BMJ Open Quality

Decreasing birth asphyxia: utility of statistical process control in a low-resource setting

Mariya Mukhtar-Yola,[1] Lamidi Isah Audu,[1] Oluyinka Olaniyan,[2] Henry T Akinbi,[3] Adekunle Dawodu,[4] Edward F Donovan[5]

To cite: Mukhtar-Yola M, Audu LI, Olaniyan O, *et al*. Decreasing birth asphyxia: utility of statistical process control in a low-resource setting. *BMJ Open Quality* 2018;**7**:e000231. doi:10.1136/bmjoq-2017-000231

Received 16 October 2017
Revised 23 June 2018
Accepted 11 August 2018

[1]Neonatal Unit, Department of Paediatrics, National Hospital Abuja (NHA), Abuja, Nigeria
[2]Department of Obstetrics and Gynecology, National Hospital Abuja, Abuja, Nigeria
[3]Perinatal Institute, Cincinnati Children's Hospital Medical Center, Cincinnatti, Ohio, USA
[4]Global Health Center, CCHMC, Cincinnati, Ohio, USA
[5]James Anderson Center for Health Systems Excellence, CCHMC, Cincinnati, Ohio, USA

Correspondence to
Dr Mariya Mukhtar-Yola; mariyamukhtar@yahoo.com

ABSTRACT

The neonatal period is a critical time for survival of the child. A disproportionate amount of neonatal deaths occur in low-resource countries and are attributable to perinatal events, especially birth asphyxia. This project aimed to reduce the incidence of birth asphyxia by 20% by June 2014 through training in neonatal resuscitation and improving the availability of resuscitation equipment in the delivery room in the National Hospital Abuja, Nigeria.

A prospective, longitudinal study using statistical process control analytical methods was done enrolling babies delivered at the National Hospital Abuja.

Low Apgar scores or birth asphyxia (defined a priori as any score <7 at 1, 5 and/or at 10 min) was assessed. To ensure reliability and validity of Apgar scoring, trainings on scoring were held for labour and delivery staff. Interventions included provision of additional equipment and trainings on neonatal resuscitation. Apgar scores were aggregated weekly over 25 months. Control charts with three SE confidence limits were used to monitor the proportion of scores ≤7.

The baseline incidence of low Apgar scores, as defined a priori, was 33%, 17% and 10% while postintervention the incidence was 18%, 17% and 6% at 1, 5 and 10 min, respectively—a reduction of 45% and 40% in the 1-min and 10-min low Apgar scores.

Increased communication, additional resuscitation equipment and training of delivery personnel on neonatal resuscitation are associated with reductions in measures of birth asphyxia. These improvements have been sustained and efforts are ongoing to spread our interventions to other special care delivery units/nursery in adjoining states. Our study demonstrates the feasibility and utility of using improvement science methods to assess and improve perinatal outcome in low-resource settings.

PROBLEM

In Nigeria, every year, over 260 000 babies die within the first month of life with about 90 000 babies dying on the first day of life.[1] About 33% of these deaths are attributed to asphyxia and yet 70%–80% of these deaths could be prevented if essential interventions in existing health packages reached women and babies on time.[2 3] Several studies have identified that limited access to healthcare; poor human and material resource and capacity to intervene at the time of delivery contribute to the high morbidity and mortality.[4] To understand the problem in detail and to identify the failure modes at the National Hospital Abuja (NHA), an audit of the baseline incidence of low Apgar scores as a measure of birth asphyxia was found to be 33%, 17% and 10% at 1, 5 and 10 min, respectively. Realising that systems and processes could be improved for the benefit of these babies, this study aimed at reducing the incidence of birth asphyxia in the delivery room by 20% by March 2014 at the NHA. We hypothesised that training on neonatal resuscitation and improving the availability of resuscitation equipment will increase the incidence of 1, 5 and 10 min Apgar scores >6 by at least 20%.

The NHA is a 400-bed tertiary facility that serves as a referral centre for all hospitals within Abuja and the neighbouring states. About 2000 newborns are delivered at this hospital every year. Some births occur to booked patients of the hospital but many births are to mothers referred shortly before delivery because of pregnancy complications. The study design was prospective and longitudinal using statistical process control analytical methods.[5] Infants delivered at the NHA during the study period were included while, babies with major congenital malformations, birth before arrival and stillbirths were excluded.

BACKGROUND

The neonatal period is a critical time for survival of the child. More than 80% of all newborn deaths result from three preventable and treatable conditions: complications due to prematurity, neonatal infections and intrapartum-related deaths (including birth asphyxia).[6 7] In 2012, it was estimated that globally about 2.9 million newborns die every year and 2.6 million are delivered stillborn.[2] Seventy-five per cent of these deaths occur in South Asia and sub-Saharan Africa and about

three-quarters of all neonatal deaths occur during the first week of life, with 1 million babies dying on the day they are born.[2] Perinatal asphyxia accounts for over 800 000 newborn deaths each year.[2] For each intrapartum-related newborn death, many more babies are left with permanent disabilities.[8] Since newborn deaths still account for 44% of under-5 deaths globally, neonatal mortality and stillbirths require greater visibility in the emerging post-2015 sustainable development agenda if the overall under-5 mortality is to be significantly reduced.[3]

Nigeria has the highest number of newborn deaths in Africa, and the second highest in the world.[5] Three-quarters of these deaths could be prevented if essential interventions in existing health packages reached women and babies on time.[1–3] Although some progress has been made in the reduction of the neonatal mortality rate from 48/1000 live birth in 2003 to 37/1000 live birth in 2013, much more can be achieved using available newer strategies.[8–10] Several reasons have been identified as challenges to reducing birth asphyxia in sub-Saharan Africa including lack of skilled workers and resuscitation equipment. In an observational study of 193 healthcare workers drawn from different counties in Kenya, only 12% of the nurses had received any formal in-service training on neonatal resuscitation and >70% of them considered their knowledge about neonatal resuscitation inadequate and blamed it on inadequate medical training programmes.[11] Similarly in western Nigeria, Ogunlesi *et al* reported that of 176 nurses sampled from 4 hospitals, only 14.0% had attended neonatal resuscitation training course within the past 5 years.[12] In a survey of four hospitals in western Nigeria, only 31.8%, 53.1%, 58.1% and 35.2% had access to radiant warmers, ambu bags, suction machine and oxygen delivery units, respectively.[12]

An important step to improving neonatal care and reducing neonatal mortality in low-income and middle-income nations is assessment of neonatal healthcare resources, community engagement and improved government funding of health services. This will allow identification of areas of healthcare policy and public participation needing modification to enhance survival of newborns.[13]

Studies from the USA demonstrated that significant improvement in Apgar scores occurred among neonates after Neonatal Resuscitation Programme (NRP) instruction.[14 15] Studies of both state-wide and individual hospital populations showed that there was a statistically significantly lower proportion of high-risk newborns with low (0–6) 5 and 10 min Apgar scores after the training. After adjusting for several maternal characteristics, logistic regression analysis revealed that high-risk newborns with low 1 min Apgar scores were more likely to increase their 5 min Apgar scores after NRP instruction.[14,15] Similar findings were reported from South Africa[16] and Cambodia.[17]

Preventive safe motherhood strategies to reduce neonatal deaths due to intrapartum hypoxia such as birth preparedness, presence of a skilled attendant at delivery, danger sign recognition and training of staff on neonatal resuscitation could reduce the incidence of birth asphyxia.[1–3] This study set out to determine the effect of reducing the gaps in knowledge and skills in neonatal resuscitation, improving communication and the availability of equipment needed for resuscitation on the incidence of birth asphyxia.

In planning this work, weekly meetings both virtual and physical took place involving all authors and at times supporting staff for about 6 months. Thereafter, meetings took place twice a month until project conclusion. Selected residents, records clerks and data entry clerks were recruited and placed on monthly stipends. Lack of a project funding was a significant barrier to maintaining engaged staff.

Staff of the labour ward and neonatal unit who participated in data collection were involved at an onsite meeting and given written project descriptions and copies of the ethical approvals. Mothers were provided with patient information sheets, which provided details about the ongoing project.

MEASUREMENTS

To determine a baseline incidence of asphyxia, a review of medical records of all births was conducted retrospectively covering the 16-month period (February 2012–June 2013) prior to initiation of study interventions. Additionally, using a questionnaire with a checklist completed by labour ward and neonatal nurses during 100 nursing shifts, we determined the availability and functionality of equipment for resuscitation, the availability of healthcare workers to support neonatal resuscitation and the proportion of staff that had already received Neonatal Resuscitation Training (NRT) or Helping Babies Breath (HBB) training. This was done to identify any gaps in required manpower, equipment and supplies.

Maternity and neonatal staff were retrained in May 2013 on the Apgar scoring system as a reproducible measure to assess asphyxia and to ensure uniformity in scoring.

Results of baseline assessment revealed that the neonatal unit is a level 2b nursery with 3 units that had a total capacity of 30 beds inclusive of cots and 10 incubators. Four consultants, 4 senior residents, 4 junior residents and about 60 nursing staff managed the unit. Results of the preliminary audit showed that the labour ward had 16 delivery beds, 4 resuscitation stations or warmers, an ultrasound machine, a cardiotocograph, mobile fetal heart monitoring machine, wall oxygen and suction points. Mobile manual suction devices and mucous extractors were also available. The staff consisted of 20 midwives/nurses, 10 consultants and 20 residents.

When surveyed, 51% of the midwives reported that they had received training in NRT or HBB in the preceding 2 years, 31% reported they had never received any formal training while 18% did not respond.

In response to survey questions regarding resuscitation equipment and supplies availability and functionality, the midwives responses are shown in table 1. In the

Table 1 Checklist for resuscitation equipment in delivery room

Equipment/material	Available and functional, n (%)	Available but non-functional, n (%)	Not available
Warmer/resuscitaire Switch on machine and confirm it works	88 (88.0)	12 (12.0)	0
Ambu bag and mask Confirm availability of different mask sizes	94 (94.0)	6 (6.0)	0
Oxygen Test for presence of gas	99 (99.0)	1 (1.0)	0
Bulb suction syringe	2 (2.0)	0	98 (98.0)
Suction machine Switch on and confirm	98 (98.0)	2 (2.0)	0
Suction tubes Check for various sizes	97 (97.0)	3 (3.0)	0

free comment section provided in the checklist, it was reported that the available equipment were not sufficient given the number of babies delivered in the unit. Consumables were also often lacking.

Sixty-four per cent of the questionnaires were completed in the labour ward, while 36% were completed in the obstetrics operating room.

Standard improvement science methods[18] and statistical process control analyses were used including special cause rules that identified probabilities of <2% ($p<0.02$). Control charts with 3 SE confidence limits were used to monitor the proportion of Apgar scores ≥7.

DESIGN

After the baseline data collection period, interventions were offered starting July 2013 and data collection continued prospectively to March 2014. Plan-do-study-act (PDSA) cycles were used to trial the improvement interventions and assess the impact on low Apgar scores. Interventions offered included education and awareness meetings with the NHA management, faculty and staff of obstetrics and gynaecology (OBGYN) and paediatrics in July 2013 to highlight the importance of communication between the two departments and the need for training and skill acquisition in order to reduce the incidence of birth asphyxia. Second, additional resuscitation equipment was supplied to the labour room in August 2013. These were expected to help in the effective resuscitation of the babies. Finally, training in neonatal resuscitation was initiated in batches starting September 2013 for 70 doctors and nurses using the HBB training tools developed by the American Academy of Paediatrics.[19] Four Neonatologists, an obstetrician, two midwives and some administrative assistants conducted the training. To ensure sustainability, refresher training was provided to the staff every 6 months.

STRATEGY

Beginning January 2012, Apgar scores were aggregated weekly over 25 months. The incidence of asphyxia was assessed and plotted monthly using statistical process control methods. Using these assessments, interventions were reviewed every 3 months to identify failure modes and balancing measures in order to determine whether the interventions needed to be modified, adapted or adopted.

PDSA1: EDUCATION AND AWARENESS (JULY 2013; WEEK 73)

Aim

To sensitise the hospital management and relevant departments on the need for effective communication, training on neonatal resuscitation and provision of equipment and supplies to reduce the incidence of low Apgar scores by 20% by March 2014.

Plan

Hold awareness meetings with hospital management, staff and faculty of OBGYN and paediatrics to highlight the importance of communication between the two departments and the need for training and skill acquisition in order to reduce the incidence of low Apgar scores. Emphasis was placed on inviting paediatricians to all high-risk deliveries and daily notification of the newborn unit of booked elective caesarean sections in order to enable a paediatrician to be in attendance.

Do

Four meetings were held; one with the hospital clinical directorate, the second with the maintenance and procurement directorate and two separate meetings between faculty and staff of OBGYN and paediatrics. The last meeting had a least 25 people in attendance while the earlier meetings each had 6 people in attendance. The management and staff of relevant departments embraced this renewed effort and offered to collaborate and plan for resources to achieve the common goal.

Study

The results showed that collaboration resulted in more commitment towards facilitating the requirements to reduce low Apgar scores. Increased communication resulted in paediatricians attending high-risk deliveries and planned surgeries.

Act

We identified the need for resuscitation equipment as our next PDSA cycle.

PDSA 2: RESUSCITATION EQUIPMENT (AUGUST 2013; WEEK 77)

Aim

To sensitise the hospital management and relevant departments on the need for effective communication, training on neonatal resuscitation and provision of equipment

and supplies to reduce the incidence of low Apgar scores by 20% by March 2014.

Plan

To request of hospital management that additional equipment was required for the labour and delivery rooms.

Prediction

Availability of additional equipment and supplies will facilitate effective resuscitation of babies and improve the skills of staff.

Do

The hospital management supplied additional resuscitaires, bag and masks ventilators, consumables, etc.

Study

The result confirmed this as a crucial intervention as the number of resuscitation equipment doubled and a supply chain was established for consumables.

Act

We put in measures for routine maintenance of equipment and sustained supply of consumables and identified the need for training on neonatal resuscitation as our target for the next PDSA.

PDSA 3: HBB TRAINING (SEPTEMBER–OCTOBER 2013; WEEKS 81–87)

Aim

To sensitise the hospital management and relevant departments on the need for effective communication, training on neonatal resuscitation and provision of equipment and supplies to reduce the incidence of low Apgar scores by 20% by March 2014.

Plan

To conduct serial trainings on neonatal resuscitation for doctors and nurses in delivery room and neonatal unit, using HBB tools.

Prediction

Neonatal resuscitation training will improve the skills of doctors and midwives as 31% of midwives reported that they had not received a formal training in the preceding 2 years.

Do

Seventy doctors and midwives were trained on neonatal resuscitation in batches.

Study

Skills in neonatal resuscitation improved as the incidence of low Apgar scores reduced to 18% in 1 min, and 6% in 10 min.

Act

This was implemented as a standard. Refresher trainings are provided every 6 months.

RESULTS

From February 2012 through March 2014, there were 3427 births at NHA, approximately 33 births per week. Only 3347 (98%) had complete records. Patients booked at the NHA were 2723 (81.4%), while unbooked patients were 624 (18.6%). Fifty-two per cent of babies were delivered vaginally, 17.7% by elective caesarean section and 28% by emergency caesarean section while the others had assisted vaginal delivery. The maternal age was 31.4±4.8 years (range 15–50 years); mean gestational age was 37.7±2.8 weeks (range 25–44 weeks); mean birth weight was 3.05±0.75 kg (range 500–5600 g). Preterm babies constituted about 20%.

Findings from this study showed that although some of the required resuscitation equipment were available, some (eg, radiant warmers) were not functional as reported by 12% of the interviewees. Appropriate-sized facemasks for positive pressure ventilation were also reported to be unavailable or non-functional by 6% of questionnaire respondents. The use of bulb syringes for suctioning was almost non-existent (2%) as wall suction or mobile suction device with nasal catheters and mucous extractors predominated. Only 51% of the labour and delivery room staff had received any formal training on NRT or HBB in the 2 years preceding the study. Although these staff are constantly working in the delivery room, there is no protocol in place for periodic skill evaluation and retraining especially when new guidelines are introduced.

During the 16-month period prior to initiating the intervention, the average incidences of Apgar scores <7 were 33%, 17% and 10% while the average incidences after the interventions (PDSA cycles) initiated were 18%, 17% and 6% at 1, 5 and 10 min, respectively (figures 1–3). This demonstrates reductions in measures of birth asphyxia of 45%, and 40% at 1 and 10 min, respectively.

Figure 1 shows a control chart with weekly per cent of 1 min Apgar scores≥7. A special cause, indicating an increase in the proportion of Apgar scores≥7 was identified in week 73 (3 weeks after initiation of interventions), thereafter a new mean for weekly Apgar scores≥7 was calculated. This indicates that there was a statistically significant change in Apgar scores likely related to improvements in care. No special cause was observed during the course of the study in the weekly Apgar scores for 5 min (figure 2). For the 10 min score, a special cause showing a statistically significant increase in the proportion of Apgar scores≥7 was identified during the first week of August 2013, that is, week 73 (3 weeks after initiation of interventions). Thereafter, a new mean for weekly 10 min Apgar score was calculated and displayed (figure 3). The three figures each suggest a decrease in variation among Apgar scores associated with the variation possibly due to standardisation of care.

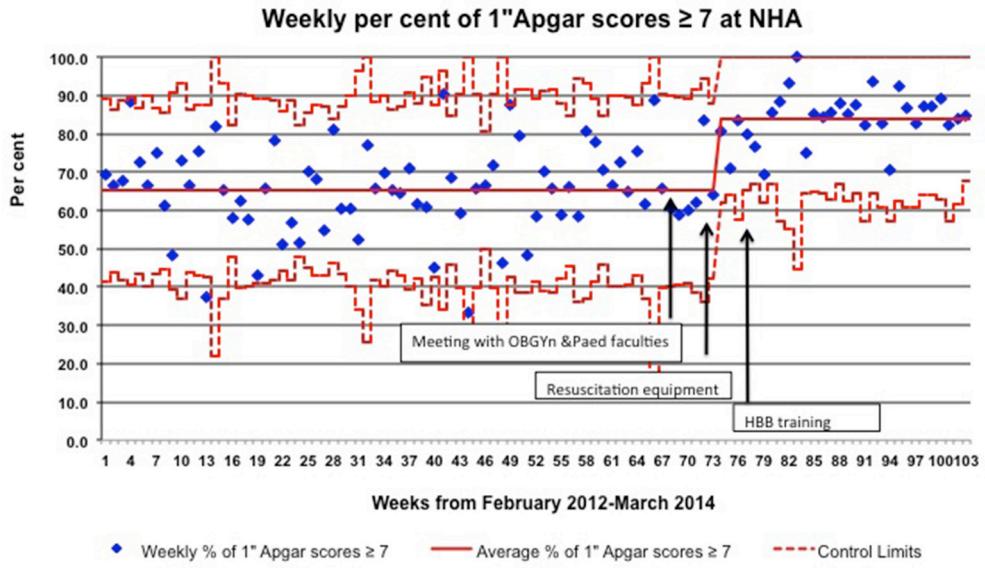

Figure 1 Control chart of weekly per cent of 1 min Apgar scores at NHA ≥7 demonstrating a special cause likely related to improvement in care. HBB, Helping Babies Breathe; NHA, National Hospital Abuja; OBGYN, obstetrics and gynaecology.

LESSONS AND LIMITATIONS

This study examined the feasibility of using improvement science methods in resource-limited settings to evaluate the effect of several interventions on babies at risk of low Apgar scores. The results of this study indicate that strengthening communication between hospital management, obstetricians, midwives, NICU nursing staff and neonatologists, providing additional equipment and trainings on neonatal resuscitation improved Apgar scores in 1 and 10 min as compared with historical controls. Important lessons learnt to keep the staff motivated about the project include: periodic project updates to the labour and delivery team by displaying run charts on the wards to show progress being made and the role of resuscitation champions for onsite mentoring.

This quality improvement project has positively impacted both the healthcare system in the NHA and the care provided by healthcare workers. The delivery room has benefited with additional equipment and supplies as well as protocols on neonatal resuscitation. Additionally, there is improved communication and interaction between the obstetricians, midwives and neonatologist, strengthened by the joint participation during the HBB training sessions.

There are a number of limitations in this study. First, the study used retrospective or historical data to obtain

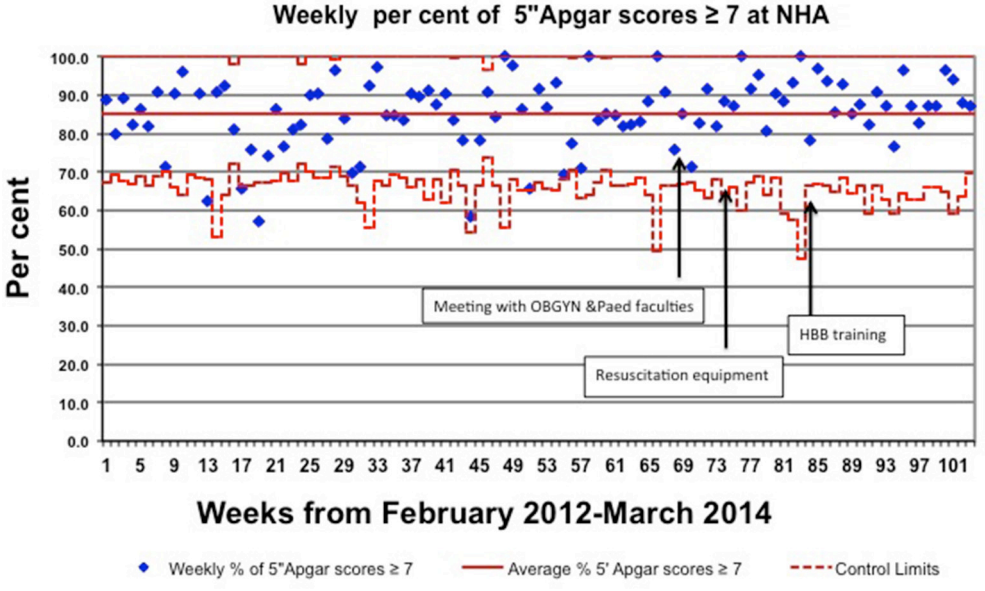

Figure 2 Control chart of weekly per cent of 5 min Apgar scores at NHA≥7. There was no special cause identified. HBB, Helping Babies Breathe; NHA, National Hospital Abuja; OBGYN, obstetrics and gynaecology.

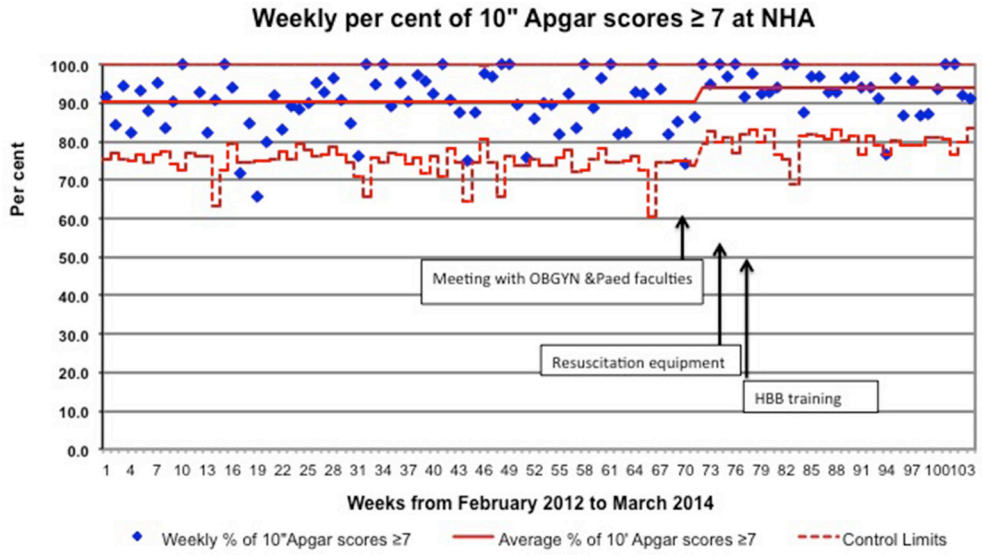

Figure 3 Control chart of weekly per cent of 10 min Apgar scores at NHA ≥7 demonstrating a special cause likely related to improvement in care. HBB, Helping Babies Breathe; NHA, National Hospital Abuja; OBGYN, obstetrics and ynaecology.

comparison data on birth asphyxia and thus was limited by the availability of a common newborn database over the years. Medical records are still kept in paper registers rather than electronic medical records, which may increase the likelihood of missing data. For example, in some shifts there were records of 1, 5, 10 and 20 min Apgar scores while some shifts carried only 1 and 5 min Apgar scores. Attempts were made to use as much of the common information as possible to control for possible differential bias over the years. Second, competence in reproducibly assigning Apgar scores may have evolved over the years. We can only vouch for the consistency of Apgar scores post-training during the study period. Rothberg *et al*[20] demonstrated that some staff tended to assign higher Apgar scores than independent observers. In order to mitigate this issue, trainings on Apgar scoring was conducted to all delivery and neonatal staff prior to the prospective arm of the study to introduce some standardisation. The emphasis placed on Apgar categories (0–3, 4–6, 7–10) rather than unit changes in an Apgar score was an attempt to minimise bias and reduce effect of inter-rater variability among healthcare personnel. This particular design in which the interventions, by necessity, were applied to all caregivers in a single hospital could not feasibly include a concurrent group of newborns. Thus, it is possible that there were unplanned and unmeasured changes in care that resulted in improved Apgar scores. Because this version of longitudinal statistical process control methods suffers from this possible bias, a type 1 error threshold of 0.02% was used rather than the conventional threshold of 0.05%. Due to two episodes of industrial action in the hospital during study period, the number of babies delivered in the hospital was not as large as under normal circumstances; however, this did not have an impact on the study.

CONCLUSION

Retraining of delivery personnel, enhanced communication and improved availability of resuscitation resources is associated with reductions in low Apgar scores as a proxy for birth asphyxia of 45% and 40% at 1 and 10 min, respectively. This study demonstrates the feasibility and utility of applying improvement science methods to assess and improve perinatal outcome in low-resource settings.

This project has established a sustainable communication channel between the obstetricians and the neonatologists. Administration of biannual refresher HBB trainings to health workers and extending lessons learnt to other neonatal centres in Abuja will ensure continuity and spread. Resuscitation champions in the labour ward are helping to drive this. The joint quarterly perinatal meetings will be strengthened to further facilitate communication among all staff. Additionally, the hospital has a policy of requesting equipment needs from various units at the beginning of each year. We will capitalise on this to sustain supply of required life-saving equipment, in addition to reaching out to partners for support.

Several lessons have been learnt during this project, including the importance of communication, teamwork, clear agreements on project responsibilities, adequate forecasting of required equipment and consumables as well as the importance of obtaining grants when conducting large projects. When change is being introduced to any system, there are ‘laggers’ and ‘leaders’, but with effective team work and communication the ‘laggers’ also join eventually to achieve the common goal. These lessons will be carried forward to our next improvement project.

Acknowledgements All the staff in the labour, delivery suite and newborn unit are hereby acknowledged for their involvement and contributions to this project. Drs AT Otuneye and AB Mairami are specially acknowledged for assisting in the HBB training.

Contributors All authors contributed to the concept and design of the study. MM-Y, LIA and OY contributed to data collection. MM-Y, EFD, AD and HTA conducted the data analysis and interpretation, MM-Y did the manuscript preparation while all authors did the editing and critical review. MM-Y is the guarantor and takes responsibility for all aspects of the work.

Funding Partial funding was received from the National Hospital Abuja for Helping Babies Breath training, while Save The Children Nigeria supported the training with resuscitation tools and charts.

Competing interests None declared.

Ethics approval Ethical approval was obtained from both Ethical Review Boards of NHA and CCHMC.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. Save the children. *Surviving the First Day, State of the Worlds Mothers*. Geneva: World Health Organization, 2013.
2. Every newborn an executive summary for the lancet's series. *Lancet* 2014.
3. World Health Organization. Neonatal and perinatal mortality: country, regional and global estimates. http://apps.who.int/iris/bitstream/handle/10665/43444/9241563206_eng.pdf?sequence=1&isAllowed=y (accessed 11 Jul 2017).
4. World Health Organization. *Every Newborn. An action plan to end preventable deaths*. Geneva: WHO, 2014.
5. Marilyn KH, Robert FH. *Introduction To Statistical Process Control Techniques*: Statit software, 2007.
6. Lawn JE, Blencowe H, Oza S, *et al*. Every Newborn: progress, priorities, and potential beyond survival. *Lancet* 2014;384:189–205.
7. Federal Ministry of Health. *Saving Newborn Lives in Nigeria: Newborn Health in the context of the Integrated Maternal, Newborn and Child Health Strategy*. 2 edn. Abuja: Federal Ministry of Health, 2011:20–6.
8. *National population commission*. *NIGERIADEMOGRAPHIC AND HEALTH SURVEY*, 2013.
9. Gl D, Kinney MV, chopra M, *et al*. Who has been caring for the baby? *Lancet* 2014;14:60458.
10. Bhutta ZA, Das JK, Bahl R, *et al*. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *Lancet* 2014;384:347–70.
11. Murila F, Obimbo MM, Musoke R. Assessment of knowledge on neonatal resuscitation amongst health care providers in Kenya. *Pan Afr Med J* 2012;11:78.
12. Ogunlesi TA, Dedeke OI, Adekambi FA, *et al*. Neonatal resuscitation: knowledge and practice of nurses In Western Nigeriaigeria. *South African Journal of Child Health* 2008;2:23–5.
13. Dawodu A. Neonatology in developing countries: problems, practices and prospects. *Ann Trop Paediatr* 1998;18 Suppl:S73–S79.
14. Patel D, Piotrowski ZH, Nelson MR, *et al*. Effect of a statewide neonatal resuscitation training program on Apgar scores among high-risk neonates in Illinois. *Pediatrics* 2001;107:648–55.
15. Patel D, Piotrowski ZH. Positive changes among very low birth weight infant apgar scores that are associated with the neonatal resuscitation program in illinois. *J Perinatol* 2002;22:386–90.
16. Couper ID, Thurley JD, Hugo JF, *et al*. The neonatal resuscitation training project in rural South Africa. *Rural Remote Health* 2005;5:459.
17. RACHA. The neonatal resuscitation skills training program in cambodia its impact on the health care professionals' competency in newborn resuscitation. 2006 http://rc.racha.org.kh (accessed 14 Feb2017).
18. Shojania KG, Grimshaw JM. Evidence-based quality improvement: the state of the science. *Health Aff* 2005;24:138–50.
19. American Academy of Paediatrics. *Helping Babies Breathe. Learner workbook*. 2010.
20. Rothberg AD, Cooper PA, Fisher HM, *et al*. Apgar scores and asphyxia. results of a study and proposal for a clinical grading system. *S Afr Med J* 1986;69:605–7.