	12.9 (18.8,6.5)**	30.5	23.9	28.5	29.1	16.9	7.6 (14.9,- 0.4) [△]	82.8	55.9	64.9	60.8	44.7	10.8 (5.9, 15.5)**	
Diarrhea	0.6	0.0	0.0	0.0	0.7	-	2.3	3.8	2.0	0.0	1.5	25.1 (45.4,- 2.8) [△]	2.9	3.8	2	0	2.2	25.5 (- 0.3, 44.6)*	
Tetanus	0.0	0.0	0.0	0.0	0.0	-	1.2	0.0	0.0	0.0	0.0	-	1.2	0	0	0	0	-	
HIV	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-	
Neonatal sepsis/meningitis	7.0	9.4	9.3	7.3	6.6	3.3 (16.7,- 12.4) [△]	9.4	5.7	11.2	6.6	12.4	-7.3 (6.7,- 23.5) [△]	16.4	15.1	20.5	13.9	19	-2.3 (- 13.2, 7.7) [△]	
Other infectious diseases	1.2	0.6	0.7	0.7	0.0	30.3 (60.9,- 24) [△]	0.6	0.0	0.6	0.0	0.0	42.4 (82.5,- 89.3) [△]	1.8	0.6	1.3	0.7	0	29.7 (- 13.7, 56.6) [△]	
Congenital	79.3	55.9	66.2	63.5	65.2	3.3 (8.2,-	35.2	34.5	41.1	35.7	30.0	2.5 (9.1,-4.6)	114.5	90.4	107.3	99.2	95.2	3.0 (-	

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

malformations						1.8) Δ						Δ						1.2, 6.9) Δ
Other diseases	65.8	64.7	55.6	39.0	46.1	11.6 (16.5,6.4)**	42.2	44.6	30.5	39.0	28.6	8.5 (14.6,1.9) *	108	109.3	86.1	78	74.7	10.3 (6.3, 14.2)**

(** means p value<0.01, * means p value<0.05, Δ means p value \geq 0.05)

For peer review only

1
2
3
4 245 The death cause distribution and AADR were also significantly different among urban-
5
6 246 rural areas. In urban areas, preterm birth, intrapartum complication, and congenital
7
8
9 247 anomalies also accounting the largest proportion of all deaths cause from 2014 to 2018.
10
11
12 248 Moreover, the AADR of preterm birth, intrapartum complications, pneumonia, and
13
14 249 congenital malformations in urban areas were all larger than that of the national level. In
15
16
17 250 rural areas, the mortality rate of preterm birth, intrapartum complication, and congenital
18
19
20 251 anomalies significantly decreased. Additionally, the NMR of diarrhea have sharply
21
22 252 decreased, with AADR was 25.5% ($p < 0.001$). (See **Table 2**)
23
24 253
25
26 254 In contrast, the urban-rural gap still existed. The contribution of tetanus among neonates in
27
28
29 255 urban areas remains zero during the study period, while the rate in rural areas has been
30
31
32 256 eliminated until 2015. In 2018, the neonatal mortality in rural areas was almost twice as
33
34 257 high as in urban areas due to preterm birth, intrapartum complications, and congenital
35
36
37 258 malformations. Moreover, during the study period, the largest number of neonatal deaths
38
39 259 in the urban and rural areas was pneumonia, increased from 2.9 times (82.8 per 100,000
40
41
42 260 live births in rural areas VS 28.8 per 100,000 live births in urban areas) in 2014 to 3.3 times
43
44
45 261 (44.7 per 100,000 live births in rural areas VS 13.5 per 1000 live births in urban areas) in
46
47 262 2018. (See **Table 2**) In the disease proportion aspect, the proportion of intrapartum
48
49
50 263 complications and pneumonia in rural areas significantly higher than that of urban areas.
51
52 264 (See Figure 2B&C) According to the data analysis, causes of neonatal death varied between
53
54
55 265 urban and rural areas ($P < 0.05$), but the correlation between neonatal mortality and whether

1
2
3
4 266 the newborn lived in urban or rural areas was weak (Cramer's $V=0.129$).
5
6

7 267
8

9 268 The mortality rates have also shown difference when divided neonates into early neonates
10
11 269 (0-6 days) and late neonates (7-28 days). Nationwide, except for neonatal sepsis (or
12
13
14 270 meningitis) and diarrhea, the mortality rate of other causes of death of early neonates was
15
16
17 271 significantly higher than that of late neonates, with the biggest difference being intrapartum
18
19
20 272 complications, preterm birth, and congenital malformations. In 2018, the mortality rate of
21
22 273 preterm birth was 73.4 per 100,000 livebirth in early neonates and 33.2 per 100,000
23
24 274 livebirth in late neonates. In the same year, the mortality rate of congenital malformations
25
26
27 275 was 52.3 per 100,000 livebirth in early neonates and 26.2 per 100,000 livebirth in late
28
29
30 276 neonates. It is worth noting that intrapartum complications were the second leading cause
31
32 277 of death among 0-28 days newborns in China from 2014 to 2018, with the mortality rate
33
34
35 278 of 78.2 per 100,000 livebirth in early neonates and only 6.4 per 100,000 livebirth in late
36
37
38 279 neonates (See **Table 2**).
39

40 280
41
42

43 281 *3. Neonate Diagnosis Facilities Level in China between 2014 and 2018*

44
45

46 282 The children's diagnosis facilities level has also be included in surveillance. Nationwide,
47
48
49 283 from 2014 to 2018, the proportion of neonate diagnosis at the provincial (or municipal)
50
51 284 level health facilities has significantly increased, and the proportion of the district (or
52
53
54 285 county) level has decreased. Moreover, the proportion of township level and village level
55
56

1
2
3
4 286 have both fluctuating declined during this period. In 2018, the proportion of neonate who
5
6
7 287 has not to seek any medical care has minimized, which declined to 3.9% in 2018. (See
8
9 288 **Figure 3**)

10
11
12 289
13
14
15
16 290 In an urban aspect, from 2014 to 2018, the majority of children (accounted for over 80%)
17
18 291 in urban areas have been diagnosed at provincial (or municipal) level medical facilities.
19
20
21 292 The proportion of the district (or county) level and township -level both have a slight rise
22
23 293 between 2014 and 2018. As a result, the percentage of children who have not to seek
24
25
26 294 medical care has declined, with 1.9% in 2014 and 1.1% in 2018. (See **Figure 3**)

27
28
29 295
30
31
32 296 On the contract, the diagnosis contribution figure of rural areas was different. Although the
33
34
35 297 proportion of provincial (or municipal) level has shown a growth trend from 2014 to 2018,
36
37
38 298 the proportion in rural areas have only half of that in urban areas. Moreover, the proportion
39
40
41 299 of street-level diagnoses in the urban area is reduced to 1.4% in 2018, while this proportion
42
43 300 in rural areas fluctuated and remained at 3.7% in the same year. Another significant
44
45
46 301 contributor is the proportion of children who have not sought medical care. The proportion
47
48
49 302 of neonate who has not to seek medical care has decreased, and still, 5.5% of children have
50
51 303 not sought any medical advice. (See **Figure 3**)

52
53
54 304

1
2
3
4 305 **Discussion**

5
6 306

7
8
9 307 The results of this study show that the NMR in urban and rural areas of China have
10
11 308 decreased significantly between 2014 and 2018. In addition, there were significant
12
13
14 309 differences in NMR between urban and rural areas, which were consistent with significant
15
16
17 310 differences in NMR between countries and regions globally^{20,21}.

18
19
20 311

21
22
23 312 From 2014 to 2018, Chinese NMR continued to decline, and it was dropped quickly. It
24
25 313 benefits from the improvement of medical treatment at all levels of health facilities, and all
26
27
28 314 levels of government attached great importance to strengthen the construction of the
29
30
31 315 pediatric institution, raise pediatricians' payment, and continue to implement neonatal
32
33 316 asphyxia recovery training program²². As a result, neonatal deaths from pneumonia and
34
35
36 317 infectious diseases, intrapartum complications, and premature delivery were significantly
37
38 318 reduced.

39
40
41
42 319

43
44
45 320 China has implemented the Safe Maternal Initiative and the National Program to Reduce
46
47 321 Maternal Mortality and Eliminate Tetanus, China has officially eliminated neonatal tetanus
48
49
50 322 in 2012²³, and from 2015 to 2018, the NMR of neonatal tetanus remained 0. Moreover,
51
52
53 323 through the success of the Prevention of Mother-to-child Transmission of HIV, Syphilis,
54
55 324 and Hepatitis B Program, the HIV/AIDS mortality rate has also been 0 from 2014 to

1
2
3
4 325 2018^{24,25}. Although the national neonatal mortality in 2018 was already less than 12 deaths
5
6 326 per 1000 live births, the preventable deaths still accounted for 73.9%, mainly were
7
8 327 pneumonia, intrapartum complication, premature birth. Among these diseases, the
9
10 328 proportion of preterm birth was highest in both nationwide, urban areas, and rural areas. In
11
12
13
14 329 the recent two decades, the prevalence of preterm birth has significantly increased¹⁸,
15
16
17 330 especially after the Two-child Policy²⁶ was implemented in China. The mortality rate
18
19
20 331 among preterm birth infants was apparently higher than the full-term infant, and the risk of
21
22 332 mortality increases proportionally with decreasing gestational age²⁷. Furthermore, with the
23
24
25 333 widespread development of assisted reproductive technique (ART), the incidence of
26
27 334 monozygotic twins has increased significantly²⁸. The NMR of twins is several times higher
28
29
30 335 than that of singletons²⁹⁻³¹.

31
32
33 336

34
35
36 337 Addressing the issue of preterm birth may require different priorities in rural and urban
37
38 338 areas. Because of the good management of many curable neonatal complications (such as
39
40
41 339 pneumonia), the proportion of preterm birth in urban areas is obviously larger than that of
42
43
44 340 rural areas³². Hence, urban areas need to pay more attention to preventing premature deaths
45
46
47 341 less than 32 weeks of gestation. For rural areas, the local government needs to focus on the
48
49
50 342 prevention of premature infants at 32-36 weeks and continue to invest in medical services
51
52 343 to improve medical services accessibility for women and children in rural areas.

53
54
55 344

1
2
3
4 345 In addition, from 2014 to 2018, the neonatal mortality rate in rural areas due to preterm
5
6 346 birth, intrapartum complications, pneumonia, and congenital malformations was
7
8
9 347 decreasing in rural areas but was still significantly higher than in urban areas. (See **Table**
10
11
12 348 **2**) The higher mortality rate may be linked to the relatively poorer economy, lower quality
13
14 349 of health care, and lack of accessibility to health care in rural China. The average median
15
16 350 net income per capita was ¥39251 (about US \$6000) in urban China, but ¥14617 (about
17
18 351 the US \$2234) in rural China in 2018³³. The annual spending on health care per capita
19
20 352 accounted for 7.8% in urban China, but 10.2% in rural China in 2018³⁴. The average health
21
22 353 care personnel were 4.0 per 1000 people in urban China and 1.8 per 1000 people in rural
23
24 354 China in 2018³⁴. The number of beds in medical institutions per 1,000 people in urban areas
25
26 355 was 8.70, compared with 4.56 in rural areas in 2018³⁴.

27
28
29
30
31
32 356
33
34
35 357 Not only markedly difference the NMR of urban and rural areas has shown, but also
36
37 358 significantly difference in early and late neonates. The results of this study showed that the
38
39 359 range of cause-specific mortality of late neonates was significantly less than that of early
40
41 360 neonates, both nationwide and urban-rural areas. (See **Table 2**) Therefore, for preventable
42
43 361 neonatal diseases, the focus should be on early neonates, especially for early neonates in
44
45 362 rural areas.

46
47
48
49
50
51 363
52
53
54
55
56
57
58
59
60

1
2
3
4 364 For neonates, surviving from preterm birth, intrapartum complication and pneumonia are
5
6
7 365 close linking to accessibility to health care, local hospitals' obstetrics and neonates
8
9 366 departments' treatment level, and rescue skills^{35,36}. Therefore, the issue can be addressed
10
11
12 367 from the following four aspects.
13
14

15 368

16
17
18 369 Firstly, the local governments need to strengthen the construction of RNTN (Regional
19
20 370 Neonatal Transport Network), carry out the transport plan according to the Guidelines for
21
22
23 371 the Construction and Management of Critical Neonatal Treatment Center³⁷, and ensure the
24
25
26 372 applying of professional medical staff and newborn rescue equipment for neonatal
27
28
29 373 transport. Secondly, one study in Japan has pointed out that the medical care resources
30
31 374 (including Neonatal Intensive Care Unit (NICU), midwives, emergency physicians, and
32
33
34 375 emergency medical care centers) would impact the NMR decline³⁸. Therefore, the local
35
36
37 376 governments may base on the Administration guide (proposal) of the Neonatal Physician
38
39 377 Branch of the Chinese Physician Association³⁹ to grading neonatal wards and establishing
40
41
42 378 NICU after analyzing local medical establishment plan and newborn medical treatment
43
44
45 379 needs. Thirdly, local health departments can regularly organize multi-level, especially
46
47 380 provincial, prefecture-level and district-level) newborn health training programs. In rural
48
49
50 381 areas, with the policies support of the New Rural Construction and the Targeted Poverty
51
52 382 Alleviation^{40,41}, the improved rural transport and higher incomes have prompted the
53
54
55 383 enhanced accessibility of health services, and the proportion of rural children receiving

1
2
3
4 384 medical treatment in provincial and municipal hospitals has significantly increased. The
5
6
7 385 proportion of rural neonate diagnosis at the provincial (or municipal) level health facilities
8
9 386 has significantly increased from 39.2% to 47.6% from 2014 to 2018. Set training objectives
10
11 387 for medical staff in health facilities of different levels, and strengthen the newborn
12
13
14 388 treatment technology in each level of health facilities. Especially for the health workers in
15
16
17 389 rural areas, the newborn resuscitation training needs to be specifically strengthened.
18
19 390 Fourthly, the local communities can strengthen publicity to encourage caregivers to take
20
21 391 children to attend the health facilities for treatment. As for poor households, local
22
23
24 392 governments can set up special subsidies for them to reduce the economic cost of medical
25
26
27 393 treatment.
28
29

30
31 394

32 33 34 395 **Conclusion**

35
36
37 396 With the joint efforts of the economic development and the governmental policies and
38
39 397 strategies, the neonatal mortality rate of China has significantly decreased from 2014 to
40
41
42 398 2018. The gap between neonatal mortality and cause-of-death distribution still existed
43
44
45 399 between urban and rural areas. The goal of government interventions should be to narrow
46
47
48 400 the urban-rural gap, reduce the health inequality of neonates, and further take targeted
49
50
51 401 measures to eliminate the preventable death of neonates, especially premature births, to
52
53 402 achieve the SDGs goal.
54
55

56 403

1
2
3
4 404

5
6
7 405 **Acknowledgments**

8
9 406 We thank the institutions and staff of the National Maternal and Child Health Surveillance
10
11
12 407 System for data collection, data provided, and case investigation.

13
14
15 408

16
17 409 **Funding**

18
19 410 This study was supported by the Ministry of Health, China (grants QT2003-009 and
20
21
22 411 05wsb-02) and UNICEF (grant YH601-11-1141).

23
24
25 412

26
27 413 **Author contributions**

28
29
30 414 Data analysis: Yuxi Liu

31
32 415 Methodology: Hanmin Liu and Yanping Wang, Leni Kang

33
34
35 416 Data curation: Jun Zhu, Juan Liang, Lei Miao, Xiaoqiong Qiu, Weipeng Xia

36
37
38 417 Software: Chunhua He, Leni Kang and Qi Li

39
40 418 Writing – original draft: Yuxi Liu

41
42
43 419 Writing – review, and editing: Yuxi Liu, Hanmin Liu, and Yanping Wang

44
45
46 420

47
48 421 **Conflicts of interest**

49
50 422 The authors declare no conflicts of interest.

51
52
53 423

424 **Data Availability Statement**

425 This study used data from the NMCHSS. This system is co-established by the National
426 Health and Family Planning Commission of the People Republic of China and Sichuan
427 University and finally owned by the National Health and Family Planning Commission of
428 the People Republic of China. The researchers did not obtain consent to publicly share
429 data. The de-identified data set is available upon request to interested researchers. For data
430 requests, please contact the Department of Science and Technology of West China Second
431 University Hospital, Sichuan University, at: fu2yuankjb@163.com. This department is in
432 charge of all the programs in the hospital, including the data management. One staff from
433 the department monitors this email.

434

435 **References**

- 436 1. UN (2015) . Sustainable Development Goals. <https://sustainabledevelopment.un.org/?menu=1300>
437 (accessed 12th Mar 2020).
- 438 2. Department of Maternal and Child Health of China. 2019 report on development of maternal and child
439 health. Beijing, 2019.
- 440 3. The State Council Information office of the People's Republic of China. The impenmentation of
441 "National Program of Action for Child Development in China in 1990s" and "National Program of Action
442 for Child Development in China (2001-2010)". 2001. <http://www.china.org.cn/e-news/news01-4-27-1.htm>
443 (accessed Dec 10th 2020).
- 444 4. WHO, UNICEF, UN & World Bank Group (2019) . Levels & Trends in Child Mortality-Report 2019.
- 445 5. Zhang. CL. (2015) Analysis of surveillance results of 4074 children under 5 years old. Maternal and
446 Child Health Care of China. **30**: 5095-8.
- 447 6. WHO (2019). Newborns: reducing mortality. [https://www.who.int/news-room/fact-](https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality)
448 [sheets/detail/newborns-reducing-mortality](https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality) (accessed 12th Mar 2020).
- 449 7. Health Ministry of China. Health Statistical Yearbook of China, 1st edn. Beijing, China: Peking Union
450 Medical College press, 2013:201.

- 451 8. National Working Committee on Children and Women under State Council. National Program for
452 Women and Child Development. http://www.nwccw.gov.cn/node_2427.htm (accessed 12th Mar 2020).
- 453 9. UN (2000). Millennium Development Goal. <http://www.un.org/zh/millenniumgoals/getinvolved.shtml>
454 (accessed 12th Mar 2020).
- 455 10. Wang Y, Li X, Zhou M, et al. Under-5 mortality in 2851 Chinese counties, 1996-2012: a subnational
456 assessment of achieving MDG 4 goals in China. *Lancet* 2016; **387**(10015): 273-83.
- 457 11. National Bureau of Statistics of China (2016). China statistical yearbook 2016.
458 <http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm> (accessed 12th Mar 2020).
- 459 12. Ministry of Foreign Affairs of China & UN China (2015). Report on China's Implementation of the
460 Millennium Development Goals (2000-2015). [http://cn.chinagate.cn/reports/2015-
461 07/28/content_36164105.htm](http://cn.chinagate.cn/reports/2015-07/28/content_36164105.htm) (accessed 12th Mar 2020).
- 462 13. Kuruvilla S, Schweitzer J, Bishai D, et al. Success factors for reducing maternal and child mortality.
463 *Bull World Health Organ* 2014; **92**(7): 533-44b.
- 464 14. The development of China's Health Care and inhabitant's health status (2018) China Public Health
465 Statistical Yearbook 2018. Peking Union Medical College Publishing House.
- 466 15. The World Bank. Mortality rate, neonatal (per 1,000 live births). 2019.
467 <https://data.worldbank.org/indicator/SH.DYN.NMRT> (accessed Dec 11th 2020).
- 468 16. Wang Y, Zhu J, He C, Li X, Miao L, Liang J. Geographical disparities of infant mortality in rural China.
469 *Arch Dis Child Fetal Neonatal Ed* 2012; **97**(4): F285-90.
- 470 17. He C, Liu L, Chu Y, et al. National and subnational all-cause and cause-specific child mortality in
471 China, 1996-2015: a systematic analysis with implications for the Sustainable Development Goals. *Lancet
472 Glob Health* 2017; **5**(2): e186-e97.
- 473 18. Lu R, Li X, Guo S, et al. Neonatal mortality in the urban and rural China between 1996 and 2013: a
474 retrospective study. *Pediatr Res* 2016; **79**(5): 689-96.
- 475 19. Nichols EK, Byass P, Chandramohan D, et al. The WHO 2016 verbal autopsy instrument: An
476 international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med*
477 2018; **15**(1): e1002486.
- 478 20. Yaya S, Uthman OA, Okonofua F, Bishwajit G. Decomposing the rural-urban gap in the factors of
479 under-five mortality in sub-Saharan Africa? Evidence from 35 countries. *BMC Public Health* 2019; **19**(1):
480 616.
- 481 21. Saikia, N., Singh, A., Jasilionis, D., et al. Explaining the rural-urban gap in infant mortality in India.
482 *Demographic Research*, 29(18), 473-506.
- 483 22. National health commission, National development and reform commission, the Ministry of Education,
484 the Ministry of Finance, the Ministry of human resources and social security & National Administration of
485 Traditional Chinese Medicine (NATCM) (2016). Circular on the issuance of opinions on strengthening the
486 reform and development of children's medical and health services.
487 http://www.mohrss.gov.cn/SYrlzyhshbzb/shehuibaozhang/zcwj/yiliao/201606/t20160601_241098.html
488 (accessed 2nd May 2020).
- 489 23. UNICEF (2012). Maternal and neonatal tetanus eliminated in China. [https://www.unicef.cn/en/press-
490 releases/maternal-and-neonatal-tetanus-eliminated-china](https://www.unicef.cn/en/press-releases/maternal-and-neonatal-tetanus-eliminated-china) (accessed 2nd May 2020).
- 491 24. Wang AL, Qiao YP, Wang LH, et al. Integrated prevention of mother-to-child transmission for human

- 1
2
3 492 immunodeficiency virus, syphilis and hepatitis B virus in China. *Bull World Health Organ* 2015; **93**(1): 52-
4 493 6.
5
6 494 25. China CDC (2011) . Prevention of mother-to-child transmission of HIV, syphilis and hepatitis b (2011-
7 495 2013). http://www.chinacdc.cn/gwswwx/fyzz/201107/t20110704_48397.html (accessed 2nd May 2020).
8
9 496 26. Institute of party history and literature of the CPC central committee (2019). Memorabilia of the
10 497 People's Republic of China (October 1949 -- September 2019)
11 498 <http://cpc.people.com.cn/n1/2019/0928/c419242-31378078.html> (accessed 3rd May 2020).
12 499 27. Boghossian NS, Geraci M, Edwards EM, Horbar JD. Morbidity and Mortality in Small for Gestational
13 500 Age Infants at 22 to 29 Weeks' Gestation. *Pediatrics* 2018; **141**(2).
14 501 28. Gee RE, Dickey RP, Xiong X, al. e. Impact of monozygotic twinning on multiple births resulting from
15 502 in vitro fertilization in the United States, 2006-2010. *Am J Obstet Gynecol* 2014; **210**(5): 468.e1-6.
16 503 29. Imaizumi Y, Hayakawa K. Infant mortality among singletons and twins in Japan during 1999-2008 on
17 504 the basis of risk factors. *Twin Res Hum Genet* 2013; **16**(2): 639-44.
18 505 30. Saleh Jafarian MA, Mahmoud Mobasher. The Effect of Twin Birth on Neonatal and Infant Mortality
19 506 Rates: A Systematic Review. *International Journal of Epidemiologic Research* 2018; **Summer 5**(3): 113-8.
20 507 31. Monden CWS, Smits J. Mortality among twins and singletons in sub-Saharan Africa between 1995 and
21 508 2014: a pooled analysis of data from 90 Demographic and Health Surveys in 30 countries. *Lancet Glob*
22 509 *Health* 2017; **5**(7): e673-e9.
23 510 32. Liang J, Mao M, Dai L, et al. Neonatal mortality due to preterm birth at 28-36 weeks' gestation in China,
24 511 2003-2008. *Paediatr Perinat Epidemiol* 2011; **25**(6): 593-600.
25 512 33. National Bureau of Statistics of China. Personal income and consumer spending in 2018. 2019.
26 513 http://www.stats.gov.cn/tjsj/zxfb/201901/t20190121_1645791.html.
27 514 34. National Health Commission of China. China Health Statistics Yearbook 2019. Beijing, 2020.
28 515 35. World Health Organization, Dept. of Reproductive Health and Research; United Nations Population
29 516 Fund; UNICEF (2003). Managing newborn problems: A guide for doctors, nurses and midwives.
30 517 36. Bryce J, Boschi-Pinto C, Shibuya K, et al. WHO estimates of the causes of death in children. *Lancet*.
31 518 2005; **365**(9465):1147-1152.
32 519 37. The National Health Commission of China (2017). Guidelines for the Construction and Management
33 520 of Critical Neonatal Treatment Center.
34 521 <http://www.nhc.gov.cn/fys/s3581/201801/1048948966a44067974a44187c6a8912.shtml> (accessed 28th Apr
35 522 2020).
36 523 38. Matsumoto Y, Nakai A, Nishijima Y, et al. Absence of neonatal intensive care units in secondary
37 524 medical care zones is an independent risk factor of high perinatal mortality in Japan. *J Obstet Gynaecol Res*
38 525 2016; **42**(10): 1304-9.
39 526 39. Neonatal Physician Branch of Chinese Physician Association (2013). Guidelines for graded
40 527 construction and management of neonatal wards in China (proposal). *Chin J Appl Clin Pediatr*, February,
41 528 28(3). 231-239.
42 529 40. Office of the central leading group for financial and economic affairs of China (2006). Five mechanisms
43 530 of the new socialist countryside. <http://finance.people.com.cn/GB/1037/4132493.html> (accessed 2nd May
44 531 2020).
45 532 41. Zhou Y, Guo, Y.,Liu, Y, et al. . Targeted poverty alleviation and land policy innovation: Some practice

1
2
3 533 and policy implications from China. Land Use Policy, 74(74), 53-65.
4

5 534
6

7
8 535
9

10
11 536
12

13
14 537
15

16
17 538
18

19
20
21 539
22

23
24 540
25

26
27 541
28

29
30
31 542
32

33
34 543
35

36
37 544 Figure 1. The national and urban-rural neonatal mortality rates (per 1,000 live births) in
38

39
40 545 China between 2014 and 2018
41

42
43 546 Figure 2A. Causes of deaths in neonates in China, 2018
44

45
46 547 Figure 2B. Causes of deaths in neonates in urban China, 2018
47

48
49 548 Figure 2C. Causes of deaths in neonates in rural China, 2018
50

51 549 Figure 3. The proportion of neonatal diagnose level in China from 2014 to 2018
52

53
54 550
55

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

551

For peer review only

Figure 1. The national and urban–rural neonatal mortality rates (per 1,000 live births) in China between 2014 and 2018

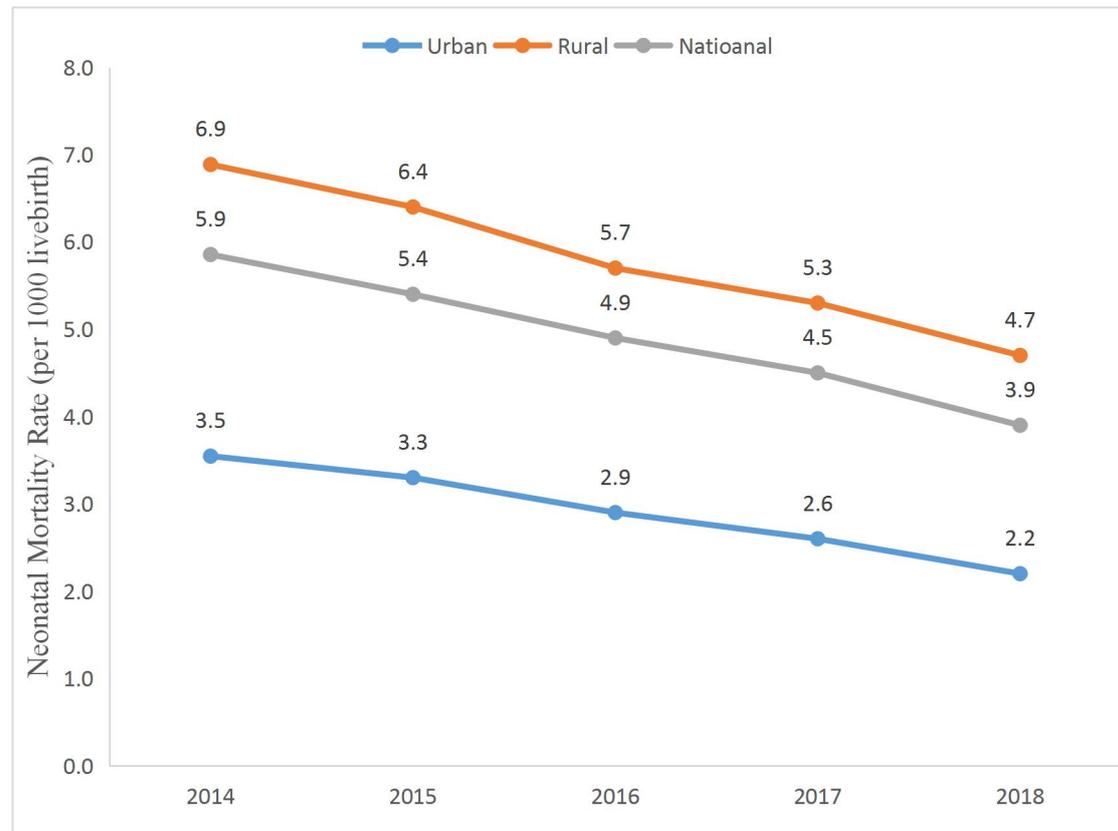


Figure 3. The proportion of neonatal diagnose level in China from 2014 to 2018

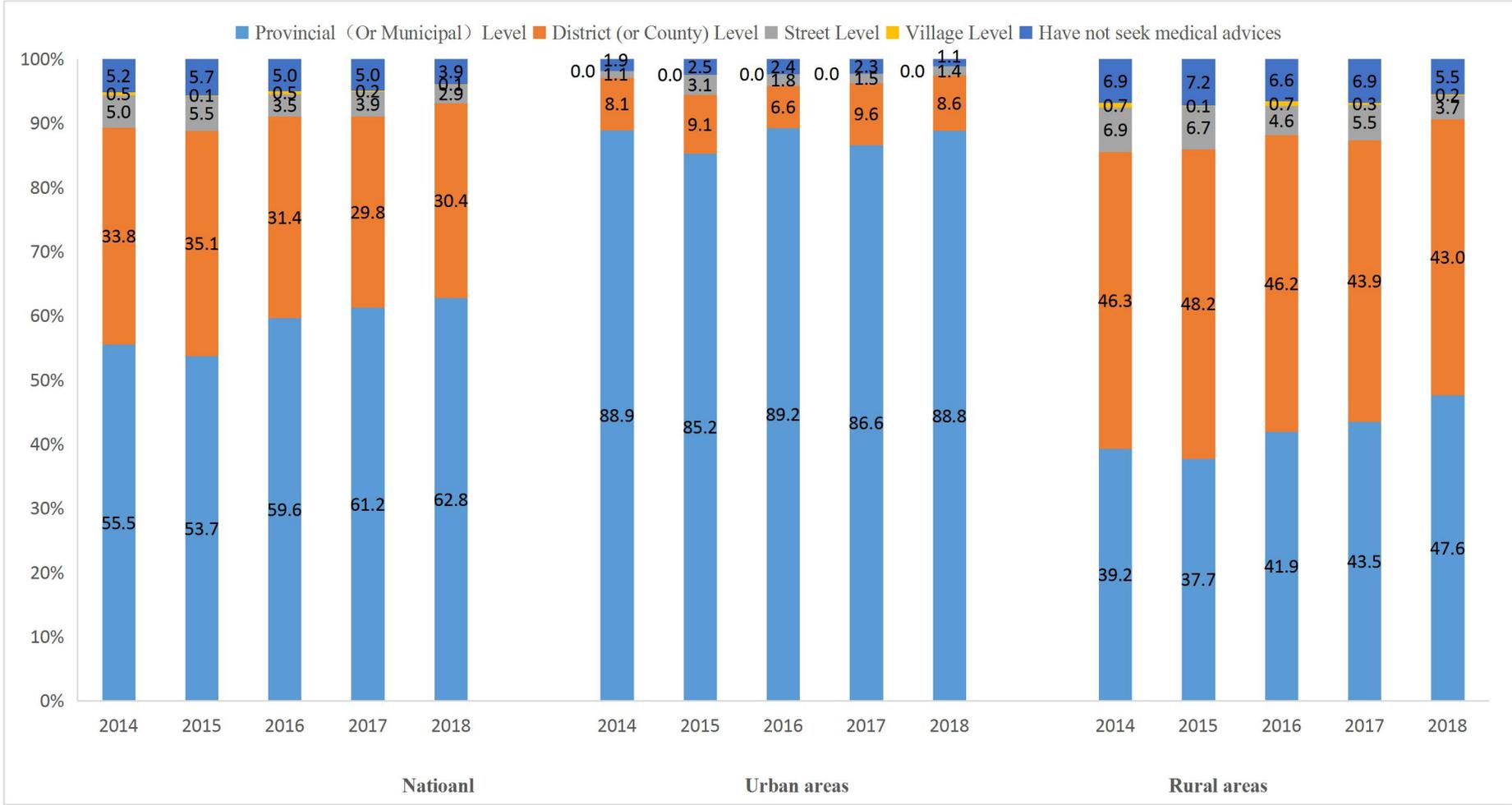


Figure 2A. Causes of deaths in neonates in China, 2018

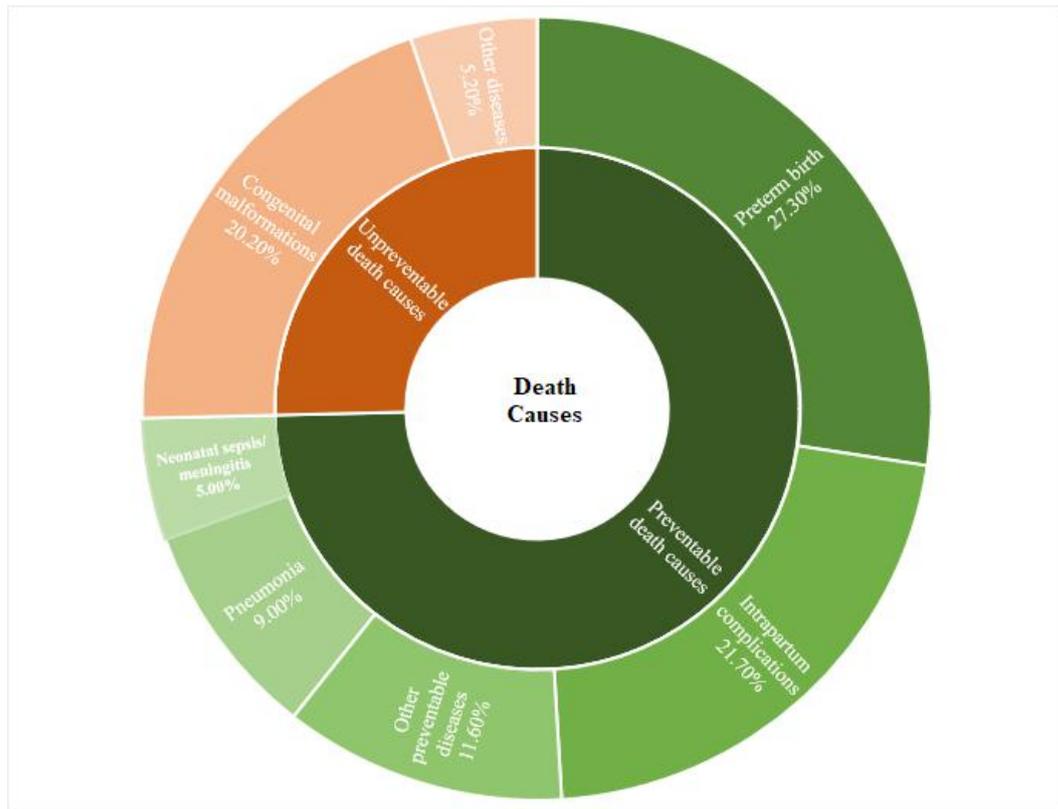
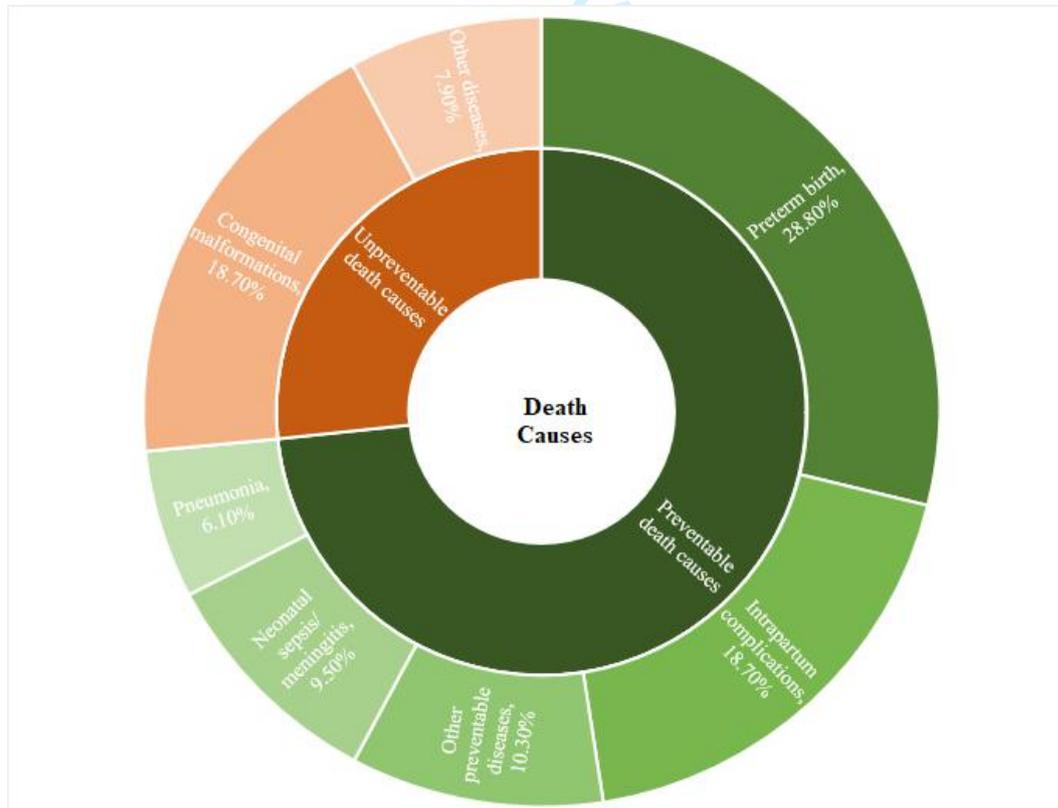
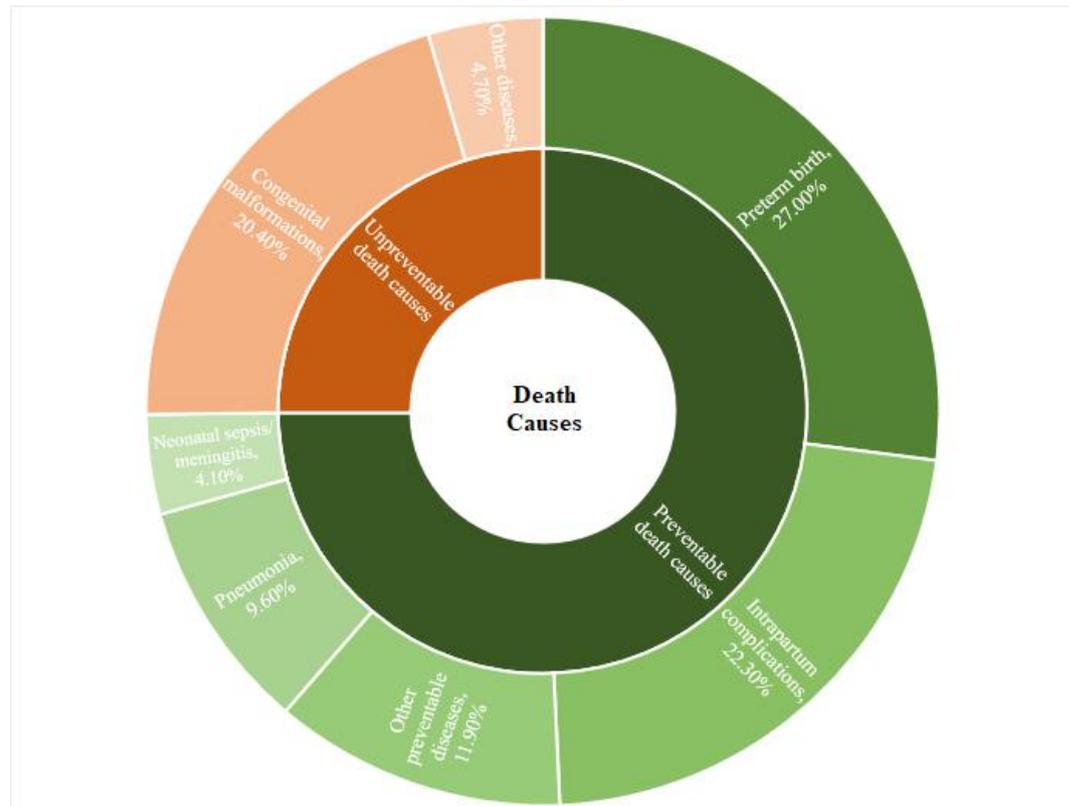


Figure 2B. Causes of deaths in neonates in urban China, 2018



1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 2C. Causes of deaths in neonates in rural China, 2018



review only

BMJ Open

Neonatal mortality and leading causes of deaths: a descriptive study in China, 2014-2018

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042654.R2
Article Type:	Original research
Date Submitted by the Author:	19-Jan-2021
Complete List of Authors:	<p>Liu, Yuxi; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Kang, Leni; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China He, Chunhua; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Miao, Lei; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Qiu, Xiaoqiong; Pidun district people's hospital, Chengdu, Sichuan Xia, Weipeng; Second People's Hospital of Zhaotong, Zhaotong, Yunnan, Department of Pediatrics Zhu, Jun; Sichuan University West China Second University Hospital, Key Laboratory of Birth Defects and Related Diseases of Women and Children of the Ministry of Education, West China Second University Hospital, Sichuan University, Chengdu, China; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Liang, Juan; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Li, Qi; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Wang, Yanping; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China Liu, Min; Sichuan University West China Second University Hospital, Department of Pediatrics</p>
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, NEONATOLOGY

SCHOLARONE™
Manuscripts

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3
4 1 **Neonatal mortality and leading causes of deaths: a descriptive study in China, 2014-**
5
6 2 **2018**
7
8
9
10 3

11
12
13 4 Yuxi Liu, MIPH, MHM^a; Leni Kang, PhD^a; Chunhua He, MD^a; Lei Miao, MD^a; Xiaoqiong
14 5 Qiu, MD^d; Weipeng Xia, MD^e; Jun Zhu, MD^{a,c}; Juan Liang, MD^a; Qi Li, MD^a; Yanping
15 6 Wang, MD^{a▲}; Hanmin Liu, PhD^{b,c▲}.
16
17
18
19
20
21
22 7

23
24
25 8 ^a National Office for Maternal and Child Health Surveillance of China, West China Second
26 9 University Hospital, Sichuan University, Chengdu, Sichuan, China
27

28
29
30
31 10 ^b Department of Pediatrics, West China Second University Hospital, Sichuan University,
32 11 Chengdu, China
33
34
35
36

37 12 ^c Key Laboratory of Birth Defects and Related Diseases of Women and Children of the
38 13 Ministry of Education, West China Second University Hospital, Sichuan University,
39 14 Chengdu, China
40
41
42
43
44

45
46 15 ^d Pidu district people's hospital, Chengdu, Sichuan, China
47
48

49 16 ^e Department of Pediatrics, Second People's Hospital of Zhaotong, Zhaotong, Yunnan,
50 17 China
51
52
53
54

1
2
3
4 18
5
6
7
8
9

10
11 19
12

13
14
15
16
17
18 20 ▲ These authors contributed equally to this work.
19

20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

20 21
22 **Corresponding authors:** Yanping Wang, National Office for Maternal and Child Health
23 Surveillance of China, West China Second University Hospital, Sichuan University,
24 Chengdu, Sichuan, China, email: wyxianping@163.com; and Hanmin Liu; Department of
25 Pediatrics, West China Second University Hospital, Sichuan University, Chengdu, China,
26 email: hanmin@vip.163.com

27

28

29

30

31

32

33

34

35

36

37

38

39

40

41

42

43 **Abstract**

44 **Objective:** The present study estimated the national and urban-rural levels and causes of
45 neonatal deaths in China annually between 2014 and 2018 to provide data support for the
46 further end of preventable neonatal deaths for China and other low-and middle-income
47 countries.

48 **Methods:** The study was based on data from the National Maternal and Child Health
49 Surveillance System (NMCHSS). All neonates of surveillance districts (gestational week
50 ≥ 28 weeks) who died after delivery have been involved in the study. The mortality rate and

1
2
3 51 the leading causes of death for neonates were analyzed.
4
5
6

7 52 **Results:** The NMR (Neonatal Mortality Rate) of China has steadily decreased from 5.9
8
9
10 53 deaths per 1000 live births in 2014 to 3.9 deaths per 1000 live births in 2018. The NMR in
11
12 54 2018 of urban and rural areas was 2.2 deaths per 1000 live births and 4.7 deaths per 1000
13
14
15 55 live births, respectively. The leading preventable causes of neonatal deaths are the same in
16
17 56 the urban and rural areas were same, which were preterm birth, intrapartum complications,
18
19
20 57 and pneumonia. Mortality rates of these three causes fell significantly between 2014 and
21
22 58 2018 but contributed to a higher proportion of deaths in rural areas than urban areas. The
23
24
25 59 proportion of preventable deaths accounted for 73.9% in 2018.
26
27

28 60 **Conclusions:** The NMR of China has decreased steadily from 2014 to 2018. However, the
29
30
31 61 inequality between urban and rural areas still exists. The goal of government interventions
32
33
34 62 should be to reduce the health inequality of neonates and further take targeted measures to
35
36 63 eliminate preventable neonatal death.
37
38

39 64 **Keywords:** neonatal mortality, leading cause, Surveillance, inequality, China
40
41
42
43
44
45

46 66 **Strengths and limitations of this study**

47
48

- 49 67 • This is the first study to show the status of neonatal deaths in China from 2014 to 2018.
50
51
52
53
54

- 1
2
3
4 68 • The study covers the most geographically extensive newborn population in mainland
5
6
7 69 China.
8
9
10 70 • The data from the National Maternal and Child Health Surveillance System used in this
11
12 71 study have been shown to be representative of mainland China and to be of high quality
13
14
15 72 for the recording of death causes of children under 5.
16
17
18 73 • The system has not covered the pre-natal assessment due to design limitations.
19
20
21
22 74
23
24
25 75
26
27
28 76
29
30
31
32 77
33
34
35 78
36
37
38 79
39
40
41
42 80
43
44

45 81 **Introduction**

46
47
48
49 82 In 2015, the United Nations (UN) summit on sustainable development formally adopted
50
51 83 the 2030 agenda for sustainable development. In the Sustainable Development Goals 3
52
53
54

1
2
3
4 84 (SDGs3), the goal is to end preventable neonatal and under-five child deaths by 2030¹,
5
6
7 85 with all countries aiming to reduce neonatal mortality to at least as low as 12 deaths per
8
9 86 1,000 live births and under-five mortality to at least as low as 25 deaths per 1,000 live
10
11
12 87 births. The importance of newborn health issues has received global attention. The Chinese
13
14 88 government has always attached great importance to the survival, protection, and
15
16
17 89 development of children, and has made great achievements in reducing child mortality.
18
19
20 90 Professional institutions for maternal and child health care began to be established in 1950².
21
22 91 Moreover, the Chinese government has taken the under-five mortality rate (U5MR), the
23
24 92 infant mortality rate (IMR), and other indicators of children's health as assessment targets
25
26
27 93 for provincial governments, and has promulgated the National Program of Action for Child
28
29
30 94 Development in China every decade since 1990s^{2,3}.

31
32
33 95
34
35
36
37 96 Globally, there were 5.3 million deaths occurred on children under 5 in 2018, 47% of them
38
39 97 died during their first month of life. The vast majority of neonatal deaths occur in low -
40
41
42 98 and middle-income countries. Approximately 73,000 neonates died in China in 2018,
43
44
45 99 accounting for about 3.0% of the total newborn deaths worldwide, ranking sixth in the
46
47
48 100 world⁴. Moreover, the global decline in neonatal mortality rate (NMR) has been slower
49
50 101 than the decline in the U5MR⁵. Global U5MR declined from 93 per 1,000 live births in
51
52 102 1990 to 39 per 1,000 live births in 2018, while that of NMR only declined from 37 per
53
54

1
2
3
4 103 1,000 live births to 18 per 1,000 live births during the same period. Additionally, a great
5
6 104 many studies have shown that neonatal deaths amounting to a large proportion of total
7
8
9 105 mortality of children under 5⁵⁻⁷. Therefore, reducing preventable neonatal deaths is
10
11
12 106 important to further reduce the U5MR.
13
14
15 107

16
17
18 108 China has achieved the MDG4 (Millennium Development Goal 4) eight years ahead of
19
20
21 109 schedule in 2007⁸⁻¹³, and it is also rated by the World Health Organization as a country
22
23
24 110 with "high performance in maternal and child health". In 2018, the NMR of China was 3.9
25
26 111 deaths per 1000 live births, which was lower than the target of SDG3¹⁴. However,
27
28
29 112 according to the NMR data from World Bank in 2018, the NMR of China is at a low level
30
31
32 113 in developing countries (such as the NMR in Brazil was 8.1 deaths per 1000 live births,
33
34 114 and Thailand was 5.0 deaths per 1000 live births), it still lags behind that in developed
35
36
37 115 countries (such as the NMR in Australia was 2.3 deaths per 1000 live births, and Germany
38
39 116 was 2.2 deaths per 1000 live births)¹⁵. Moreover, since urban areas generally have better
40
41
42 117 economic development than rural areas, resulting in better health service infrastructure and
43
44
45 118 health service infrastructures¹⁶, there is an urban-rural inequity in neonatal mortality in
46
47
48 119 China¹⁷. To further shorten the gap with developed countries, and reduce the difference in
49
50
51 120 neonatal mortality between urban and rural areas, there is still room for improvement in
52
53 121 neonatal deaths in China. This study will analyze neonatal mortality trends and its mortality
54

1
2
3
4 122 of major causes of death in China from 2014 to 2018 to provide data support for the further
5
6 123 elimination of key preventable diseases that can cause neonatal deaths.
7
8
9

10 124

11 12 13 125 **Materials and Methods**

14 15 16 126 *Study subjects*

17
18
19
20 127

21
22
23 128 The study covered all the 327 districts of the National Maternal and Child Health
24
25 129 Surveillance Districts (with 124 urban districts and 203 rural districts) in 31 provinces,
26
27 130 autonomous regions, and municipalities of China. Further details about the National
28
29 131 Maternal and Child Health Surveillance System (NMCHSS) have been described
30
31 132 elsewhere¹⁸.
32
33
34
35
36
37
38
39
40

41 134 All neonates of surveillance districts (gestational week ≥ 28 weeks) who died after delivery,
42
43 135 and had one of the four vital signs would be involved in surveillance subject, including
44
45 136 heartbeat, breath, umbilical cord pulsation, and voluntary muscle contraction. The
46
47 137 surveillance subject also includes adoption children and children of non-local household
48
49
50 138 residents whose mothers have living in the surveillance districts for more than one year.
51
52
53
54

1
2
3
4 1395
6
7 140 *Data collection and quality control*

8
9
10 141 After each child died in the surveillance districts, the local village doctor (or community
11
12
13 142 doctor) needs to report to the local township health centers (or community health service
14
15
16 143 centers) within 10 days. Local township health centers (or community health service
17
18 144 centers) need to be verified within 7 days after reporting and fill the Child Death Report
19
20
21 145 Card based on the hospital's death diagnosis. If the child died at home or on the way to the
22
23
24 146 health facilities, infer the cause of death would base on the 2016 WHO Verbal Autopsy
25
26 147 Standards¹⁹ and then fill the Child Death Report Card. The classification of diseases
27
28
29 148 according to the international classification of diseases-10 (ICD-10).

30
31
32 149

33
34
35 150 The children's mortality data was reported level by level, and the data is timely reported
36
37
38 151 through the network direct reporting system. Technical personnel responsible for
39
40
41 152 monitoring work are set up at all levels to complete the collection, review, and operation
42
43 153 of surveillance data. The completed child death data would send to the county (or district)
44
45
46 154 level maternal and child health institutions each season. The county (or district) level
47
48
49 155 maternal and child health institutions would report the local child deaths status to
50
51 156 prefecture-level and province-level maternal and child health institutions each season, the

1
2
3
4 157 National Office of Maternal and Child Health would summarize and analyzes the data
5
6
7 158 finally.
8
9

10 159

11
12
13 160 For quality control, we have used the regular level-by-level on-site quality control system.

14
15 161 At the county (district), city, and provincial levels, following the requirements of the

16
17
18 162 Chinese Maternal and Child Health Surveillance Work Manual, a multi-source data cross-

19
20
21 163 check method is used to complete the on-site quality control work in sampling surveillance

22
23 164 districts. The National Office of Maternal and Child Health will select 18 districts in 6

24
25
26 165 provinces each year for quality inspection^{17,18}.

27
28
29 166
30
31

32 167 *Statistical analysis*

33
34
35
36 168 Results were collected in Microsoft Excel and analyzed using SPSS 22.0 (IBM, Armonk,

37
38 169 NY, USA). The neonatal mortality rates (NMR) of different areas (urban areas & rural

39
40
41 170 areas) and stages (early neonates & late neonates), and the main cause-specific mortality

42
43
44 171 rates were corrected using the average underreporting rate of the national-level surveillance

45
46 172 data quality checks in the past three years. The national NMR and the main cause-specific

47
48
49 173 mortality rate were weighted calculated according to the proportion of the urban and rural

50
51 174 population in the census. The diagnostic level composition ratio of the neonate is calculated

1
2
3
4 175 based on the reported Child Death Report Card, excluding children who died of accidental
5
6 176 injuries¹⁷.

7
8
9
10 177

11
12
13 178 The Poisson regression model was used to calculate the average annual rate of decline of
14
15 179 NMR, cause-of-death mortality, and its 95% confidence interval in the country, urban and
16
17
18 180 rural areas, and its 95% confidence interval in early and late neonates, respectively. Linear
19
20
21 181 by the linear association in the chi-square test using SPSS software was used to test whether
22
23 182 there was a linear downward trend in different regions and causes of death.

24
25
26
27 183

28
29
30 184 *Ethics approval and consent to participate*

31
32
33 185 This study was approved by the Ethics Committee of West China Second University
34
35
36 186 Hospital, Sichuan University, China.

37
38
39 187

40
41
42 188 *Patient and public involvement*

43
44
45 189 Patients and members of the public were not involved in the design of this study.

46
47
48
49 190

50
51
52 191 **Result**

1
2
3
4 192 *1. The NMR of China from 2014 to 2018*

5
6
7 193 At the national level, the NMR of China has steadily decreased from 5.9 deaths per 1000
8
9
10 194 live births in 2014 to 3.9 deaths per 1000 live births in 2018 ($p<0.001$), the average
11
12 195 annual rate of decline was 10.7%. The NMR of urban and rural areas have both showed a
13
14
15 196 declining trend in the same period ($p<0.001$). The mortality rate of urban areas
16
17 197 decreased from 3.5 deaths per 1000 live births to 2.2 deaths per 1000 live births, with the
18
19
20 198 average annual rate of decline was 13.0%. In rural areas, the NMR decreased significantly
21
22 199 from 2014 to 2018 (6.9 deaths per 1000 live births to 4.7 deaths per 1000 live births, the
23
24
25 200 average annual rate of decline was 10.6%, $p<0.001$). The absolute difference between
26
27
28 201 NMR of urban and rural areas has reduced from 3.4 deaths per 1000 live births to 2.5 deaths
29
30
31 202 per 1000 live births, but the relative difference has increased from 2.0 to 2.2. (See **Figure**
32
33 203 **1**)

34
35
36
37 204
38
39
40 205 *2. Cause of neonates mortality in China from 2014 to 2018*

41
42
43 206 Nationwide, compared with 2014, the neonatal deaths caused due to preterm birth,
44
45 207 intrapartum complication, and pneumonia in 2018 have sharply decreased. Among the
46
47
48 208 particular diseases, the intrapartum complications have the highest average annual decline
49
50
51 209 rate (AADR) from 2014 to 2018 (with 13.5%, $p<0.001$). The smallest AADR belonged to
52
53
54 210 Tetanus (with 0.8%, $p<0.05$). In any given year, preterm birth, intrapartum complication,

1
2
3
4 211 and pneumonia were the top three leading causes of neonatal death in China, total
5
6 212 accounting for nearly 60%. (See **Table 1**) In 2018, all deaths causes have been divided into
7
8
9 213 preventable diseases and unpreventable diseases to analyze the proportion. The proportion
10
11
12 214 of preventable diseases reached 73.9%. Moreover, the top three diseases at the national
13
14 215 level were preterm birth, intrapartum complications, and congenital malformations. (See
15
16
17 216 **Figure 2A**)

217 Table 1. The proportion of cause-specific neonatal mortality in China from 2014 to 2018

Causes of death	0-6 days					7-28 days					0-28 days				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Nationalwide															
Preterm birth	32.3	33.1	32.0	36.2	26.7	19	24.2	19.9	22.3	28.8	29.1	30.8	28.7	32.2	27.3
Intrapartum complications	29.0	31.9	27.0	26.4	28.5	8.4	7.1	6	6.2	5.6	24.2	25.5	21.4	20.6	21.7
Pneumonia	9.5	6.9	9.0	8.0	7.9	17.3	13.5	18	18.2	11.5	11.3	8.6	11.4	11	9
Diarrhea	0.1	0.0	0.0	0.0	0.2	1.3	2	1.1	0.2	1	0.4	0.5	0.3	0	0.4
Tetanus	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.1	0	0	0	0
HIV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Neonatal sepsis/meningitis	1.6	2.1	2.7	2.4	3.0	5.3	4.3	7.5	5.8	9.8	2.5	2.6	4	3.3	5
Other infectious diseases	0.3	0.3	0.2	0.3	0.0	0.3	0.0	0.4	0.0	0.0	0.3	0.2	0.3	0.2	0
Congenital	15.5	12.5	16.1	16.7	19.0	23.4	22.8	26.4	22.7	22.8	17.4	15.2	18.9	18.5	20.2

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

malformations															
Other diseases	11.7	13.2	12.9	9.9	14.7	24.4	26.1	20.7	24.6	20.5	14.7	16.6	15	14.2	16.4
Urban area															
Preterm birth	35.5	30	26.6	36.5	29.1	15.5	24.6	22.8	19.8	27.9	31.4	28.6	25.5	31.8	28.8
Intrapartum complications	28	30	28.2	27.8	24.3	18.1	10.4	5.5	11.2	6.4	25.9	24.6	21.8	23.2	18.7
Pneumonia	7.3	7.9	10.7	6.4	5.3	11.3	8.2	15.1	14.5	8.1	8.1	8	12	8.6	6.1
Diarrhea	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.0	0.7	0.9	0.2	0.2	0	0.2	0.3
Tetanus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
HIV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Neonatal sepsis/meningitis	2.7	2.5	4.7	4.3	8.1	3.4	7.5	8.3	12.4	12.6	2.9	3.9	5.7	6.6	9.5
Other infectious diseases	0.7	0.9	0.5	0.8	0.0	0.0	0.0	0.7	0.0	0	0.5	0.6	0.6	0.5	0
Congenital malformations	17.3	16.4	17.8	16.3	15.4	32.8	28.4	24.2	20.4	26.2	20.5	19.7	19.6	17.5	18.7

Other diseases	8.4	12.2	11.5	7.9	17.8	18.1	20.1	23.4	21.0	17.9	10.5	14.4	14.9	11.6	17.9
Rural area															
Preterm birth	31.5	33.7	33.2	36.1	26.2	19.6	24.1	19.1	22.9	29	28.6	31.3	29.5	32.3	27
Intrapartum complications	29.2	32.3	26.8	26.1	29.3	6.4	6.2	6.1	5.2	5.4	23.8	25.7	21.3	20.1	22.3
Pneumonia	10.0	6.7	8.7	8.4	8.4	18.6	14.8	18.7	18.9	12.4	12	8.7	11.3	11.5	9.6
Diarrhea	0.1	0.0	0.0	0.0	0.2	1.4	2.4	1.3	0.0	1.1	0.4	0.6	0.3	0	0.5
Tetanus	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.2	0	0	0	0
HIV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
Neonatal sepsis/meningitis	1.3	2.0	2.2	1.9	2.0	5.7	3.5	7.4	4.3	9.1	2.4	2.4	3.6	2.6	4.1
Other infectious diseases	0.2	0.1	0.2	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.3	0.1	0.2	0.1	0
Congenital malformations	15.1	11.7	15.7	16.8	19.8	21.4	21.4	27.0	23.3	22.0	16.6	14.1	18.7	18.7	20.4
Other diseases	12.5	13.5	13.2	10.4	14.0	25.7	27.6	20.0	25.4	21.0	15.7	17.1	15	14.7	16.1

1
2
3
4
5 218
6
7 219
8
9 220
10
11 221
12
13 222
14
15
16 223

Table 2. Leading causes of death in neonates in China from 2014 to 2018

Causes of death	Cause-specific mortality (per 100,000livebirths)																	
	0-6 (<7) days newborns						7-27 days newborns						0-27 (<28) days newborns					
	2014	2015	2016	2017	2018	Average annual decline rate (%)	2014	2015	2016	2017	2018	Average annual decline rate (%)	2014	2015	2016	2017	2018	Average annual decline rate (%)
Nationalwide																		
Preterm birth	144.8	133.5	113.8	115.7	73.4	12.7 (15.1,10.2)**	25.9	33.7	26.0	28.7	33.2	-3.2 (2.4,-9.1) △	170.7	167.2	139.8	144.4	106.6	9.7 (7.4, 11.9)**
Intrapartum	130.2	128.7	96.1	84.5	78.2	13.5	11.5	9.8	7.8	8.0	6.4	12.7	141.7	138.5	103.9	92.5	84.6	13.5 (11.0,

complications						(16.1,10.9)**						(21.3,3.3)**						15.9)**
Pneumonia	42.4	27.9	32.1	25.7	21.7	13.6 (18.3,8.7)**	23.7	18.8	23.6	23.4	13.3	7.2 (13.1,0.8) *	66.1	46.7	55.7	49.1	35	11.0 (7.1, 14.7)**
Diarrhea	0.4	0.0	0.0	0.0	0.5	-	1.8	2.8	1.4	0.2	1.2	24.5 (41.7,2.1) Δ	2.2	2.8	1.4	0.2	1.7	20.1 (- 2.0, 37.4) Δ
Tetanus	0.0	0.0	0.0	0.0	0.0	-	0.8	0.0	0.0	0.0	0.0	-	0.8	0	0	0	0	-
HIV	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-
Neonatal sepsis/meningitis	7.2	8.4	9.4	7.6	8.3	-2 (8.2,-13.3) Δ	7.3	5.9	9.9	7.4	11.3	-12.1 (-0.9,- 24.5)*	14.5	14.3	19.3	15	19.6	-6.5 (- 14.7, 1.2) Δ
Other infectious diseases	1.4	1.1	0.8	0.9	0.0	30.1 (51,0.3) Δ	0.4	0.0	0.6	0.0	0.0	35.6 (68,- 29.5) Δ	1.8	1.1	1.4	0.9	0	33.1 (7.9, 51.4)*
Congenital malformations	69.8	50.6	57.3	53.5	52.3	5.6 (9.3,1.8) **	31.9	31.7	34.6	29.3	26.2	4.3 (9.4,-1) Δ	101.7	82.3	91.9	82.8	78.5	5.1 (2.0, 8.1)**
Other diseases	52.8	53.6	45.9	31.6	40.2	10.4	33.3	36.4	27.1	31.8	23.6	7.4 (12.3,2.2)	86.1	90	73	63.4	63.8	9.2 (5.9,

						(14.3,6.2)**							**						12.3)**
Urban area																			
Preterm birth	99.7	70.9	55.6	69.6	44.2	15 (19.4,10.4)**	11.5	22.0	18.9	14.7	19.1	-4.2 (6.2,- 15.7) Δ	111.2	92.9	74.5	84.3	63.3	11.4 (7.1, 15.5)**	
Intrapartum complications	78.6	70.9	59.0	53.1	36.9	15.8 (20.5,10.9)**	13.4	9.3	4.6	8.3	4.3	21.2 (32.7,7.9)*	92	80.2	63.6	61.4	41.2	16.4 (11.8, 20.7)**	
Pneumonia	20.4	18.7	22.3	12.2	8.0	18 (26.5,8.5) **	8.4	7.4	12.6	10.7	5.5	2.7 (15.8,- 12.4) Δ	28.8	26.1	34.9	22.9	13.5	12.4 (4.5, 19.7)**	
Diarrhea	0.0	0.0	0.0	0.0	0.0	-	0.6	0.7	0.0	0.5	0.6	2.7 (51.8,- 96.6) Δ	0.6	0.7	0	0.5	0.6	2.7 (- 96.6, 51.8) Δ	
Tetanus	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-	
HIV	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-	
Neonatal sepsis/meningitis	7.7	6.0	9.7	8.3	12.3	-13.8 (1.9,- 32.1) Δ	2.5	6.7	6.9	9.2	8.6	-25.5 (-5.7,- 49.1)**	10.2	12.7	16.6	17.5	20.9	2.7 (- 96.6,	

																			51.8)**
Other infectious diseases	1.9	2.0	1.1	1.5	0.0	33 (56,-1.9) △	0.0	0.0	0.6	0.0	0.0	2.7 (76.2,-297.1) [△]	1.9	2	1.7	1.5	0	25.2 (-7.7, 48.1) [△]	
Congenital malformations	48.6	38.8	37.2	31.2	23.3	14.9 (20.9,8.4)**	24.3	25.4	20.1	15.1	17.9	10.8 (19,1.8)*	72.9	64.2	57.3	46.3	41.2	13.6 (8.4, 18.5)**	
Other diseases	23.6	28.7	24.1	15.1	27.0	3.5 (11.8,-5.5) [△]	13.5	18.1	19.4	15.6	12.3	3.3 (13.3,-7.8) △	37.1	46.8	43.5	30.7	39.3	3.2 (-3.7, 9.7) △	
Rural area																			
Preterm birth	165.0	161.4	139.8	136.2	86.4	12 (15.2,8.8) **	32.2	38.9	29.1	35.1	39.5	-4.1 (2.9,-11.7) [△]	197.2	200.3	168.9	171.3	125.9	9.2 (6.3, 12.1)**	
Intrapartum complications	153.2	154.5	112.6	98.5	96.6	13.1 (16.3,9.7)**	10.6	10.0	9.3	8.0	7.4	8.2 (20.2,-5.5) △	163.8	164.5	121.9	106.5	104	12.8 (9.5, 15.9)**	
Pneumonia	52.3	32.0	36.4	31.7	27.8	12.9 (18.8,6.5)**	30.5	23.9	28.5	29.1	16.9	7.6 (14.9,-0.4) △	82.8	55.9	64.9	60.8	44.7	10.8 (5.9, 15.5)**	

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

Diarrhea	0.6	0.0	0.0	0.0	0.7	-	2.3	3.8	2.0	0.0	1.5	25.1 (45.4,-2.8) [△]	2.9	3.8	2	0	2.2	25.5 (-0.3, 44.6) [*]
Tetanus	0.0	0.0	0.0	0.0	0.0	-	1.2	0.0	0.0	0.0	0.0	-	1.2	0	0	0	0	-
HIV	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0	0	0	0	0	-
Neonatal sepsis/meningitis	7.0	9.4	9.3	7.3	6.6	3.3 (16.7,-12.4) [△]	9.4	5.7	11.2	6.6	12.4	-7.3 (6.7,-23.5) [△]	16.4	15.1	20.5	13.9	19	-2.3 (-13.2, 7.7) [△]
Other infectious diseases	1.2	0.6	0.7	0.7	0.0	30.3 (60.9,-24) [△]	0.6	0.0	0.6	0.0	0.0	42.4 (82.5,-89.3) [△]	1.8	0.6	1.3	0.7	0	29.7 (-13.7, 56.6) [△]
Congenital malformations	79.3	55.9	66.2	63.5	65.2	3.3 (8.2,-1.8) [△]	35.2	34.5	41.1	35.7	30.0	2.5 (9.1,-4.6) [△]	114.5	90.4	107.3	99.2	95.2	3.0 (-1.2, 6.9) [△]
Other diseases	65.8	64.7	55.6	39.0	46.1	11.6 (16.5,6.4) ^{**}	42.2	44.6	30.5	39.0	28.6	8.5 (14.6,1.9) [*]	108	109.3	86.1	78	74.7	10.3 (6.3, 14.2) ^{**}

224 (** means p value<0.01, * means p value<0.05, △ means p value≥0.05)

225

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

226

227

228

229

230

231

232

233

234

235

236

237

238

239

240

For peer review only

1
2
3
4
5 241
6
7 242
8
9 243
10
11 244
12
13
14 245
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

For peer review only

1
2
3
4 246 The death cause distribution and AADR were also significantly different among urban-
5
6
7 247 rural areas. In urban areas, preterm birth, intrapartum complication, and congenital
8
9 248 anomalies also accounting the largest proportion of all deaths cause from 2014 to 2018.
10
11
12 249 Moreover, the AADR of preterm birth, intrapartum complications, pneumonia, and
13
14 250 congenital malformations in urban areas were all larger than that of the national level. In
15
16
17 251 rural areas, the mortality rate of preterm birth, intrapartum complication, and congenital
18
19
20 252 anomalies significantly decreased. Additionally, the NMR of diarrhea have sharply
21
22 253 decreased, with AADR was 25.5% ($p < 0.001$). (See **Table 2**)
23
24

25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53

254
255 In contrast, the urban-rural gap still existed. The contribution of tetanus among neonates in
256 urban areas remains zero during the study period, while the rate in rural areas has been
257 eliminated until 2015. In 2018, the neonatal mortality in rural areas was almost twice as
258 high as in urban areas due to preterm birth, intrapartum complications, and congenital
259 malformations. Moreover, during the study period, the largest number of neonatal deaths
260 in the urban and rural areas was pneumonia, increased from 2.9 times (82.8 per 100,000
261 live births in rural areas VS 28.8 per 100,000 live births in urban areas) in 2014 to 3.3 times
262 (44.7 per 100,000 live births in rural areas VS 13.5 per 1000 live births in urban areas) in
263 2018. (See **Table 2**) In the disease proportion aspect, the proportion of intrapartum
264 complications and pneumonia in rural areas significantly higher than that of urban areas.
265 (See Figure 2B&C) According to the data analysis, causes of neonatal death varied between

1
2
3
4 266 urban and rural areas ($P<0.05$), but the correlation between neonatal mortality and whether
5
6 267 the newborn lived in urban or rural areas was weak (Cramer's $V=0.129$).
7
8
9

10 268

11
12
13 269 The mortality rates have also shown difference when divided neonates into early neonates
14
15
16 270 (0-6 days) and late neonates (7-28 days). Nationwide, except for neonatal sepsis (or
17
18
19 271 meningitis) and diarrhea, the mortality rate of other causes of death of early neonates was
20
21
22 272 significantly higher than that of late neonates, with the biggest difference being intrapartum
23
24
25 273 complications, preterm birth, and congenital malformations. In 2018, the mortality rate of
26
27 274 preterm birth was 73.4 per 100,000 livebirth in early neonates and 33.2 per 100,000
28
29 275 livebirth in late neonates. In the same year, the mortality rate of congenital malformations
30
31
32 276 was 52.3 per 100,000 livebirth in early neonates and 26.2 per 100,000 livebirth in late
33
34
35 277 neonates. It is worth noting that intrapartum complications were the second leading cause
36
37
38 278 of death among 0-28 days newborns in China from 2014 to 2018, with the mortality rate
39
40
41 279 of 78.2 per 100,000 livebirth in early neonates and only 6.4 per 100,000 livebirth in late
42
43 280 neonates (See **Table 2**).
44

45 281

46
47
48
49 282 *3. Neonate Diagnosis Facilities Level in China between 2014 and 2018*
50
51
52
53
54

1
2
3
4 283 The children's diagnosis facilities level has also be included in surveillance. Nationwide,
5
6 284 from 2014 to 2018, the proportion of neonate diagnosis at the provincial (or municipal)
7
8
9 285 level health facilities has significantly increased, and the proportion of the district (or
10
11
12 286 county) level has decreased. Moreover, the proportion of township level and village level
13
14
15 287 have both fluctuating declined during this period. In 2018, the proportion of neonate who
16
17 288 has not to seek any medical care has minimized, which declined to 3.9% in 2018. (See
18
19 289 **Figure 3**)
20
21
22
23
24
25

26 291 In an urban aspect, from 2014 to 2018, the majority of children (accounted for over 80%)
27
28 292 in urban areas have been diagnosed at provincial (or municipal) level medical facilities.
29
30
31 293 The proportion of the district (or county) level and township -level both have a slight rise
32
33
34 294 between 2014 and 2018. As a result, the percentage of children who have not to seek
35
36 295 medical care has declined, with 1.9% in 2014 and 1.1% in 2018. (See **Figure 3**)
37
38
39
40
41
42

43 297 On the contract, the diagnosis contribution figure of rural areas was different. Although the
44
45 298 proportion of provincial (or municipal) level has shown a growth trend from 2014 to 2018,
46
47
48 299 the proportion in rural areas have only half of that in urban areas. Moreover, the proportion
49
50
51 300 of street-level diagnoses in the urban area is reduced to 1.4% in 2018, while this proportion
52
53
54 301 in rural areas fluctuated and remained at 3.7% in the same year. Another significant
55
56
57
58
59
60

1
2
3
4 302 contributor is the proportion of children who have not sought medical care. The proportion
5
6 303 of neonate who has not to seek medical care has decreased, and still, 5.5% of children have
7
8
9 304 not sought any medical advice. (See **Figure 3**)
10
11
12
13 305

15 306 **Discussion**

17
18
19 307
20
21
22 308 The results of this study show that the NMR in urban and rural areas of China have
23
24 309 decreased significantly between 2014 and 2018. In addition, there were significant
25
26
27 310 differences in NMR between urban and rural areas, which were consistent with significant
28
29 311 differences in NMR between countries and regions globally^{20,21}.
30
31
32
33
34 312

35
36
37 313 From 2014 to 2018, Chinese NMR continued to decline, and it was dropped quickly. It
38
39 314 benefits from the improvement of medical treatment at all levels of health facilities, and all
40
41
42 315 levels of government attached great importance to strengthen the construction of the
43
44 316 pediatric institution, raise pediatricians' payment, and continue to implement neonatal
45
46
47 317 asphyxia recovery training program²². As a result, neonatal deaths from pneumonia and
48
49 318 infectious diseases, intrapartum complications, and premature delivery were significantly
50
51
52 319 reduced.
53
54

1
2
3
4 320
5
6

7 321 China has implemented the Safe Maternal Initiative and the National Program to Reduce
8
9 322 Maternal Mortality and Eliminate Tetanus, China has officially eliminated neonatal tetanus
10
11 323 in 2012²³, and from 2015 to 2018, the NMR of neonatal tetanus remained 0. Moreover,
12
13 324 through the success of the Prevention of Mother-to-child Transmission of HIV, Syphilis,
14
15 325 and Hepatitis B Program, the HIV/AIDS mortality rate has also been 0 from 2014 to
16
17 326 2018^{24,25}. Although the national neonatal mortality in 2018 was already less than 12 deaths
18
19 327 per 1000 live births, the preventable deaths still accounted for 73.9%, mainly were
20
21 328 pneumonia, intrapartum complication, premature birth. Among these diseases, the
22
23 329 proportion of preterm birth was highest in both nationwide, urban areas, and rural areas. In
24
25 330 the recent two decades, the prevalence of preterm birth has significantly increased¹⁸,
26
27 331 especially after the Two-child Policy²⁶ was implemented in China. The mortality rate
28
29 332 among preterm birth infants was apparently higher than the full-term infant, and the risk of
30
31 333 mortality increases proportionally with decreasing gestational age²⁷. Furthermore, with the
32
33 334 widespread development of assisted reproductive technique (ART), the incidence of
34
35 335 monozygotic twins has increased significantly²⁸. The NMR of twins is several times higher
36
37 336 than that of singletons²⁹⁻³¹.

38
39
40
41
42
43
44
45
46
47
48
49 337
50
5152
53 338 Addressing the issue of preterm birth may require different priorities in rural and urban
54

1
2
3
4 339 areas. Because of the good management of many curable neonatal complications (such as
5
6
7 340 pneumonia), the proportion of preterm birth in urban areas is obviously larger than that of
8
9 341 rural areas³². Hence, urban areas need to pay more attention to preventing premature deaths
10
11
12 342 less than 32 weeks of gestation. For rural areas, the local government needs to focus on the
13
14 343 prevention of premature infants at 32-36 weeks and continue to invest in medical services
15
16
17 344 to improve medical services accessibility for women and children in rural areas.
18
19
20
21 345

22
23
24 346 In addition, from 2014 to 2018, the neonatal mortality rate in rural areas due to preterm
25
26 347 birth, intrapartum complications, pneumonia, and congenital malformations was
27
28
29 348 decreasing in rural areas but was still significantly higher than in urban areas. (See **Table**
30
31 349 **2**) The higher mortality rate may be linked to the relatively poorer economy, lower quality
32
33
34 350 of health care, and lack of accessibility to health care in rural China. The average median
35
36
37 351 net income per capita was ¥39251 (about US \$6000) in urban China, but ¥14617 (about
38
39 352 the US \$2234) in rural China in 2018³³. The annual spending on health care per capita
40
41
42 353 accounted for 7.8% in urban China, but 10.2% in rural China in 2018³⁴. The average health
43
44
45 354 care personnel were 4.0 per 1000 people in urban China and 1.8 per 1000 people in rural
46
47 355 China in 2018³⁴. The number of beds in medical institutions per 1,000 people in urban areas
48
49
50 356 was 8.70, compared with 4.56 in rural areas in 2018³⁴.

51
52
53 357

1
2
3
4 358 Not only markedly difference the NMR of urban and rural areas has shown, but also
5
6
7 359 significantly difference in early and late neonates. The results of this study showed that the
8
9
10 360 range of cause-specific mortality of late neonates was significantly less than that of early
11
12 361 neonates, both nationwide and urban-rural areas. (See **Table 2**) Therefore, for preventable
13
14 362 neonatal diseases, the focus should be on early neonates, especially for early neonates in
15
16
17 363 rural areas.
18
19

20 364

21
22
23 365 For neonates, surviving from preterm birth, intrapartum complication and pneumonia are
24
25
26 366 close linking to accessibility to health care, local hospitals' obstetrics and neonates
27
28
29 367 departments' treatment level, and rescue skills^{35,36}. Therefore, the issue can be addressed
30
31
32 368 from the following four aspects.
33
34

35 369

36
37
38 370 Firstly, the local governments need to strengthen the construction of RNTN (Regional
39
40
41 371 Neonatal Transport Network), carry out the transport plan according to the Guidelines for
42
43 372 the Construction and Management of Critical Neonatal Treatment Center³⁷, and ensure the
44
45
46 373 applying of professional medical staff and newborn rescue equipment for neonatal
47
48
49 374 transport. Secondly, one study in Japan has pointed out that the medical care resources
50
51 375 (including Neonatal Intensive Care Unit (NICU), midwives, emergency physicians, and
52
53
54 376 emergency medical care centers) would impact the NMR decline³⁸. Therefore, the local

1
2
3
4 377 governments may base on the Administration guide (proposal) of the Neonatal Physician
5
6 378 Branch of the Chinese Physician Association³⁹ to grading neonatal wards and establishing
7
8
9 379 NICU after analyzing local medical establishment plan and newborn medical treatment
10
11
12 380 needs. Thirdly, local health departments can regularly organize multi-level, especially
13
14 381 provincial, prefecture-level and district-level) newborn health training programs. In rural
15
16
17 382 areas, with the policies support of the New Rural Construction and the Targeted Poverty
18
19 383 Alleviation^{40,41}, the improved rural transport and higher incomes have prompted the
20
21
22 384 enhanced accessibility of health services, and the proportion of rural children receiving
23
24
25 385 medical treatment in provincial and municipal hospitals has significantly increased. The
26
27 386 proportion of rural neonate diagnosis at the provincial (or municipal) level health facilities
28
29
30 387 has significantly increased from 39.2% to 47.6% from 2014 to 2018 (See **Figure 3**). Set
31
32 388 training objectives for medical staff in health facilities of different levels, and strengthen
33
34
35 389 the newborn treatment technology in each level of health facilities. Especially for the health
36
37
38 390 workers in rural areas, the newborn resuscitation training needs to be specifically
39
40
41 391 strengthened. Fourthly, the local communities can strengthen publicity to encourage
42
43 392 caregivers to take children to attend the health facilities for treatment. As for poor
44
45
46 393 households, local governments can set up special subsidies for them to reduce the economic
47
48 394 cost of medical treatment.

51 395
52
53
54

1
2
3
4 396 **Conclusion**
5
6

7 397 With the joint efforts of the economic development and the governmental policies and
8
9
10 398 strategies, the neonatal mortality rate of China has significantly decreased from 2014 to
11
12 399 2018. The gap between neonatal mortality and cause-of-death distribution still existed
13
14
15 400 between urban and rural areas. The goal of government interventions should be to narrow
16
17 401 the urban-rural gap, reduce the health inequality of neonates, and further take targeted
18
19
20 402 measures to eliminate the preventable death of neonates, especially premature births, to
21
22
23 403 achieve the SDGs goal.
24
25

26 404

27
28
29 405
30
31

32 406 **Acknowledgments**
33
34
35

36 407 We thank the institutions and staff of the National Maternal and Child Health Surveillance
37
38
39 408 System for data collection, data provided, and case investigation.
40
41

42 409
43
44

45 410 **Funding**
46
47
48

49 411 This study was supported by the Ministry of Health, China (grants QT2003-009 and
50
51
52 412 05wsb-02) and UNICEF (grant YH601-11-1141).
53
54

1
2
3
4 413
5
6

7 414 **Author contributions**
8
9

10 415 Data analysis: Yuxi Liu
11
12

13
14 416 Methodology: Hanmin Liu and Yanping Wang, Leni Kang
15
16

17 417 Data curation: Jun Zhu, Juan Liang, Lei Miao, Xiaoqiong Qiu, Weipeng Xia
18
19

20
21 418 Software: Chunhua He, Leni Kang and Qi Li
22
23

24 419 Writing – original draft: Yuxi Liu
25
26

27
28 420 Writing – review, and editing: Yuxi Liu, Hanmin Liu, and Yanping Wang
29
30

31 421
32
33

34
35 422 **Conflicts of interest**
36
37

38 423 The authors declare no conflicts of interest.
39
40

41 424
42
43
44

45 425 **Data Availability Statement**
46
47

48 426 This study used data from the NMCHSS. This system is co-established by the National
49

50
51 427 Health and Family Planning Commission of the People Republic of China and Sichuan
52

53 428 University and finally owned by the National Health and Family Planning Commission of
54
55

1
2
3
4 429 the People Republic of China. The researchers did not obtain consent to publicly share
5
6 430 data. The de-identified data set is available upon request to interested researchers. For data
7
8
9 431 requests, please contact the Department of Science and Technology of West China Second
10
11 432 University Hospital, Sichuan University, at: fu2yuankjb@163.com. This department is in
12
13
14 433 charge of all the programs in the hospital, including the data management. One staff from
15
16
17 434 the department monitors this email.
18
19
20
21 435

22 23 436 **References**

- 24
25
26 437 1. UN (2015) . Sustainable Development Goals. <https://sustainabledevelopment.un.org/?menu=1300>
27
28 438 (accessed 12th Mar 2020).
- 29
30 439 2. Department of Maternal and Child Health of China. 2019 report on development of maternal and child
31
32 440 health. Beijing, 2019.
- 33
34 441 3. The State Council Information office of the People's Republic of China. The impenmentation of
35
36 442 "National Program of Action for Child Development in China in 1990s" and "National Program of Action
37
38 443 for Child Development in China (2001-2010)". 2001. <http://www.china.org.cn/e-news/news01-4-27-1.htm>
39
40 444 (accessed Dec 10th 2020).
- 41
42 445 4. WHO, UNICEF, UN & World Bank Group (2019) . Levels & Trends in Child Mortality-Report 2019.
- 43
44 446 5. WHO (2019). Newborns: reducing mortality. [https://www.who.int/news-room/fact-](https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality)
45
46 447 [sheets/detail/newborns-reducing-mortality](https://www.who.int/news-room/fact-sheets/detail/newborns-reducing-mortality) (accessed 12th Mar 2020).
- 47
48 448 6. Zhang. CL. (2015) Analysis of surveillance results of 4074 children under 5 years old. Maternal and
49
50 449 Child Health Care of China. **30**: 5095-8.
- 51
52 450 7. Health Ministry of China. Health Statistical Yearbook of China, 1st edn. Beijing, China: Peking Union
53
54 451 Medical College press, 2013:201.

- 1
2
3 452 8. National Working Committee on Children and Women under State Council. National Program for
4 453 Women and Child Development. http://www.nwccw.gov.cn/node_2427.htm (accessed 12th Mar 2020).
5
6
7 454 9. UN (2000). Millennium Development Goal. <http://www.un.org/zh/millenniumgoals/getinvolved.shtml>
8 455 (accessed 12th Mar 2020).
9
10
11 456 10. Wang Y, Li X, Zhou M, et al. Under-5 mortality in 2851 Chinese counties, 1996-2012: a subnational
12 457 assessment of achieving MDG 4 goals in China. *Lancet* 2016; **387**(10015): 273-83.
13
14
15 458 11. National Bureau of Statistics of China (2016). China statistical yearbook 2016.
16 459 <http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm> (accessed 12th Mar 2020).
17
18
19 460 12. Ministry of Foreign Affairs of China & UN China (2015). Report on China's Implementation of the
20 461 Millennium Development Goals (2000-2015).
21
22 462 http://cn.chinagate.cn/reports/2015-07/28/content_36164105.htm (accessed 12th Mar 2020).
23
24
25 463 13. Kuruvilla S, Schweitzer J, Bishai D, et al. Success factors for reducing maternal and child mortality.
26 464 *Bull World Health Organ* 2014; **92**(7): 533-44b.
27
28
29 465 14. The development of China's Health Care and inhabitant's health status (2018) China Public Health
30 466 Statistical Yearbook 2018. Peking Union Medical College Publishing House.
31
32
33 467 15. Bank TW. Mortality rate, neonatal (per 1,000 live births). 2019.
34
35 468 <https://data.worldbank.org/indicator/SH.DYN.NMRT> (accessed Dec 11th 2020).
36
37 469 16. Wang Y, Zhu J, He C, Li X, Miao L, Liang J. Geographical disparities of infant mortality in rural China.
38 470 *Arch Dis Child Fetal Neonatal Ed* 2012; **97**(4): F285-90.
39
40
41 471 17. He C, Liu L, Chu Y, et al. National and subnational all-cause and cause-specific child mortality in
42 472 China, 1996-2015: a systematic analysis with implications for the Sustainable Development Goals. *Lancet*
43 473 *Glob Health* 2017; **5**(2): e186-e97.
44
45
46 474 18. Lu R, Li X, Guo S, et al. Neonatal mortality in the urban and rural China between 1996 and 2013: a
47 475 retrospective study. *Pediatr Res* 2016; **79**(5): 689-96.
48
49
50 476 19. Nichols EK, Byass P, Chandramohan D, et al. The WHO 2016 verbal autopsy instrument: An
51 477 international standard suitable for automated analysis by InterVA, InSilicoVA, and Tariff 2.0. *PLoS Med*
52 478 2018; **15**(1): e1002486.

- 1
2
3
4 479 20. Yaya S, Uthman OA, Okonofua F, Bishwajit G. Decomposing the rural-urban gap in the factors of
5 480 under-five mortality in sub-Saharan Africa? Evidence from 35 countries. *BMC Public Health* 2019; **19**(1):
6 481 616.
- 7
8
9 482 21. Saikia, N., Singh, A., Jasilionis, D., et al. Explaining the rural-urban gap in infant mortality in India.
10 483 *Demographic Research*, 29(18), 473-506.
- 11
12 484 22. National health commission, National development and reform commission, the Ministry of Education,
13 485 the Ministry of Finance, the Ministry of human resources and social security & National Administration of
14 486 Traditional Chinese Medicine (NATCM) (2016). Circular on the issuance of opinions on strengthening the
15 487 reform and development of children's medical and health services.
16
17 488 http://www.mohrss.gov.cn/SYrlzyhshbzb/shehuibaozhang/zcwj/yiliao/201606/t20160601_241098.html
18
19 (accessed 2nd May 2020).
20
21
22
23 490 23. UNICEF (2012). Maternal and neonatal tetanus eliminated in China. [https://www.unicef.cn/en/press-](https://www.unicef.cn/en/press-releases/maternal-and-neonatal-tetanus-eliminated-china)
24 491 [releases/maternal-and-neonatal-tetanus-eliminated-china](https://www.unicef.cn/en/press-releases/maternal-and-neonatal-tetanus-eliminated-china) (accessed 2nd May 2020).
- 25
26
27 492 24. Wang AL, Qiao YP, Wang LH, et al. Integrated prevention of mother-to-child transmission for human
28 493 immunodeficiency virus, syphilis and hepatitis B virus in China. *Bull World Health Organ* 2015; **93**(1): 52-
29 494 6.
- 30
31
32 495 25. China CDC (2011) . Prevention of mother-to-child transmission of HIV, syphilis and hepatitis b (2011-
33 496 2013). http://www.chinacdc.cn/gswswx/fyzz/201107/t20110704_48397.html (accessed 2nd May 2020).
- 34
35
36 497 26. Institute of party history and literature of the CPC central committee (2019). Memorabilia of the
37 498 People's Republic of China (October 1949 -- September 2019)
39
40 499 <http://cpc.people.com.cn/n1/2019/0928/c419242-31378078.html> (accessed 3rd May 2020).
- 41
42 500 27. Boghossian NS, Geraci M, Edwards EM, Horbar JD. Morbidity and Mortality in Small for Gestational
43 501 Age Infants at 22 to 29 Weeks' Gestation. *Pediatrics* 2018; **141**(2).
- 44
45
46 502 28. Gee RE, Dickey RP, Xiong X, al. e. Impact of monozygotic twinning on multiple births resulting from
47 503 in vitro fertilization in the United States, 2006-2010. *Am J Obstet Gynecol* 2014; **210**(5): 468.e1-6.
- 48
49
50 504 29. Imaizumi Y, Hayakawa K. Infant mortality among singletons and twins in Japan during 1999-2008 on
51 505 the basis of risk factors. *Twin Res Hum Genet* 2013; **16**(2): 639-44.
- 52
53
54 506 30. Saleh Jafarian MA, Mahmoud Mobasher. The Effect of Twin Birth on Neonatal and Infant Mortality

- 1
2
3 507 Rates: A Systematic Review. *International Journal of Epidemiologic Research* 2018; **Summer 5**(3): 113-8.
4
5
6 508 31. Monden CWS, Smits J. Mortality among twins and singletons in sub-Saharan Africa between 1995 and
7 509 2014: a pooled analysis of data from 90 Demographic and Health Surveys in 30 countries. *Lancet Glob*
8 510 *Health* 2017; **5**(7): e673-e9.
- 10
11 511 32. Liang J, Mao M, Dai L, et al. Neonatal mortality due to preterm birth at 28-36 weeks' gestation in China,
12 512 2003-2008. *Paediatr Perinat Epidemiol* 2011; **25**(6): 593-600.
- 14
15 513 33. National Bureau of Statistics of China. Personal income and consumer spending in 2018. 2019.
16
17 514 http://www.stats.gov.cn/tjsj/zxfb/201901/t20190121_1645791.html.
- 19
20 515 34. China NHC. China Health Statistics Yearbook 2019. Beijing, 2020.
- 22
23 516 35. World Health Organization, Dept. of Reproductive Health and Research; United Nations Population
24 517 Fund; UNICEF (2003). Managing newborn problems: A guide for doctors, nurses and midwives.
- 26
27 518 36. Bryce J, Boschi-Pinto C, Shibuya K, et al. WHO estimates of the causes of death in children. *Lancet*.
28 519 2005;365(9465):1147-1152.
- 30
31 520 37. The National Health Commission of China (2017). Guidelines for the Construction and Management
32 521 of Critical Neonatal Treatment Center.
33 522 <http://www.nhc.gov.cn/fys/s3581/201801/1048948966a44067974a44187c6a8912.shtml> (accessed 28th Apr
34 523 2020).
- 36
37 524 38. Matsumoto Y, Nakai A, Nishijima Y, et al. Absence of neonatal intensive care units in secondary
38 525 medical care zones is an independent risk factor of high perinatal mortality in Japan. *J Obstet Gynaecol Res*
39 526 2016; **42**(10): 1304-9.
- 42
43 527 39. Neonatal Physician Branch of Chinese Physician Association (2013). Guidelines for graded
44 528 construction and management of neonatal wards in China (proposal). *Chin J Appl Clin Pediatr*, February,
45 529 28(3). 231-239.
- 47
48 530 40. Office of the central leading group for financial and economic affairs of China (2006). Five mechanisms
49 531 of the new socialist countryside. <http://finance.people.com.cn/GB/1037/4132493.html> (accessed 2nd May
50 532 2020).
- 52
53 533 41. Zhou Y, Guo, Y., Liu, Y, et al. . Targeted poverty alleviation and land policy innovation: Some practice
54

1
2
3 534 and policy implications from China. *Land Use Policy*, 74(74), 53-65.
4
5

6 535
7
8

9 536
10
11

12 537
13
14

15 538
16
17

18 539
19
20

21 540
22
23

24 541
25
26

27 542
28
29

30 543
31
32

33 544
34
35

36
37
38
39 545 Figure 1. The national and urban-rural neonatal mortality rates (per 1,000 live births) in
40

41 546 China between 2014 and 2018
42
43

44
45 547 Figure 2A. Causes of deaths in neonates in China, 2018
46

47
48 548 Figure 2B. Causes of deaths in neonates in urban China, 2018
49

50
51 549 Figure 2C. Causes of deaths in neonates in rural China, 2018
52
53

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

550 Figure 3. The proportion of neonatal diagnose level in China from 2014 to 2018

551

For peer review only

Figure 1. The national and urban–rural neonatal mortality rates (per 1,000 live births) in China between 2014 and 2018

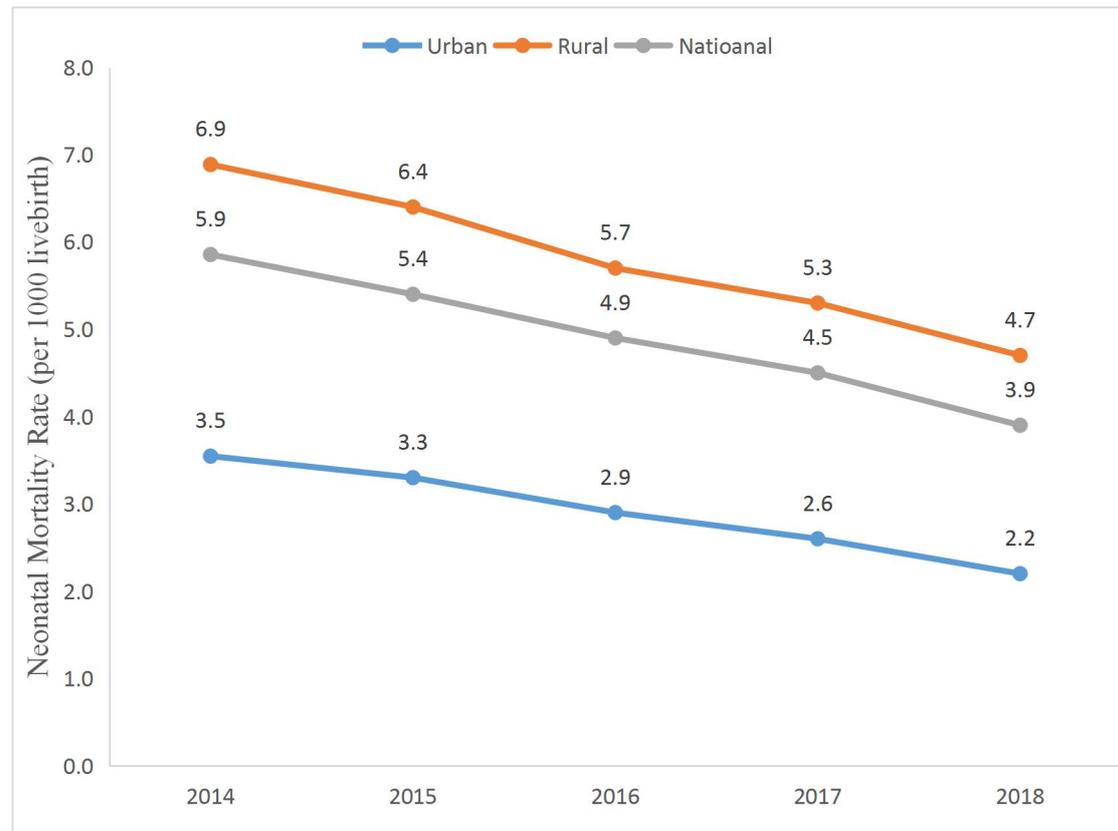


Figure 2A. Causes of deaths in neonates in China, 2018

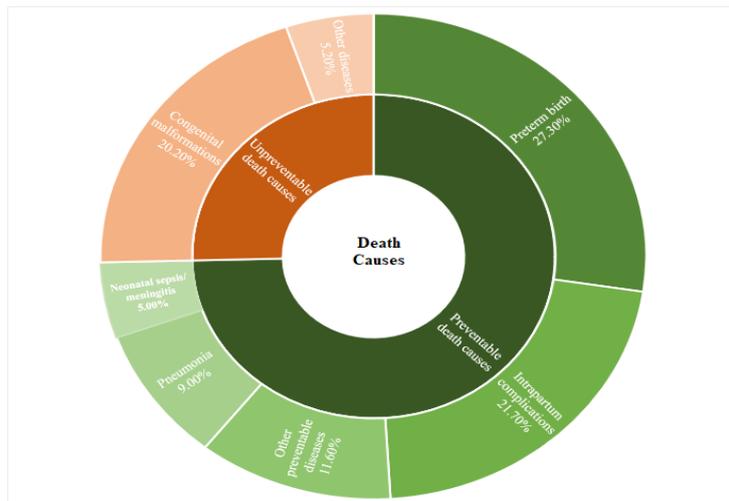


Figure 2B. Causes of deaths in neonates in urban China, 2018

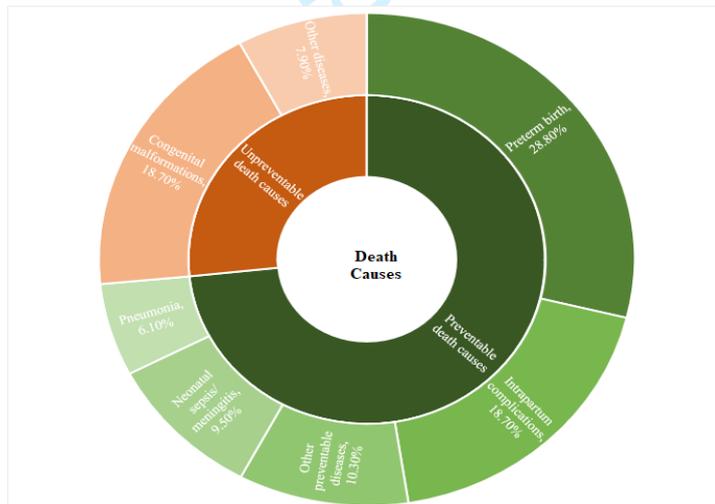


Figure 2C. Causes of deaths in neonates in rural China, 2018

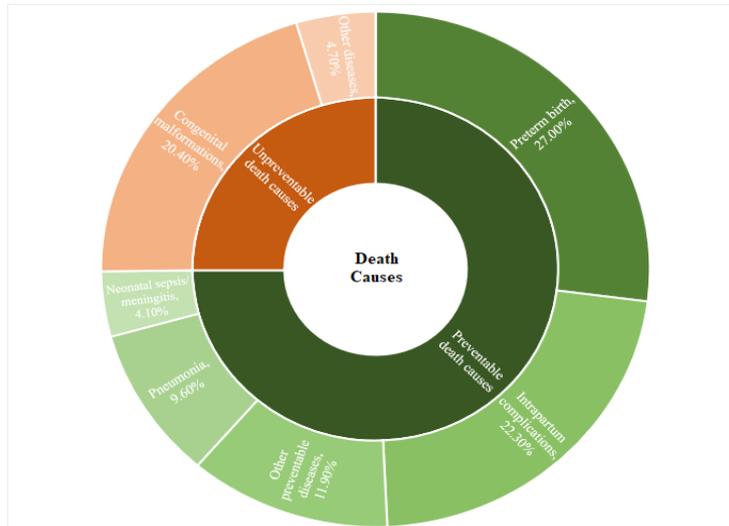


Figure 3. The proportion of neonatal diagnose level in China from 2014 to 2018

