


# Development of capability lists for neonatal critical care at three levels in China: a modified Delphi study

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## ABSTRACT

**Background** The standardised management of neonatal critical care centres can help improve health outcomes of vulnerable newborns. Guidance is required to update evidence related to construction and management of neonatal critical care centres in China.

**Objective** To establish expert consensus on the essential capability lists for neonatal critical care at three levels in China.

**Design and setting** According to China's administrative divisions, the Chinese guidelines stratifies neonatal critical care into three levels: county level (basic and special care), city level (intensive care) and province level (comprehensive care including neonatal surgery and more subspecialty interventions). A modified Delphi study was conducted. A group of 20 neonatologists from the Chinese Association of Neonatologists rated the importance of capability items on a 5-point Likert scale.

**Results** At county level, the list consisted of 29 items related to basic and special care, and 3 items were unanimously rated very important by all experts: neonatal resuscitation, endotracheal intubation and continuous positive airway pressure  $\geq 72$  hours. At city level, group consensus defined 38 items as essential. Besides the essential items of county level, more items for intensive care were included in city level. At province level, 64 items reached consensus, including neonatal surgery and more advanced subspecialty interventions. The Kendall's W values showed good agreement among experts in both rounds, and an increase from round 1 to round 2.

**Conclusions** We developed the capability lists for neonatal critical care at three levels in China. Neonatal resuscitation should be provided by all levels. Interventions for preterm newborns are stratified according to gestational age and birth weight. Congenital abnormalities requiring surgical services need to be managed in high-level centres.

## INTRODUCTION

To achieve the sustainable development goal to end preventable newborn deaths by 2030, countries need to expand provision of care to reach all newborns to ensure that every newborn has the chance to live a healthy and productive life.<sup>1–3</sup> In 2021, approximately 2.3 million newborns died globally.<sup>4</sup> In addition, many small and sick newborns survive

## WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ A tiered provision of neonatal care is proven to be effective in preventing neonatal mortality and disability, which has been implemented in some countries and regions.
- ⇒ Delphi method has been widely used and accepted in the field of healthcare.
- ⇒ No relevant Delphi studies on the essential capabilities for different levels of neonatal care were identified through our literature search.

## WHAT THIS STUDY ADDS

- ⇒ We have established expert consensus on the essential capabilities for neonatal critical care, and discussed evidence-based practices for the improvement of neonatal outcomes.
- ⇒ This study presents detailed lists of capabilities in Chinese guidelines, and compares the similarities and differences of the guidelines and standards previously published.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ We are developing quality indicators based on the results, which will provide a resource for policy-makers, healthcare providers and health service planners to plan and deliver neonatal health services, and thus improve outcomes of vulnerable newborns.

with a long-term disability. Most disabilities among newborns are preventable with quality maternal and neonatal care.

In China, the neonatal mortality rate decreased from 33.1% in 1991 to 3.1% in 2021.<sup>5,6</sup> In January 2016, China began implementing the 'Comprehensive Two-Child Policy'. The numbers of pregnant women with advanced maternal age and newborns at high-risk both increased.<sup>7</sup> UNICEF and China's National Health Commission had jointly carried out 'Maternal and Child Health Cooperation Programme' from 2016 to 2020 in China. *Guidelines for Construction and Management of Neonatal Critical Care Centres* were published on 8 December 2017.<sup>8</sup>

The guidelines standardise the capabilities of neonatal care systems at different levels, and guide local health departments to organise neonatal care networks. During the implementation of the guidelines, we have received feedback from facilities and local health departments all over the country. In order to update the guidelines, we conducted the Delphi study to establish expert consensus on the essential capability lists for neonatal critical care at three levels.

## METHODS

### Study design

A modified Delphi method was conducted, which has been widely used and accepted in the field of healthcare.<sup>9–13</sup> We first convened an expert panel and followed a two-round modified Delphi process with experts answering questionnaires to rate importance of capability items.

### Participants

The majority of Delphi studies have used between 11 and 50 respondents.<sup>11–13</sup> A group of 20 professional neonatologists who were members of the Chinese Association of Neonatologists were recruited. Experts were required to have professional experience for at least 15 years, and have an academic rank of associate professor or above. Geographical spread was also taken into account.

### Questionnaire preparation

It is an acceptable and common modification of the Delphi process to use a structured questionnaire that is based on basic information and/or literature review.<sup>9–14</sup> PubMed search was conducted on 18 October 2020, using the search terms ‘neonatal care’ and ‘level’. After reading the titles and abstracts, we identified 30 articles published in English which mentioned levels of neonatal care in different countries and regions, and then reviewed the full texts and references. We subsequently searched the websites of WHO, UNICEF, American Academy of Pediatrics (AAP) and British Association of Perinatal Medicine (BAPM) for more evidence-based practices in newborn health. A preliminary set of questionnaires were identified through the Chinese guidelines<sup>8</sup> and the articles were reviewed.<sup>3 15–17</sup>

In this study, a ‘newborn’ refers to an infant in the first 28 days after birth; ‘preterm’ refers to delivery at <37 weeks of gestation. The Chinese guidelines define a neonatal critical care centre as a facility or unit constructed in a hospital with a neonatal ward or a neonatal intensive care unit, providing 24-hour inpatient care for newborns, and undertaking referral, consultation, training and mentoring within a regionalised system.

According to China’s administrative divisions, the Chinese guidelines stratifies neonatal critical care into county, city and province level. In practice, the hospital levels of neonatal critical care should take into account local factors such as geographic regions, regional

population size and need, regional organisation of health-care services and the functional capabilities of hospitals that provide inpatient care for newborns. County-level centres provide basic and special care (eg, newborns born  $\geq 32$  weeks’ gestation or weighing  $\geq 1500$  g, and those with moderate illness); city-level centres provide intensive care (eg, newborns born  $\geq 28$  weeks’ gestation or weighing  $\geq 1000$  g, and those with critical illness) and province-level centres provide comprehensive care (eg, newborns born <28 weeks’ gestation or weighing <1000 g, and those requiring neonatal surgery or medical subspecialty interventions).

Three questionnaires were compiled in Chinese language, each for a different level. All the capabilities were categorised into four domains: clinical techniques, laboratory and imaging tests, management measures for inpatient newborns and neonatal surgery.

### Delphi process

The experts were asked by email to rate the importance of each item on a 5-point Likert scale (1=very unimportant; 2=unimportant; 3=neutral; 4=important and 5=very important).<sup>10 12 14 18</sup> They could give responses and provide other items not listed previously.<sup>11 12</sup> Each expert completed the questionnaires independently from 28 October to 4 November 2020.

The mean score with SD of ratings for each item, and the percentage of experts rating 4 or 5 were calculated. If  $\geq 75\%$  of the experts rated an item as 4 or 5 and the mean Likert score was  $\geq 4$ , the item was considered to have reached consensus to be included.<sup>9–13 18</sup> Items which did not fulfil the criterion were excluded or revised after discussion. However, when some certain items believed to be important fell just below the threshold for inclusion, the authors could consider including these items as posteriori considerations if sufficient justification was provided.<sup>13</sup> Additional items proposed by experts were included as new items after discussion.

The new questionnaires were brought forward to round 2 with specific feedback. The experts were requested by email to rate the importance of the items of the newly refined lists from 26 November to 3 December 2020. The result regarding a certain item could be retained or adjusted by individual experts based on their review and assessment of the feedback of round 1.<sup>9–13</sup> Items were either included or rejected based on the results of round 2.

### Statistical analysis

The quantitative data were analysed using descriptive statistics (Microsoft Excel, V.2010). The interexpert agreement was computed with Kendall coefficient of concordance (Kendall’s W), and the calculations were performed with IBM SPSS Statistics V.22. The Kendall’s W refers to the extent of group response agreement among experts across all items, ranging from 0 (no agreement) to 1 (complete agreement). Kendall’s W value was

**Table 1** Demographic information of the experts (n=20)

Characteristics	N	%
Gender		
Female	11	55.0
Male	9	45.0
Age (years)		
40–49	4	20.0
50–54	6	30.0
55–59	9	45.0
60–65	1	5.0
Degree		
Doctor	16	80.0
Master	2	10.0
Bachelor	2	10.0
Academic rank		
Full professor	20	100.0
Associate professor	0	0.0
Years of professional experience		
15–24	4	20.0
25–30	7	35.0
31–40	9	45.0

tested by  $\chi^2$  test, and p values <0.05 were considered to be statistically significant.<sup>14 18 19</sup>

## RESULTS

### Experts

The demographic information and professional characteristics of experts is presented in [table 1](#). All the 20 experts responded to the study and completed both rounds. They were from 16 provinces, autonomous regions and municipalities of China. The mean (SD) age was 53.5 (4.8) years.

### County-level capabilities

The items with the importance scores of county level are presented in [table 2](#). The final list consisted of 29 items related to basic and special care of county-level centres. Three items were unanimously rated very important by all experts in both rounds: neonatal resuscitation, endotracheal intubation and continuous positive airway pressure (CPAP)  $\geq 72$  hours.

In round 1, ‘chest drainage’ was assessed as important or very important by 70.0% (14/20) of the experts. We proposed changing the ‘chest drainage’ to ‘thoracocentesis and/or chest drainage’ based on experts’ comments. In round 2, 19 of 20 experts (95.0%) rated it as important or very important. At last, ‘thoracocentesis and/or chest drainage’ was included in the final list.

According to comments during round 1, five additional items were included in round 2: lumbar puncture, abdominocentesis, bone marrow aspiration, enteral

nutrition and 24-hour blood gas analysis. In round 2, ‘bone marrow aspiration’ had low agreement on importance (55.0%, 11/20) with mean (SD) score of 3.55 (0.51), and consequently was removed from the final list of county level. The other four items met the inclusion criteria and were included.

In round 1, the mean (SD) score of ‘24-hour neonatal transport service’ was 3.65 (0.49) with 65.0% (13/20) agreement on its importance, which was lower than the inclusion criteria. The item was carried forward to round 2 for further discussion. The result of mean and percentage of importance remained unchanged in round 2. The scores and comments of the experts were reviewed, resulting in ‘neutral’ rated by 7 experts and ‘important’ rated by 13 experts. The experts who rated ‘neutral’ expressed concern that it would be difficult to perform this service in some counties. Considering regional disparity in services offered, ‘24-hour neonatal transport service’ was expected to be strengthened, particularly at county level in rural areas. This item was still retained in the final list of county level.

### City-level capabilities

[Table 3](#) shows the results of the city-level items. Group consensus defined 38 items as essential. Besides the essential items of county level, more items for intensive care were included in city level. In round 1, no items were eliminated. We included five additional items in round 2 (lumbar puncture, abdominocentesis, bone marrow aspiration, enteral nutrition and 24-hour blood gas analysis), which all reached consensus. After round 1, three items were revised based on experts’ comments, and the restated items (thoracocentesis and/or chest drainage, peripherally inserted central catheters and blood transfusion) were evaluated as better than the original items.

### Province-level capabilities

Importance scores of province-level items are presented in [table 4](#). 64 items reached consensus and included more advanced subspecialty interventions. In round 1, no items were eliminated. Six items (lumbar puncture, abdominocentesis, bone marrow aspiration, enteral nutrition, 24-hour blood gas analysis and surgery for neonatal hydrocephalus) were added in round 2, and all reached consensus to be included. Four items were revised after round 1. At last, three items were accepted based on the descriptions of round 2 (thoracocentesis and/or chest drainage, peripherally inserted central catheters and blood transfusion), whereas ‘gastroscopy’ was retained as the description of round 1.

### Kendall coefficient of concordance

The Kendall’s W value are presented in [table 5](#). The results showed good agreement among experts in both rounds, and an increase from round 1 to round 2 (0.590–0.661 at county level, 0.634–0.683 at city level and 0.612–0.622 at province level).

**Table 2** Capability list for neonatal critical care centre of county level and the importance scores

County-level capability items	Round 1				Round 2			
	Mean*	SD*	N†	%†	Mean*	SD*	N†	%†
Domain 1: clinical technique								
Neonatal resuscitation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Endotracheal intubation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Oxygen therapy	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Continuous positive airway pressure ≥72 hours	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Conventional ventilation ≥24 hours	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Surfactant administration	4.90	0.31	20	100.0	4.90	0.31	20	100.0
(Round 1) Chest drainage; (round 2, revised and included) Thoracocentesis and/or chest drainage	4.15	0.99	14	70.0	4.85	0.49	19	95.0
(Round 2, added and included) Lumbar puncture	–	–	–	–	4.95	0.22	20	100.0
(Round 2, added and included) Abdominocentesis	–	–	–	–	4.05	0.39	19	95.0
(Round 2, added but excluded) Bone marrow aspiration	–	–	–	–	3.55	0.51	11	55.0
Intravenous cannula insertion	4.80	0.52	19	95.0	4.80	0.52	19	95.0
(Round 1) An on-site blood bank; (round 2, revised and included) Blood transfusion	4.80	0.52	19	95.0	4.80	0.52	19	95.0
Non-invasive physiological monitoring	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Phototherapy	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Total parenteral nutrition	4.85	0.49	19	95.0	4.85	0.49	19	95.0
(Round 2, added and included) Enteral nutrition	–	–	–	–	4.90	0.31	20	100.0
Domain 2: laboratory and imaging tests								
Mobile ultrasound scanning	4.00	0.46	18	90.0	4.00	0.46	18	90.0
Mobile X-ray	4.05	0.39	19	95.0	4.05	0.39	19	95.0
(Round 2, added and included) 24-hour blood gas analysis	–	–	–	–	4.85	0.49	19	95.0
Hearing screening	4.30	0.47	20	100.0	4.30	0.47	20	100.0
Test for haemolytic disease	4.00	0.56	17	85.0	4.00	0.56	17	85.0
Biochemical test	4.80	0.41	20	100.0	4.80	0.41	20	100.0
Domain 3: management measures for inpatient newborns								
Paediatric critical illness score	4.85	0.49	19	95.0	4.85	0.49	19	95.0
Follow-up after discharge	4.00	0.56	17	85.0	4.00	0.56	17	85.0
24-hour neonatal transport service	3.65	0.49	13	65.0	3.65	0.49	13	65.0
Assessment and postnatal care for newborns born healthy	4.80	0.52	19	95.0	4.80	0.52	19	95.0
Medical care for physiologically stable term newborns with mild abnormalities or at high risk	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Medical care for physiologically stable newborns born ≥32 weeks' gestation or weighing ≥1500 g	4.90	0.31	20	100.0	4.90	0.31	20	100.0

Continued

Table 2 Continued

County-level capability items	Round 1				Round 2			
	Mean*	SD*	N†	%†	Mean*	SD*	N†	%†
Medical care for unstable newborns with moderate illness but not anticipated to organ failure	4.85	0.37	20	100.0	4.85	0.37	20	100.0
Stabilisation for newborns with critical illness until transfer to a higher-level centre	4.95	0.22	20	100.0	4.95	0.22	20	100.0

\*Mean and SD of 5-point Likert scores (1=very unimportant; 2=unimportant; 3=neutral; 4=important and 5=very important).  
†Number and percentage of experts who rated 4 (important) or 5 (very important).

## DISCUSSION

As countries expand health systems towards achieving universal health coverage, both access to care and quality of care will be important to ending preventable newborn deaths by 2030.<sup>20</sup> Supporting healthy development during early childhood is the best investment a country and society can make in the future generation.<sup>21</sup> High-quality care requires an integrated health system and multidisciplinary teams from all levels working in a coordinated and facilitative manner to ensure equitable provision of effective services.<sup>22</sup> A neonatal critical care centre is part of an integrated network with clear referral pathways and should be designated according to a standardised level of care. Special and intensive care is centralised in hospitals of designated levels.<sup>23</sup>

WHO indicates that inpatient interventions are proven to be effective in preventing neonatal mortality and disability, according to different health system levels. Special and intensive care is required based on well-established obstetric care and basic neonatal care. Vulnerable newborns require high-quality inpatient care delivered by professional providers in dedicated health facilities. Newborns may have different needs depending on their fragility. When small and sick newborns require intensive care, they should be managed in a higher-level hospital. WHO defines neonatal care as three levels with different types of care: primary level providing essential newborn care; secondary level providing special newborn care and tertiary level providing intensive newborn care.<sup>3</sup>

AAP updated policy statement for a tiered provision of care in 2012, and reaffirmed the need for uniform and nationally applicable definitions, and consistent standards of service for public health to improve neonatal outcomes. AAP classifies neonatal care into four levels, and defines the capabilities of each level: level I (well newborn nursery) providing basic care; level II (special care nursery) providing specialty care; level III (neonatal intensive care units (NICUs)) providing subspecialty intensive care and also ideally maternal-fetal medicine and level IV (regional NICU) providing care for the most complex and critically ill newborns, and surgical repair of complex conditions.<sup>16</sup>

In the 2010 edition of *Service Standards for Hospitals Providing Neonatal Care* published by BAPM, managed

clinical networks are recommended as the best approach to service delivery for neonatal care. The BAPM standards describe networks as being comprising three types of unit: special care units (SCU) providing special care; local neonatal units (LNU) providing special care, high dependency care and a restricted volume of intensive care (as agreed locally) and NICUs providing the whole range of medical (and sometimes surgical) neonatal care for their local population.<sup>17</sup>

These guidelines and standards all recommend a tiered provision of neonatal care. We compared the similarities and differences of them. Basic care is provided at county level of Chinese guidelines, primary level of WHO standards and level I of AAP statement. Special care is provided at county level of Chinese guidelines, secondary level of WHO standards, level II of AAP statement and SCUs of BAPM standards. In BAPM standards, LNUs provide special care, high dependency care and a restricted volume of intensive care. Neonatal intensive care and paediatric surgery are provided by high-level centres or units, such as tertiary level of WHO standards, level III/IV of AAP statement and NICUs of BAPM standards. Level IV of AAP statement is expected to manage the most complex conditions. In Chinese guidelines, intensive care is provided at city level and province level, but paediatric surgery and some advanced subspecialty techniques are provided at province level. Furthermore, Chinese guidelines suggest that newborns born <28 weeks' gestation or weighing <1000g are expected to be managed in province-level centres.

Globally, the leading causes of neonatal deaths were preterm birth complications (36.1%), intrapartum-related events (23.9%) and congenital abnormalities (9.7%) in 2019.<sup>24</sup> In China, the leading causes were preterm birth (27.3%), intrapartum complications (21.7%) and congenital malformations (20.2%) in 2018.<sup>25</sup>

### Preterm birth

Preterm birth had been the leading cause of under-5 deaths in China continually from 2009 to 2018.<sup>25 26</sup> Newborns who are born too soon, too small or acutely ill are at greatest risk of death or developmental delays, physical disabilities and poor neurodevelopmental

**Table 3** Capability list for neonatal critical care centre of city level and the importance scores

City-level capability items	Round 1				Round 2			
	Mean*	SD*	N†	%†	Mean*	SD*	N†	%†
Domain 1: clinical technique								
Neonatal resuscitation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Endotracheal intubation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Oxygen therapy	4.85	0.49	19	95.0	4.85	0.49	19	95.0
Continuous positive airway pressure	4.90	0.45	19	95.0	4.90	0.45	19	95.0
Conventional ventilation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Surfactant administration	4.95	0.22	20	100.0	4.95	0.22	20	100.0
(Round 1) Chest drainage; (round 2, revised and included) Thoracocentesis and/or chest drainage	4.90	0.31	20	100.0	5.00	0.00	20	100.0
(Round 2, added and included) Lumbar puncture	–	–	–	–	5.00	0.00	20	100.0
(Round 2, added and included) Abdominocentesis	–	–	–	–	5.00	0.00	20	100.0
(Round 2, added and included) Bone marrow aspiration	–	–	–	–	4.05	0.51	18	90.0
Intravenous cannula insertion	4.85	0.37	20	100.0	4.85	0.37	20	100.0
Umbilical arterial and venous catheters	5.00	0.00	20	100.0	5.00	0.00	20	100.0
(Round 1) Peripheral vein catheterisation; (round 2, revised and included) Peripherally inserted central catheters	4.90	0.31	20	100.0	5.00	0.00	20	100.0
Exchange transfusion	5.00	0.00	20	100.0	5.00	0.00	20	100.0
(Round 1) An on-site blood bank; (round 2, revised and included) Blood transfusion	4.75	0.44	20	100.0	4.95	0.22	20	100.0
Non-invasive physiological monitoring	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Phototherapy	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Total parenteral nutrition	4.95	0.22	20	100.0	4.95	0.22	20	100.0
(Round 2, added and included) Enteral nutrition	–	–	–	–	4.95	0.22	20	100.0
Rehabilitative care	4.00	0.46	18	90.0	4.00	0.46	18	90.0
Medical care for severe sepsis and multiple system organ failure	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Domain 2: laboratory and imaging tests								
Mobile ultrasound scanning	4.80	0.41	20	100.0	4.80	0.41	20	100.0
Mobile X-ray	4.85	0.37	20	100.0	4.85	0.37	20	100.0
(Round 2, added and included) 24-hour blood gas analysis	–	–	–	–	5.00	0.00	20	100.0
CT	4.05	0.39	19	95.0	4.05	0.39	19	95.0
Hearing screening	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Screening for retinopathy of prematurity	4.85	0.37	20	100.0	4.85	0.37	20	100.0
Test for haemolytic disease	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Biochemical test	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Aetiological diagnosis (eg, bacteria, fungus, TORCH)	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Immunological test	4.05	0.51	18	90.0	4.05	0.51	18	90.0

Continued

Table 3 Continued

City-level capability items	Round 1				Round 2			
	Mean*	SD*	N†	%†	Mean*	SD*	N†	%†
Cytological examination	4.00	0.46	18	90.0	4.00	0.46	18	90.0
Pathological examination	4.05	0.39	19	95.0	4.05	0.39	19	95.0
Chromosome examination	4.00	0.46	18	90.0	4.00	0.46	18	90.0
Domain 3: management measures for inpatient newborns								
Paediatric critical illness score	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Follow-up after discharge	4.90	0.31	20	100.0	4.90	0.31	20	100.0
24-hour neonatal transport service	4.75	0.55	19	95.0	4.75	0.55	19	95.0
Medical care for newborns born $\geq 28$ weeks' gestation or weighing $\geq 1000$ g	4.95	0.22	20	100.0	4.95	0.22	20	100.0

\*Mean and SD of 5-point Likert scores (1=very unimportant; 2=unimportant; 3=neutral; 4=important and 5=very important).

†Number and percentage of experts who rated 4 (important) or 5 (very important).

TORCH, Toxoplasma gondii, Rubella virus, Cytomegalovirus, Herpes simplex viruses, and other agents.

functioning.<sup>27</sup> AAP suggests that very low birth weight and/or very preterm infants should be delivered in a level III facility.<sup>16</sup> In BAPM's opinion, newborns delivered at <27 weeks of gestational age require complex and long-term intensive care, and should be transferred to the nearest NICU.<sup>23</sup>

In this study, neonatal care is stratified by gestational age and birth weight. County-level centres should provide CPAP  $\geq 72$  hours and conventional ventilation  $\geq 24$  hours; city-level and province-level centres should provide these two techniques routinely and continuously and province-level centres are expected to perform high-frequency ventilation. Preterm infants need to be assessed for pulmonary surfactant deficiency, and surfactant replacement therapy should be administered appropriately at all three levels.

### Intrapartum complications

Most of the neonatal deaths caused by intrapartum-related events can be prevented with low-cost interventions.<sup>28</sup> Neonatal resuscitation can largely reduce deaths related to neonatal asphyxia.<sup>29</sup> In China, 'Neonatal Resuscitation Programme' which was implemented from 2004 to 2021 has trained a competent workforce to ensure that at least one attendant skilled in neonatal resuscitation is at the site of every delivery.<sup>30</sup> The mortality due to neonatal asphyxia remarkably decreased from 0.76% in 2003 to 0.19% in 2020.<sup>29</sup> In our study, neonatal resuscitation is one of the most important techniques of neonatal critical care at all levels. Neonatal resuscitation and endotracheal intubation were unanimously rated 'very important' by all experts in both rounds.

### Congenital abnormalities

Newborns with congenital abnormalities may require immediate surgical interventions, and some conditions may require access to genetic services. WHO recommends that all newborns need to be assessed for

congenital abnormalities, managed appropriately and referred in time. Paediatric surgery and genetic services are required in tertiary-level hospitals which provide neonatal intensive care.<sup>3</sup> AAP suggests that major surgery should be performed by level III units, and that level IV units should have the capability for surgery of complex conditions.<sup>16</sup> Paediatric surgical specialists and anaesthesiologists with paediatric expertise are recommended to perform neonatal surgery.<sup>31</sup> BAPM indicates that newborns requiring surgical care should receive the same level of care, support and specialist expertise in a medical neonatal unit.<sup>17</sup>

In our lists, a county-level centre has the responsibility to provide medical care for physiologically stable term newborns with mild abnormalities, and to stabilise newborns with critical illness until transfer to a higher-level centre. Neonatal surgery is recommended to be performed in a province-level centre. The hospitals should be equipped with appropriate laboratory and diagnostic tests for managing congenital abnormalities at a standardised level.

### Neonatal transport

Specialist neonatal transport services can provide safe and efficient transfer by experienced teams equipped with special transport vehicles. Health provision varies in different areas due to geographic, economic, cultural and demographic disparities. In China, the neonatal mortality rate in urban areas was lower than that in rural areas every year during 1991–2021.<sup>6</sup> The distribution of cause-specific deaths was significantly different between rural and urban areas.<sup>25</sup> In China, antenatal care and hospital delivery services have achieved universal coverage.<sup>5</sup> However, when newborns suffer critical conditions after discharge, but cannot be managed effectively with available resources, particularly in rural areas, they should be transported appropriately and timely.<sup>32</sup>

**Table 4** Capability list for neonatal critical care centre of province level and the importance scores

Province-level capability items	Round 1				Round 2			
	Mean*	SD*	N†	%†	Mean*	SD*	N†	%†
Domain 1: clinical technique								
Neonatal resuscitation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Endotracheal intubation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Oxygen therapy	4.80	0.62	18	90.0	4.80	0.62	18	90.0
Continuous positive airway pressure	4.90	0.45	19	95.0	4.90	0.45	19	95.0
Conventional ventilation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
High-frequency ventilation	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Surfactant administration	4.90	0.45	19	95.0	4.90	0.45	19	95.0
(Round 1) Chest drainage; (round 2, revised and included) Thoracocentesis and/or chest drainage	4.90	0.45	19	95.0	5.00	0.00	20	100.0
(Round 2, added and included) Lumbar puncture	–	–	–	–	5.00	0.00	20	100.0
(Round 2, added and included) Abdominocentesis	–	–	–	–	5.00	0.00	20	100.0
(Round 2, added and included) Bone marrow aspiration	–	–	–	–	5.00	0.00	20	100.0
Intravenous cannula insertion	4.90	0.45	19	95.0	4.90	0.45	19	95.0
Umbilical arterial and venous catheters	5.00	0.00	20	100.0	5.00	0.00	20	100.0
(Round 1) Peripheral vein catheterisation; (round 2, revised and included) Peripherally inserted central catheters	4.95	0.22	20	100.0	5.00	0.00	20	100.0
Exchange transfusion	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Peritoneal dialysis	4.05	0.39	19	95.0	4.05	0.39	19	95.0
Continuous blood purification	4.05	0.39	19	95.0	4.05	0.39	19	95.0
(Round 1) An on-site blood bank; (round 2, revised and included) Blood transfusion	4.95	0.22	20	100.0	5.00	0.00	20	100.0
Non-invasive physiological monitoring	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Cerebral function monitoring	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Invasive cardiovascular monitoring	4.80	0.62	18	90.0	4.80	0.62	18	90.0
Phototherapy	4.75	0.64	18	90.0	4.75	0.64	18	90.0
Total parenteral nutrition	4.90	0.31	20	100.0	4.90	0.31	20	100.0
(Round 2, added and included) Enteral nutrition	–	–	–	–	5.00	0.00	20	100.0
Mild therapeutic hypothermia	4.90	0.45	19	95.0	4.90	0.45	19	95.0
Inhaled nitric oxide treatment	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Treatment for retinopathy of prematurity	4.85	0.49	19	95.0	4.85	0.49	19	95.0
Bronchoscope	4.85	0.49	19	95.0	4.85	0.49	19	95.0
(Round 1, included) Gastroscopy; (round 2, revised but not accepted) Gastrointestinal endoscopy	4.10	0.55	18	90.0	4.05	0.69	16	80.0
Rehabilitative care	4.05	0.51	18	90.0	4.05	0.51	18	90.0
Extracorporeal membrane oxygenation	4.00	0.65	16	80.0	4.00	0.65	16	80.0
Treatment for inherited metabolic disorders	4.00	0.46	18	90.0	4.00	0.46	18	90.0
Medical care for severe sepsis and multiple system organ failure	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Domain 2: laboratory and imaging tests								

Continued



Table 4 Continued

Province-level capability items	Round 1				Round 2			
	Mean*	SD*	N†	%†	Mean*	SD*	N†	%†
Mobile ultrasound scanning	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Mobile X-ray	5.00	0.00	20	100.0	5.00	0.00	20	100.0
(Round 2, added and included) 24-hour blood gas analysis	–	–	–	–	5.00	0.00	20	100.0
CT	4.80	0.62	18	90.0	4.80	0.62	18	90.0
MRI	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Hearing screening	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Screening for retinopathy of prematurity	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Test for haemolytic disease	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Biochemical test	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Aetiological diagnosis (eg, bacteria, fungus, TORCH)	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Immunological test	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Cytological examination	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Pathological examination	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Chromosome examination	4.90	0.31	20	100.0	4.90	0.31	20	100.0
Mass spectrometry screening for inherited metabolic disorders	4.55	0.51	20	100.0	4.55	0.51	20	100.0
Molecular test	4.00	0.46	18	90.0	4.00	0.46	18	90.0
Domain 3: management measures for inpatient newborns								
Paediatric critical illness score	4.85	0.49	19	95.0	4.85	0.49	19	95.0
Follow-up after discharge	4.90	0.31	20	100.0	4.90	0.31	20	100.0
24-hour neonatal transport service	4.95	0.22	20	100.0	4.95	0.22	20	100.0
Medical care for newborns born <28 weeks' gestation or weighing <1000 g	5.00	0.00	20	100.0	5.00	0.00	20	100.0
Domain 4: neonatal surgery								
Surgery for hypertrophic pyloric stenosis	4.00	0.56	17	85.0	4.00	0.56	17	85.0
Surgery for oesophagotracheal fistula	4.70	0.66	18	90.0	4.70	0.66	18	90.0
Surgery for gastrointestinal tract perforation	4.80	0.62	18	90.0	4.80	0.62	18	90.0
Surgery for gastrointestinal tract atresia	4.80	0.62	18	90.0	4.80	0.62	18	90.0
Surgery for congenital diaphragmatic hernia	4.80	0.62	18	90.0	4.80	0.62	18	90.0
Surgery for meningocele	4.60	0.68	18	90.0	4.60	0.68	18	90.0
Removal of intracranial haemorrhage	4.05	0.51	18	90.0	4.05	0.51	18	90.0
Surgery for urinary malformation	4.00	0.56	17	85.0	4.00	0.56	17	85.0
Ligation of patent ductus arteriosus	4.85	0.49	19	95.0	4.85	0.49	19	95.0
Surgery with cardiopulmonary bypass	4.00	0.46	18	90.0	4.00	0.46	18	90.0
(Round 2, added and included) Surgery for neonatal hydrocephalus	–	–	–	–	4.80	0.62	18	90.0

\*Mean and SD of 5-point Likert scores (1=very unimportant; 2=unimportant; 3=neutral; 4=important and 5=very important).

†Number and percentage of experts who rated 4 (important) or 5 (very important).

### Limitations

There were multiple challenges to developing networking. First, the Chinese guidelines include a variety of

measures, but we did not discuss all of them in this manuscript (eg, regional organisation, beds arrangement of hospitals, physical environment, hygiene infrastructures

**Table 5** Interexpert agreement (Kendall's W) of the two rounds

Level	Round 1				Round 2			
	W	$\chi^2$	df	P value	W	$\chi^2$	df	P value
County	0.590	283.259	24	<0.001	0.661	383.260	29	<0.001
City	0.634	405.504	32	<0.001	0.683	505.291	37	<0.001
Province	0.612	697.385	57	<0.001	0.622	784.052	63	<0.001

and equipment, human resources, data and information systems, quality control, infection prevention and control, support for breast feeding, developmental supportive care, collaboration of maternal and neonatal care, in utero transport and maternal-fetal medicine). Second, only literature published in the English language was reviewed. In addition, future studies on the current state of neonatal critical care centres in China relative to the criteria developed with input of experts are needed.

## CONCLUSION

We have developed the essential capability lists for neonatal critical care at three levels in China. Neonatal resuscitation should be provided by all levels. Interventions for preterm newborns are stratified according to gestational age and birth weight. Congenital abnormalities requiring surgical services need to be managed in high-level centres. The results will provide a resource for policy-makers, healthcare providers and health service planners to plan and deliver neonatal health services.

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