Newborn hearing screening coverage and detection rates of hearing impairment across China from 2008-2016

Xuelian Yuan
Sichuan University West China Second University Hospital https://orcid.org/0000-0002-1913-8689
Kui Deng
Sichuan University West China Second University Hospital
Jun Zhu
Sichuan University West China Second University Hospital
Liangcheng Xiang
Sichuan University West China Second University Hospital
Yongna Yao
Sichuan University West China Second University Hospital
Qi Li
Sichuan University West China Second University Hospital
Xiaohong Li (lixiaohong82@scu.edu.cn)
Hanmin Liu
Sichuan University West China Second University Hospital

Research article

Keywords: newborn hearing screening, detection rate, congenital hearing impairment, national.

Posted Date: February 28th, 2020

DOI: https://doi.org/10.21203/rs.2.24801/v1

Version of Record: A version of this preprint was published on July 30th, 2020. See the published version at https://doi.org/10.1186/s12887-020-02257-9.

Abstract

Background: Newborn hearing screening (NHS) can reduce the economic and social burden of hearing impairment. The present study examined NHS coverage and detection of hearing impairment across China for 2008-2010 and 2016. Methods: Medical institutions across China were surveyed in 2012 and 2018 by the National Center for Birth Defects Monitoring of China to collect data for the period 2008-2010 and for 2016 on live births, initial screening rates (total and failed), secondary screening rates (total and failed), and rates of hearing impairment diagnosis among infants who failed secondary screening. To calculate NHS coverage, the number of newborns who received NHS within four weeks after birth was divided by the number of live births. The detection rate of hearing impairment was calculated by combining failure rates on primary and secondary screening with the rate of diagnosis. Results: National NHS coverage increased from 29.9 in 2008 to 86.5 in 2016, with different regions showing different increases. During this period, the number of provinces with NHS coverage over 90.0% increased from 2 to 17, with NHS coverage in 2016 substantially higher in eastern provinces (93.1%) than in western ones (79.4%). In 2016, the detection rate of hearing impairment across the country was 0.23% (95%CI 0.15-0.25%), and it varied from 0.17% in western provinces to 0.22% in central ones and 0.28% in eastern ones. The lowest rate was 0.02% in Heilongjiang and the highest rate was 0.63% in Hainan. Conclusions: National NHS coverage has increased substantially from 2008 to 2016, but provinces and regions still show differences. The detection rate of infant hearing impairment in China is comparable to that in other countries. A national individual-level information system is urgently needed in China to facilitate integration of screening, diagnosis and treatment of infant hearing impairment, which may also lead to a more accurate estimate of the detection rate.

Background

Hearing impairment in children is a serious obstacle to their development and education: it has been associated with delayed development of speech, language and cognitive skills, as well as with slow learning and difficulty in school [1]. According to the World Health Organization, impaired hearing affects 34 million children worldwide [2], including 0.5-5 of every 1000 newborns and infants [1]. In the US, hearing loss is associated with education costs of $115,600 per child [3].

1213

Newborn hearing screening (NHS) can effectively enable diagnosis of hearing impairment and intervention during the first 6 months, ensuring better outcomes for children [1, 4, 5]. Such screening may reduce special education costs by up to 37%, saving children from the need for up to 12 years of special classes for deaf children [6]. Starting with the work of Marion Downs in 1964 [7], the concept of universal NHS has taken root in many developed countries [8–10], where NHS coverage in 2016 was as high as 98.0% [9, 10]. NHS lags behind in many developing countries [11], reflecting lack of financing for equipment; lack of audiologists and newborn health workers, especially in rural areas; families' concern

over costs, which leads them to refuse NHS for their infants or refuse follow-up when indicated; and discharge of neonates in fewer than 24 h, which prevents timely NHS [11].

In China, NHS was adopted first in Shanghai in 1994 [12], and in 2004 it was incorporated into the national neonatal disease screening program [13]. Since then, the number of institutions providing NHS and the number of newborns receiving it have increased substantially [14, 15], but detailed data on national and subnational NHS coverage and detection rates of infant hearing impairment are lacking.

The present study examined NHS coverage and detection rates based on two national surveys in 2012 and 2018 in order to benchmark China against other developing countries and potentially provide useful insights for improvement of NHS.

Methods

Study area and design

The data used in the study came from two surveys conducted in 2012 and 2018 by the National Center for Birth Defects Monitoring of China. The data in the 2012 survey covered the period from 2008 to 2010, while the data in the 2018 survey covered the year 2016. The surveys were reviewed and approved by National Health Commission of the People's Republic of China with an national administrative notice was transmitted before each survey. All related medical institutions reported the tabulated data accordingly, which did not involve individual information, and the ethics approval and consent to participate were not necessary in the study.

Subjects

The two surveys included all licensed medical institutions providing NHS or diagnosis of congenital hearing impairment in China. The 2012 survey included 7,001 institutions that provided NHS and 116 that diagnosed infant hearing impairment, which were located in 30 provinces comprising 1,657 districts/counties. The 2018 survey included 11,875 institutions that provided NHS and 214 that diagnosed impairment, located in 31 provinces comprising 2,664 districts/counties (Appendix 1).

Data collection

A uniform questionnaire was used to collect data on live births, initial screening rates (total and failed), secondary screening rates (total and failed), and rates of hearing impairment diagnosis among infants who failed secondary screening.

For each county/district, designated maternal and child health institutions collected data in their respective jurisdictions and reported the data to municipal- and provincial-level maternal and child health institutions for quality control. The audited questionnaires were then reported to the National Center for Birth Defects Monitoring (Figure 1). The National Center checked the data and interviewed staff in charge

of NHS and infant hearing impairment diagnosis at 45 medical institutions in three provinces to further confirm the correctness of the data.

Statistical analysis

NHS was defined as well-born babies who received NHS before discharge and babies in the neonatal intensive care unit who received hearing screening based on the results of an automatic auditory brainstem response test before discharge [16]. Diagnosis of hearing impairment was defined as well-born babies who failed secondary NHS and were diagnosed with hearing impairment within 3 months after birth, and babies in the neonatal intensive care unit who failed auditory brainstem response screening and were immediately diagnosed with hearing impairment.

To calculate NHS coverage, the number of newborns who received NHS within four weeks after birth was divided by the number of live births. The detection rate of hearing impairment was calculated by combining the rates of primary and secondary screening failure with the rate of newborns who failed secondary screening and were later diagnosed with hearing impairment (Appendix 2). This aggregate approach to calculating the detection rate was necessary because individual-level data on detection were unavailable. This aggregate detection rate does not take into account neonates admitted to the intensive care unit after birth.

Data were analyzed for all 31 provinces in China, which were stratified into three geographic areas based on social and economic development [17]: eastern provinces included Beijing, Tianjin, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, and Guangdong; central provinces included Hebei, Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, and Hainan; and western provinces included Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, and Tibet. All data were entered into Epidata 3.0 (The Epidata Association, Odense, Denmark) and analyzed using R version 3.5.1 (R Foundation for Statistical Computing, http://www.r-project.org).

Estimated detection rates of hearing impairment in our study were calculated based on data from the 2018 survey. Rates were calculated for all provinces except Chongqing and Tibet, because data were unavailable on the number of Chongqing newborns diagnosed with hearing impairment among newborns who failed secondary screening, and only 1979 of 50896 live births received NHS in Tibet in 2016. National detection rates were estimated together with 95% confidence intervals (CIs), which were calculated by performing multiple sampling 1000 times based on provincial detection rates.

Results

NHS coverage

National NHS coverage increased from 56.6% in 2008 to 86.5% in 2016, and substantial increases occurred in eastern provinces (66.0% to 93.1%), central provinces (11.2% to 84.9%), and western

provinces (6.8% to 79.4%) (Figure 2).

In 2008, 5 central provinces and 10 western ones had an NHS coverage of less than 10%, and coverage in 13 of these provinces increased to at least 70% in 2016. In the same year, only two provinces, both in the eastern region, had NHS coverage of more than 90%. In 2016, 17 provinces had NHS coverage over 90.0%, comprising 8 eastern, 5 central, and 4 western provinces. Nevertheless, NHS coverage remained lower for western provinces than for eastern ones. In 2016, Guizhou had the lowest NHS coverage of 46.1%, though that of Tibet was probably much lower (Table 1).

Detection rate

In 2016, a total of 28,167 cases were diagnosed as congenital hearing impairment by NHS, and the national detection rate of hearing impairment was 0.23% (95%CI 0.15-0.25%), which varied regionally from 0.17% (6,186 cases) in western provinces to 0.22% (10,272 cases) in central provinces and 0.28% (11,709 cases in the eastern provinces. In that year, the highest detection rate was 0.63% in Hainan province, and the lowest was 0.02% in Heilongjiang province (Figure 3, Appendix 1).

Discussion

Our results provide the most detailed insights to date into NHS coverage and detection rates across China. They also provide what appear to be the first provincial and national estimates of the detection rate of neonatal hearing impairment in the country. Our analysis indicates that from 2008 to 2016, the number of institutions providing NHS and actual NHS coverage have improved substantially, especially in central and western provinces. Nevertheless, different regions of the country continue to show disparities.

NHS coverage in some Chinese provinces reached nearly 100%, similar to the high coverage reported for the USA (98.0%) [9], UK (97.5%) [18], Poland (96.0%) [19] and parts of Italy where NHS has been incorporated into law (99.3%) [20]. Such high coverage in developed countries has been attributed to programs that subsidize the costs of NHS or even make it free [18], the existence of national NHS guidelines [21] and Ministry of Health regulations, government funding for NHS to maternal and child health institutions, and productive collaboration of neonatologists, ear-nose-throat specialists, audiologists, nurses, midwives and parents [19]. Several of these factors may also help explain the substantial increase in NHS coverage in China. In 2009, the National Health Commission of the People's Republic of China began to promote NHS through its "National technical guidelines for screening of neonatal diseases" [16], which was part of a larger goal of reducing disparities in public health services [22]. In fact, the province Shaanxi [23] and some areas in certain provinces such as Tianjin [24] and Beijing [25] began to provide free NHS in order to increase its acceptance by families. In addition, the National Health Commission launched a project in 2013 specifically aimed at neonatal disease screening in poverty-stricken areas, which stipulated improving NHS network, training staff, subsidizing NHS for families, and assessing the quality of NHS [26]. The project was implemented in all central and western provinces, excluding Hainan, which meant that 21 provinces and 200 counties were covered. By 2014, the

project had expanded to 364 counties [27]. NHS coverage of the 21 provinces increased from 21.5% in 2010 to 82.4% in 2016.

At the same time, several Chinese provinces such as Tibet and Guizhou show quite low NHS coverage akin to that of several developing countries [11]. This low coverage has been attributed in some countries to lack of funding and equipment in medical institutions, lack of medical personnel, and a generally low priority for NHS [11, 28]. Data indicate that 8 medical institutions provide NHS in Tibet and 155 in Guizhou; these numbers correspond to rates of 1.6 and 3.1 institutions per 10,000 live birth respectively, which is far below the national average of 6.6 per 10,000 across China as a whole, according to our unpublished report. Unpublished reports of the National Health Commission suggest that Guizhou has undertaken several measures to promote NHS including the acquisition and dissemination of NHS equipment and free training for hearing screening professionals. These measures may help explain why NHS coverage in Guizhou increased from 0.5% in 2008 to 71.4% in 2018.

We report here, apparently for the first time, detection rates of neonatal hearing impairment at the provincial and national levels in China. Since NHS coverage has reached 86.5%, our detection rates may be reasonable estimates of the actual incidence of newborn hearing impairment. We measured a national detection rate of 0.23% (95%CI 0.15-0.26%) in 2016. According to the data we acquired from the survey conducted in 2018, only 72.7% of neonates who failed primary screening underwent secondary screening (secondary screening rate), and only 53.9% of neonates who failed secondary screening were referred to medical institutions for diagnosis (referral rate). Given the lack of a national, individual-level information system, we had to collect all our data from licensed medical institutions providing diagnosis or treatment, which means that we missed patients who were screened or treated at unlicensed places. Therefore, we caution that our estimated referral rate may underestimate the true rate. Nevertheless, our estimate falls within the global incidence of 0.05-0.5%among neonates and infants [1]. This finding suggests that the data analyzed in the present study can provide a reasonable basis for analyzing neonatal hearing impairment in China, and it suggests that the country has succeeded in improving NHS coverage and detection. On the other hand, the observation that rates of secondary screening and of diagnosis/treatment are substantially below 100% indicates lagging integration of diagnosis and treatment. They also reflect the urgent need for a national individual-level information system to monitor and address this integration gap. Province-level studies have confirmed that unified individual-level information systems can ensure the availability of timely, accurate and comprehensive data [29-31].

Several limitations of the study should be noted. One is that owing to the low NHS coverage in 2008-2010, especially in western areas with NHS coverage of 6.8-16.2% during the three years, our estimated detection rate may not accurately represent the province-level detection rate. Hence, we estimated the detection rate only for 2016. Another limitation is that the detection rate in 2016 was estimated based on tabulated data rather than individual-level information, and the rates of secondary screening and referral were not 100%. This may cause error between estimated and actual detection rates. For the reason, it may be attributed to that cases attended secondary screening or referral to the licensed institutions may have a higher risk than others who did not attend or referral to the licensed institutions, leading to a

higher diagnostic rate of hearing impairment than the actual one, which could then affect the detection rate.

Conclusions

National NHS coverage in China increased substantially from 2008 to 2016, but geographic disparities remain. The detection rate of infant hearing impairment in China appears to be similar to that in many other countries. A national individual-level information system is needed to help integrate screening, diagnosis and treatment in China, which may also help determine a more accurate detection rate.

Abbreviations

NHS: Newborn hearing screening

Declarations

Acknowledgments

The authors thank the National Health Commission of the People's Republic of China for their support of the two national surveys, and they are grateful to the medical institutions that participated in them.

Authors' contributions

All authors contributed to study design, collection and analysis of data, and manuscript preparation. X.Y. and K.D. analyzed data and drafted the main article; J.Z., L.X., Y.Y. and Q.L. reviewed data from all sites and drafted the article; X.L. and H.L. revised the article. All authors discussed the results and implications and commented on the manuscript at all stages.

Funding

This article presents independent research funded by The National Key R&D Program of China (grant 2018YFC1002200) and Special Foundation for State Basic Research Program of China (grant 2014FY110700).

Availability of data and materials

The primary data set collected from medical institutions and analyzed during the current study is available from the corresponding author. Besides, an administrative consent must be obtained to share data.

Ethics approval and consent to participate

The surveys were reviewed and approved by National Health Commission of the People's Republic of China with an national administrative notice was transmitted before each survey. All related medical

institutions reported the tabulated data accordingly, which did not involve individual information, and the ethics approval and consent to participate were not necessary in the study.

Consent for publication

Not applicable.

Competing Interes

The authors declare that they have no competing interests.

References

1. WHO: **Newborn and infant hearing screening: current issues and guiding principles for action**. In.; 2009.
2. Organization WH: **Deafness and hearing loss.** *https://wwwwhoint/news-room/fact-sheets/detail/deafness-and-hearing-loss* 2019.
3. Yang kun YX, Wang Yan, Xu Yong: **The American Academy of Audiology Childhood Hearing Screening Guidelines (Chinese)**. *Journal of Audiology and Speech Pathology* 2017, **2**.
4. Swanepoel DW: **Global epidemic of infant hearing loss - priorities for prevention**. *Infant Hearing Loss* 2010.
5. Wroblewska-Seniuk KE, Dabrowski P, Szyfter W, Mazela J: **Universal newborn hearing screening: methods and results, obstacles, and benefits**. *Pediatr Res* 2017, **81**(3):415-422.
6. Mehl AL, Thomson V: **Newborn hearing screening: the great omission**. *Pediatrics* 1998, **101**(1):E4.
7. Downs M P SGM: **Identification audiometry for neonates: A preliminary report**. *Journal of Auditory Research* 1965, **4**(2):80.
8. Vos B, Senterre C, Lagasse R, Tognola G, Leveque A: **Organisation of newborn hearing screening programmes in the European Union: widely implemented, differently performed**. *Eur J Public Health* 2016, **26**(3):505-510.
9. **Summary of 2016 National CDC EHDI Data.**
10. Bouillot L VM, Durand C: **Implementing universal newborn hearing screening in the French Rhône-Alpes region. State of affairs in 2016 and the 1st half of 2017**. *Int J Pediatr Otorhinolaryngol* 2019:117.
11. Harris MS, Dodson EE: **Hearing health access in developing countries**. *Curr Opin Otolaryngol Head Neck Surg* 2017, **25**(5):353-358.
12. Xu X WH, Peng YM, Liu XY: **The results of newborn hearing screening data of 2378 newborns in Shanghai.** *Chin J Pediatr* 1997, **35**.
13. Yu Limei YY, Sun Xibin: **The present situation of newborn hearing screening in China. (Chinese)**. *Chinese Scientific Journal of Hearing and Speech Rehabilitaion* 2010, **(5):32-34.**

14. Xiangli YTZ: **Analyze the Factors Influencing the Qual ity of Newborn Hearing Screening in Guangdong Province and Its Improvement Measures**. *Journal of Audiology and Speech Pathology* 2018, **3(26)**.
15. Wu Dan DC, Tian Ying: **Investigation on the present situation of newborn hearing screening in hubei province**. *Journal of Audiology and Speech Pathology* 2019, **2(27)**.
16. China NHCotPsRo: **Technical specifications for newborn hearing screening**. *Chinese Journal of Child Health Care* 2011.
17. Xu Jie WH, Li Ping: **The challenge of building an innovation-oriented country in China – based on the difference of scientific and technological progress in the eastern and western regions. (Chinese)**. *Exploration of economic problems* 2016, **2**:15.
18. Wood SA, Sutton GJ, Davis AC: **Performance and characteristics of the Newborn Hearing Screening Programme in England: The first seven years**. *Int J Audiol* 2015, **54**(6):353-358.
19. Greczka G, Wrobel M, Dabrowski P, Mikolajczak K, Szyfter W: **Universal Neonatal Hearing Screening Program in Poland–10-year summary**. *Otolaryngol Pol* 2015, **69**(3):1-5.
20. Bubbico L, Tognola G, Grandori F: **Evolution of Italian Universal Newborn Hearing Screening Programs**. *Ann Ig* 2017, **29**(2):116-122.
21. Grosse SD, Mason CA, Gaffney M, Thomson V, White KR: **What Contribution Did Economic Evidence Make to the Adoption of Universal Newborn Hearing Screening Policies in the United States?** *Int J Neonatal Screen* 2018, **4**(3):25.
22. **Opinions of the CPC central committee and the state council on deepening the reform of the medical and health care system**
23. **The development of maternal and child health in shaanxi province is good**
24. **mobile children enjoy five free screening**
25. **Beijing has screened more than 3.7 million newborns for diseases**
26. China TNHCotPsRo: **Program of Neonatal Disease Screening Project in Poverty-stricken Areas in 2013.** *http://wwwnhcgovcn/fys/s3585/201311/4ce5a095f552423d82fcd0738cc13102shtml* 2013.
27. China TNHCotPsRo: **Program of Neonatal Disease Screening Project in Poverty-stricken Areas in 2014**. *http://wwwnhcgovcn/fys/s3585/201412/4a9a8047bb2449c4b4da811e5a0960aashtml* 2014.
28. Galhotra A, Sahu P: **Challenges and Solutions in Implementing Hearing Screening Program in India**. *Indian J Community Med* 2019, **44**(4):299-302.
29. Li Zhenkai WS, Zhao Xueyong.: **Establishment and Application Evaluation of Information Platform for Neonatal Disease Screening in Zhengzhou**. *J Mod Med Health* 2018, **34**(17).
30. Chen Yaqiu WH, Liu Shuang, Ding Yibing, Wang Meiling: **Newborn Hearing Screening and Information Construction in Tianjin**. *Chinese Archives of Otolaryngology-Head and Neck Surgery* 2012, **7**(19):357.

31. Xue Y: **Operation Mode of Information Collection and Reporting System for Newborn Hearing Screening in Beijing. (Chinese)**. *Chin Matern Child Health Care* 2005, **20**.

Table

Table 1. Number of newborns receiving hearing screening (n) and the corresponding newborn hearing screening coverage by region and province of China in 2008 and 2016

Area	2008 [b]		2016 [c]	
	n	Coverage [d] (%)	n	Coverage [d] (%)
National	4,200,725	29.9	15,264,841	86.5
Regional				
Eastern	3,363,861	66.0	6,193,095	93.1
Central	584,198	11.2	5,301,210	84.9
Western	252,666	6.8	3,770,536	79.4
Provincial				
Beijing	151,835	88.5	244,731	95.9
Tianjin	69,926	64.4	132,654	99.4
Liaoning	211,699	65.1	333,811	94.4
Shanghai	174,435	100.0	207,659	98.2
Jiangsu	655,967	83.1	939,898	98.2
Zhejiang	515,557	85.0	711,994	97.0
Fujian	242,036	60.0	554,845	92.4
Shandong	908,824	94.6	1,570,953	97.3
Guangdong	433,582	27.9	1,496,550	83.5
Hebei	132,157	15.7	923,921	91.4
Shanxi	14,860	4.9	291,067	69.2
Jilin	12,029	5.7	183,103	94.1
Heilongjiang	57,676	22.8	197,917	95.5
Anhui	68,943	11.0	672,544	86.9
Jiangxi	28,822	5.2	494,026	80.0
Henan	57,606	4.9	1,106,339	80.0
Hubei	131,553	25.8	478,441	73.0
Hunan	79,336	12.2	830,235	98.2
Hainan	1,216	1.1	123,617	91.5
Inner Mongolia	18,632	9.4	169,299	73.1
Guangxi	46,361	6.3	783,560	93.4
Chongqing	36,182	14.5	223,785	70.5
Sichuan	68,266	9.1	578,015	69.6
Guizhou	1,790	0.5	227,496	46.1
Yunnan	8,803	2.1	555,658	92.0
Shaanxi	35,801	13.1	458,343	89.1
Gansu	14,262	5.5	290,104	94.3
Qinghai	2,122	2.7	42,144	68.3
Ningxia	4,048	5.7	93,282	95.8
Xinjiang	16,399	5.6	346,871	86.5
Tibet	0	——	1,979	3.9

[b] There were 14,051,291 live births in 2008 in China, which was from the live births reported by midwives in each province.

[c] There were 17,644,192 live births in 2016 in China, which was from the live births reported by midwives in each province.

[d] Calculated as described in Methods.

Supplementary Information

Additional file 1. Coverage area of medical institutions that participated in the two surveys.

Additional file 2. Detection rate of newborn hearing impairment in 2016 in China, by province and region.

Figures

Figure 1

Flow chart of data reporting and auditing.

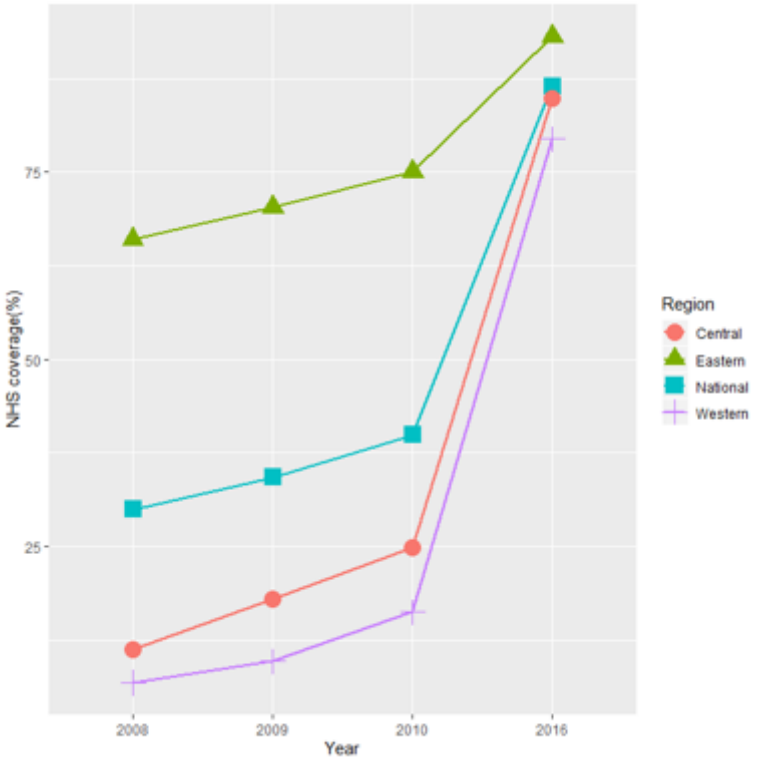

Figure 2

Newborn hearing screening (NHS) coverage by region in China from 2008 to 2016. *Regions are defined in Methods.

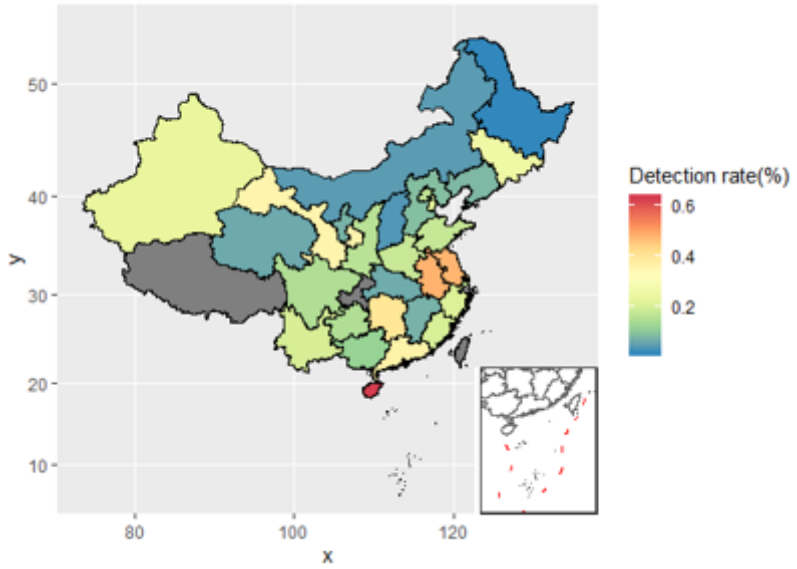

Figure 3

Detection rate of infant hearing impairment in 2016 in China, by province. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion

whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile2.docx
- Additionalfile1.docx