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Original Article

The implementation of newborn cardiac screening in developing regions: Evaluating a training program in rural China

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ABSTRACT

Although congenital heart defects are the most common birth defects, occurring in nearly 1 in 100 births, many developing regions do not practice proper newborn cardiac screening, which uses pulse oximeter and stethoscope. We therefore designed and implemented an on-site training program of newborn cardiac screening for obstetric personnel in rural Yunnan province, China. The aims of this study were to evaluate whether the training improved trainees' knowledge on newborn cardiac screening and resulted in higher newborn cardiac screening rates. The training program, which started in July 2015 and lasted through 2016, trained 2,175 obstetric doctors and nurses from 104 rural hospitals. The trainees demonstrated significant knowledge improvement on the knowledge of cardiac screening. Additionally, before June 2016, the trained personnel performed proper cardiac screening on 44,614 (93.6%) newborn babies. Given the effectiveness and cost-efficiency of this program in Yunnan, we recommend similar programs be implemented in other developing areas.

1. Introduction

Congenital heart defects (CHD) are the most common and severe types of congenital anomalies . The incidence of CHD, as reported by Hoffman and Kaplan (2002), is 12–16 per 1000 live births. Critical Congenital Heart Diseases (CCHD) are defined as CHD lesions that require surgical or catheter-based intervention in the neonatal period (e.g. pulmonary atresia, transposition of the great arteries) (Chang et al., 2008). About 25% CHDs are considered CCHD (Chang et al., 2008), which along with large shunt lesions are the most severe types of CHDs. Large shunt lesions are ventricular septal defects (VSD) and patent ductus arteriosus (PDA) that require surgery in order to prevent death from irreversible pulmonary vasculature disease. The incidence of VSD and PDA is approximately 4.4 per 1000 live births (Hoffman and Kaplan, 2002). We estimated that one-fourth of the VSDs and PDAs are large shunt lesions, so an estimated one in every 1000 neonates are born with large shunt lesions. Most of these heart defects are curable if discovered early in life (Chang et al., 2008).

Nevertheless, many infants with CCHD or large shunt lesions are not diagnosed and are directly discharged from the hospital (Abu-Harb et al., 1994; Chang et al., 2008). Many of them die in infancy and some develop incurable pulmonary vascular disease and Eisenmenger's syndrome and then die in young adulthood. Thus, hospitals should improve the method of screening for CCHD and large shunt lesions.

Pulse oximetry screening is effective and reliable for early detection of CCHD, with a sensitivity of 75.0–83.6% and specificity of 99.4–99.9% (Ewer et al., 2011; Meberg et al., 2008; Plana et al., 2018; Zhao et al., 2014). In many developed countries, this method has been added to the uniform newborn screening panel (Committee et al., 2012; Glidewell et al., 2015; Kemper et al., 2011; Manzoni et al., 2017). However, according to the results of our preliminary study (not published), many rural hospitals in Yunnan, China did not implement pulse oximetry screening on newborn babies.

By contrast, in large hospitals of developed countries, many

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educational programs for newborn pulse oximetry screening have been successfully implemented (Attin et al., 2002; Farner et al., 2014; Mazrouei et al., 2013; Ryan et al., 2014). One of the largest such programs, TxPOP, successfully and quickly trained neonatal nurses in Texas in the proper use of pulse oximetry (Farner et al., 2014). Despite the success of such programs, there has been insufficient effort to disseminate pulse oximetry screening method to rural areas in developing countries.

Pulse oximetry may not detect severe non-hypoxemic lesions in the newborn period. Cardiac auscultation can detect these lesions when a murmur is present. For example, large shunt lesions (VSDs and PDAs) can usually be detected by heart auscultation. A large study conducted in Shanghai has reported that newborn cardiac screening using pulse oximeter and stethoscope could achieve a higher sensitivity (93.2%) than that of using pulse oximeter alone (83.6%) (Zhao et al., 2014). Based on our preliminary study in rural areas of Yunnan, hospitals did not conduct proper cardiac auscultation on every newborn baby. Hence, training rural hospital personnel in the proper use of stethoscope is also imperative.

To meet this challenge, we designed and implemented a training program for newborn pulse oximetry and stethoscope screening, for obstetric doctors and nurses working in rural areas of Yunnan Province. The aims of the study were 1) to test whether the training program resulted in trainees' improvement in knowledge of cardiac screening and the proper use of pulse oximeter and stethoscope, 2) to test whether the training program led to high newborn cardiac screening rates in the participating hospitals, and 3) to discuss the best practices in educating rural obstetric personnel on newborn cardiac screening.

Yunnan is a socio-economically depressed province of China (per capita annual income of $1,222). An estimated 592,000 neonates are born in Yunnan province each year ("National Bureau of Statistics of China," n.d.). Assuming a CCHD incidence of two per 1,000, and a large shunt lesion incidence of one per 1,000, approximately 1,800 Yunnan infants are affected per year. These affected infants can benefit from an effective cardiac screening program.

2. Methods

2.1. Training strategy

In China's rural county hospitals, where most birthing occurs, obstetricians and obstetric nurses take responsibility for the care of all asymptomatic neonates; pediatricians are only consulted for infants with signs or symptoms of disease. We therefore designed a training program—the Newborn Cardiac Screening Training Program (NCASTP)—for obstetricians and obstetric nurses in Yunnan rural county hospitals. We established a training team in June 2015, which included three core members (a cardiologist, a Ph.D. student in Public Health and a research assistant) and a number of volunteers. All members in the training team spoke fluent Chinese. The team visited every rural county hospital which was interested in the training program and trained the obstetric personnel in office/classrooms near the neonatal units.

Using the donated Masimo Rad 5 pulse oximeter from Irvine California, we implemented the training according to the following steps:

(1) pre-training quiz and behavior assessment
(2) 30-min lecture on newborn cardiac screening
(3) one-on-one pulse oximeter practice training
(4) one-on-one stethoscope practice training
(5) post-training quiz test
(6) quiz test and a second behavior assessment

In the practical training, the trainers modeled the correct use of a pulse oximeter to measure pre- and post-ductal oxygen saturation on a plastic model and then on real babies. Then obstetricians and obstetric nurses practiced measuring on the plastic model. When the trainers verified that trainees demonstrated proper use, the trainees moved on to the stethoscope practice training. The stethoscope practice training was elective for the obstetric nurses. In this part, the cardiac specialist trainer used a plastic infant model designed by the General Doctor Company in Shanghai to show the trainees normal and abnormal sounds at four auscultatory sites. The training team would not leave until the cardiac specialist verified that the trainees were able to distinguish normal from the abnormal sounds and knew where the four sites were located.

The pulse oximetry screening algorithm used, was a variation of Granelli's method (Granelli et al., 2009). The neonates were measured 24 h after birth on their right hand and on either foot. The neonate was provisionally considered as screen-positive if both pre- and post-ductal oxygen saturation were less than the cut-off value or the difference between the two was greater than 3%. If the first screening was abnormal, a repeat measurement was performed before hospital discharge. Neonates with two repeated positive measurements were finally regarded as screen-positive and were referred for an immediate cardiac ultrasound exam.

By the end of 2016, NCASTP had trained 2,175 obstetric nurses and doctors (on average 21 per hospital) in 13 of the 16 Yunnan prefectures including 104 of the 125 Yunnan counties (91.2%) (Fig. 1).

2.2. Evaluation strategy

2.2.1. Phase I: knowledge improvement and behavior change of trainees

Trainees in 22 hospitals in Zhaotong and Honghe prefectures (Fig. 1) participated in the first phase of training evaluation. First, a 19-item multiple-choice quiz was implemented before, immediately after and three months after training. The quiz included ten questions on newborn cardiac screening, three questions on patho-physiology, two questions on treatment, two questions on communicating with parents, one question on the symptoms of CCHD and one question on CCHD incidence. In addition, before training and three months after training, we assessed each of the trainees regarding usage of stethoscope and pulse oximeter. We interviewed them based on a behavior checklist, which included questions such as:

'Have you ever applied this device (pulse oximeter/stethoscope) on newborn babies?'

'How often do you use this device?' and

'Do you use the device on every newborn baby?'

Finally, we asked each of the trainees to use the devices on a doll and we observed and recorded their performance.

2.2.2. Phase II: assessment of screening rate

We evaluated the screening rates by collecting monthly cardiac screening data from 36 hospitals (Fig. 1), which received our training in 2015. We provided a data entry sheet to the obstetric directors and chief nurses of those hospitals and instructed them on how to record screening results. The items on the data entry sheet included the number of neonates born in the hospital every month and each baby's randomized ID, birth month, pre- and post-ductal oxygen saturation and auscultation results (with/without murmur) measured at 24 h of age and before hospital discharge.

2.3. Statistical analysis

We summarized the number of correct answers on knowledge quizzes and the behavior scores on the use of stethoscope and pulse oximeter at three points of time (before training, immediately after training and three months after training). We applied independent two-sample t-tests to compare mean correct scores before training and

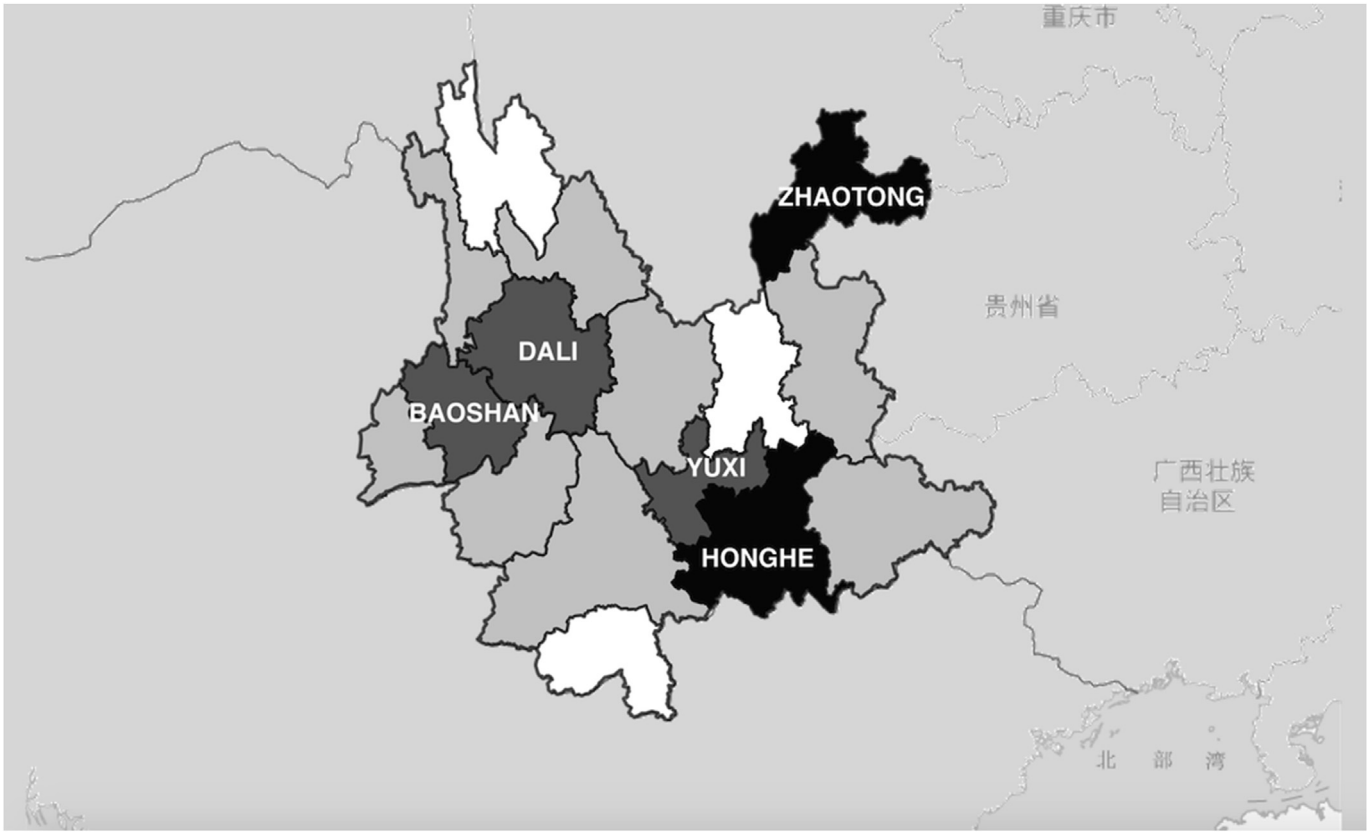

Fig. 1. Training Map of Yunnan Province. Figure legend: This is a map of Yunnan Province of China. Areas in black are the prefectures where we trained and implemented the first and second phases of evaluation. Areas in dark grey are the prefectures where we trained and implemented the second phase of evaluation. Areas in grey are the prefectures that we trained but did not evaluate. Areas in white are the prefectures that we have not trained yet.

immediately after training as well as before training and three months after training. Because quizzes were anonymous, matched analysis was not possible. We used Chi-square tests to compare the proportion of proper use of the stethoscope and pulse oximeter before and three months after training. Statistical tests were performed with the level of significance set at 0.05.

3. Results

3.1. Phase I: knowledge improvement and behavior change of trainees

A total of 332 trainees from 22 hospitals of Zhaotong and Honghe prefectures enrolled in the evaluation of knowledge improvement. All of them participated in the pre-training quiz, 313 (94.3%) in the immediate post-training quiz, and 200 (60.8%) in the 3-month post-training quiz. Participants answered 45.3%, 81.9% and 64.9% of questions correctly in the pre-, post- and 3-month quizzes, respectively. Trainees showed significant knowledge improvement immediately after and three months after training ($p < 0.001$).

Before training, 180 nurses participated in the evaluation of pulse oximeter use. None of them had a neonatal pulse oximeter available. Three months after the training, 99 nurses took part in the evaluation. Fifteen nurses (15.2%) reported they never used the pulse oximeter; 23 (23.2%) used it sometimes; 61 (61.6%) used it frequently. For those 61 nurses who reported using pulse oximeter frequently, all demonstrated proper use. We assessed the proper use of stethoscopes on 107 doctors before training and 61 doctors three months after the training. Before training, 32.7% of the doctors performed cardiac auscultation on every newborn baby. After, this increased to 72.1% ($p < 0.001$). Before training, 80.4% of doctors used the stethoscope improperly. After training, this dropped to 3.3% ($p < 0.001$).

3.2. Phase II: assessment of screening rate

From September 2015 to May 2016, the trained obstetricians and nurses from 36 hospitals applied cardiac screening on a total of 44,614 newborn babies. Screening rates in those hospitals were between 90.6% and 98.0%.

4. Discussion

The NCASTP is the first training program to focus on newborn cardiac screening in rural China. This program resulted in significant knowledge improvement and behavior change for rural obstetric personnel. Before training, none of the obstetrics departments of the participating hospitals implemented proper newborn cardiac screening. Three months after training, all these hospitals had mastered and applied the cardiac screening. Besides, it also resulted in a large number of newborn screenings in the participating hospitals. One limitation of our study is that the screening results were not made available to the researchers.

The NCASTP is both efficient and practical. Similar to the results of TxPOP conducted in Texas (Farner et al., 2014), the results of NCASTP showed that a one-day training was sufficient for rural obstetric doctors and nurses to understand the importance of cardiac screening and to master the screening skills. Additionally, NCASTP has proven to be highly cost-effective. The cost of providing NCASTP trainers was about US$300 per hospital, which includes transportation and lodging. The estimated cost does not include the cost of devices.

Despite being unable to directly train all obstetric personnel, we still found the program to be effective and successful. A small portion of the trainees (less than 6%) had to leave at various times throughout the training when their patients needed immediate care. We compared the

pre-test scores of trainees who attended all of the training sessions with those who left partway through the training, and we observed no significant difference. In addition, we gave all the training materials to the directors and chief nurses of each obstetrics department. During the month after our visit, these local directors organized a second training for the obstetric personnel who did not attend the first training.

We think the approach of on-site training might be the best practice for educating rural obstetric personnel. Prior to the training program, we attempted a traditional training approach by inviting obstetric personnel from three different counties to a central location and training all participants on newborn cardiac screening. The training procedures were the same as the procedures used in the later on-site training. The only difference was that the trainees in the centralized training were told to disseminate training to their respective hospitals. This method failed in that the newborn cardiac screening was not implemented in any of the participating hospitals. Comparing the results of the centralized training approach with those from the on-site training approach, we concluded that the latter approach would provide better training results for rural doctors and nurses.

Newborn CCHD screening is not one of the items on the uniform newborn screening in rural China. However, the Chinese government is continuously improving health insurance options for pediatric heart surgery and resources such as charitable foundations exist to correct heart defects in babies born to poor families. Given these improvements in Chinese healthcare, it is time to institute newborn cardiac screening throughout rural China.

5. Conclusion

Study results indicated that one-day training was sufficient for rural obstetric doctors and nurses to understand the medical knowledge and master the skills regarding newborn cardiac screening. More importantly, the participating hospitals achieved very high newborn cardiac screening rates. Given the success of this training program, we recommend similar programs be implemented in other developing areas.

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Conflicts of interest

The authors have no conflicts of interest relevant to this article to disclose.

Ethical statement

The study design and procedures were approved by the Institutional Review Board, University of California, Irvine.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnn.2018.09.004.

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