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Article type : Regular Article

A multimodal quality improvement approach to promote normothermia in very preterm infants

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Short Title: Normothermia in Very Preterm Infants

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Abbreviations

NNAP National Neonatal Audit Programme
SHIP Stopping Hypothermia in Premmies
NNU Neonatal Unit
SNRP Standardised Neonatal Resuscitation Practice
T-ABC Temperature, Airway, Breathing, Circulation

Abstract

Aim*:* To achieve the National Neonatal Audit Programme (NNAP) standard of 90% normothermia among preterm infants born under 30 weeks' gestation. **Methods:** Project SHIP (Stopping Hypothermia In Premmies) was a quality improvement programme to improve admission normothermia. Phase 1 of the project implemented low-fidelity simulations during 2011-2016. In Phase 2 (2017), a multimodal approach to quality improvement was used, including in situ simulations, videos of simulated scenarios, an allocated team member for thermal care, a clear protocol for thermal care, a coordinating "lollipop man" role and monthly performance feedback. Additionally, continuous temperature monitoring using servo-control during stabilisation was introduced during Phase 2. Phase 3 (2018-2019) focused on embedding practice and maintaining performance. **Results:** Phase 1 initiatives resulted in improvement of normothermia rates from 58% to 75%. However, the results plateaued. During Phase 2, the hypothermia rate fell from 16% to 3%. During Phase 3, this improvement in the hypothermia rate was sustained, achieving the standard of 90% normothermia in 2018 and falling just short in 2019 due to an increased hyperthermia rate. **Conclusion:** A multimodal quality improvement approach achieved sustained improvement in normothermia. Continuous temperature monitoring during stabilisation allows resuscitating teams to plan interventions to treat hypothermia and hyperthermia.

Keywords: Hyperthermia, Hypothermia, Normothermia, Preterm, Quality Improvement

Key Notes:

- Admission hypothermia and hyperthermia are detrimental in very preterm babies
- Continuous temperature monitoring with responsive interventions improved thermal outcomes
- Further work should focus on quality improvement strategies specific to different settings

Background

Several studies demonstrate a higher risk of adverse neonatal outcomes when preterm infants become hypothermic after birth. Preterm infants with hypothermia also have a higher risk of complications related to prematurity, including hypoglycaemia, metabolic acidosis, respiratory distress syndrome, intraventricular haemorrhage, late-onset sepsis, necrotising enterocolitis and death (1, 2). While relevant studies are, by necessity, observational, there remains a strong correlation between hypothermia below 36.5°C and early neonatal death when adjustment is made for likely confounders (1, 3, 4).

These findings have formed the basis for large audit projects examining admission temperatures, including the National Neonatal Audit Programme (NNAP) in the UK. This programme sets a standard of 90% of preterm infants born before 32 weeks gestation to have a temperature of 36.5°C – 37.5°C when measured within the first hour of life. Despite this standard and regular unit-level reporting of performance, normothermia at admission has remained persistently and significantly below this audit standard (67% compliance in 2018) (5).

Strategies implemented to improve thermal have included a multidisciplinary team approach and the standardisation of resuscitation practices in the delivery suite (6, 7); improving the temperature in the delivery room (8, 9); and the use of plastic bags, plastic wrapping, polyethylene caps, thermal blankets (10-13) and exothermic heat mattresses (14, 15). The use of humidified gases during neonatal resuscitation has also been evaluated (16). The focus of quality improvement programmes has been on the prevention of hypothermia. Single interventions and care bundles have been shown to reduce the rates of hypothermia (17-20), albeit with an increase in the rate of hyperthermia (14, 21-23). Pinheiro and co-workers carried out a coordinated quality improvement programme over five years, including the use of servo-controlled heating, and achieved over 90% normothermia (albeit with a more permissive definition of normothermia)(19). An extensive study of admission temperatures in 18 neonatal centres demonstrated that the proportion of extremely preterm infants admitted with temperatures between 36.5°C and 37.5°C more than doubled in 2012–2013 compared to a decade earlier. The number of babies with admission temperatures >37.5°C also trebled from 2.0% to 6.1%(23). There is emerging evidence that admission temperatures >37.5°C may be associated with worse composite outcomes in extremely preterm neonates (24).

Continuous temperature monitoring after birth may improve thermal outcomes in preterm neonates from birth until arrival at the neonatal unit by allowing resuscitation teams to plan interventions to treat both hypothermia and hyperthermia (25). This project aimed to implement a thermal care bundle for neonates under 30 weeks gestation at birth to address both hypothermia and hyperthermia in very preterm neonates in 3 phases over a decade.

Patients and Methods

This quality improvement project was undertaken at the Princess Anne Hospital, a tertiary neonatal unit in southern England, and captured data for infants born before 30 weeks of completed gestation (the national audit standard population at the time of project conception). Ethical approval was not required for this project which used established methods to achieve a national audit target.

Before the design and implementation of the first phase of the project, admission normothermia rates were in line with national performance (58% compliance with the NNAP audit standard in 2010). The protocol for early thermal care was as per the national Newborn Life Support protocol (26). Very preterm infants born in delivery rooms on the labour ward or in obstetric theatres were stabilised or resuscitated on a standard Dräger Resuscitaire using a radiant warmer set to full power. Infants under 30 weeks' gestation were placed in a plastic bag with a hat in the centre of the radiant warmer after birth. Despite guidance that delivery areas should be kept at 26°C, delivery rooms could not be heated to the target temperature and theatres could only be warmed to 24°C. Gel warming mattresses (Transwarmers) were used on an ad hoc basis, especially in extremely preterm neonates. There was no policy for measuring temperature during stabilisation. A transport incubator set at 36°C was used to transfer infants to the NNU. All neonates were moved into a humidified incubator set to 36.6°C on the neonatal unit, and the first temperature was measured on admission.

Phase 1 – Planning Intervention and Implementation (December 2010-December 2016)

In 2010, after the recognition that normothermia rates were very significantly below the audit standard of 90% (Table 1), a decision was made to formulate a quality improvement programme using low-fidelity simulation scenarios with an emphasis on thermal care, using a temperature, airway, breathing, circulation (T-ABC) approach. Staff were taught how to adjust the theatre temperature and how to place a Simulaid Micropremmie in a plastic bag in the centre of the radiant warmer with a three-member team. The aim was standardised neonatal resuscitation practice (SNRP). In 2011, monthly multidisciplinary low-fidelity simulation was delivered to address resuscitation, emphasising the above steps. In 2012, this method was formalised in the departmental teaching package. Training in T-ABC management of preterm babies was delivered at junior doctor induction every six months and part of neonatal nurses' work-based learning programme. Ad hoc point of care simulation emphasising thermal care in preterm birth was carried out every four months (27). A video on SNRP was prepared to reinforce practice and was circulated to all staff (www.bit.ly/soton_snrp).

Phase 2 – Planning Intervention and Implementation (January 2017-December 2017)

By 2016, progress towards the NNAP standard stagnated, with persistent compliance of 70-80%. That year, a reduction in cases of hyperthermia was associated with a sharp rise in cases of hypothermia. A need for change was recognised.

These findings inspired a QI initiative coined Project SHIP (**S**topping **H**ypothermia **I**n **P**remmies). This iteration of the project was underpinned by a comprehensive standardised protocol for preterm stabilisation based on the defined roles and carefully rehearsed actions of a Formula 1 motor racing pit stop. In this model, each team member was assigned a distinct role (Figure 1). A dedicated member was allocated to focus on thermal care (named the T-Person). This individual was responsible for placing the Resuscitaire temperature probe in the baby's axilla after birth and monitoring temperature until the baby was stable for transfer. Periodic spot-check axillary temperature measurement was carried out using a digital thermometer just before transfer from the Resuscitaire to the transport incubator (T1), upon arrival to the neonatal unit whilst still in the transport incubator (T2) and immediately after transfer from the transport incubator to the neonatal unit incubator (T3). The T-person was empowered to adjust thermal care methods and to point out deviations from normothermia to the stabilisation team. If the temperature remained below 36.5°C, agreed-upon interventions were activation of the servo-control temperature and/or the addition of a Transwarmer during resuscitation. Other practices included keeping the infant in the transport incubator until 80-85% humidity was reached in the neonatal unit incubator. In June 2017, it was noticed that use of Transwarmers with plastic bags was associated with increased rates of hyperthermia. A decision was made to use the servo-control of the Resuscitaire. A servo-temperature setting of 37°C was used as it lay in the middle of the acceptable range of temperatures and it would prompt adjustment of the radiant heater in the case of hypothermia or hyperthermia. Rather than being used routinely, it was decided that a Transwarmer would be added only if the temperature remained below 36.5°C before moving to the transport incubator. It was noticed that the transport incubator stopped heating whenever mains power was removed and this was resolved by replacing the battery. Larger plastic bags were also introduced during Phase 2.

The following QI methodologies supported these practices: teaching sessions, task training, simulation, and real-time clinical debriefing after case reviews. Monthly outcome data regarding rates of hypothermia, normothermia and hyperthermia were plotted graphically as a gauge of the effectiveness of these practices. Feedback took place via email, text messages and run charts (Figure 2).

Phase 3 (January 2018-December 2019)

Phase 3 focused on embedding new practices and maintaining the gains of Phase 2 in the long term. The presence of a 4-member team with a dedicated person monitoring temperature and the use of the servo-control on the Resuscitaire and axillary temperature monitoring were formalised into guidelines and became the norm. In addition to the multimodal education strategies above, a video training package was implemented alongside regular simulation at induction.

Data Analysis

Admission temperature was routinely gathered and entered onto the BadgerNet clinical information system (Clevermed PLC). This system compiles data that can be extracted and analysed locally. In addition, the T-person recorded T1, T2 and T3 measurements on a predesigned Project SHIP form, recording any interventions that were made during the resuscitation, stabilisation, and transfer of the baby. Data were extracted locally for analysis and validated against published data from the NNAP. Data were sorted using StataIC 15 (StataCorp, Texas, USA, 2017). Descriptive data were expressed as absolute frequencies and percentages or medians and interquartile ranges (IQRs). Categorical variables were compared with the chi-square test or Fisher's exact test as needed. Group comparator data were analysed using Student's t-test. Chi-square tests of proportions and one-way analysis of variance were used to determine statistical significance when three groups were compared.

Results

Phase 1 – Results

The implementation of Phase 1 was associated with a substantial increase in admission normothermia from 58% in 2010 to 75% in 2012. The improvement was maintained over subsequent years, but further reductions in the rates of hypothermia were offset by increases in the rates of hyperthermia (Table 1).

Phase 2 – Results

During Phase 2, 75% (54/72) of babies under 30 weeks' gestation had continuous temperature monitoring until transfer from the transport incubator to the neonatal unit incubator. T1, T2 and T3 were measured in 66% (48/72) of infants (with at least one temperature missing in the remaining third). The implementation of Phase 2 of Project SHIP in 2017 precipitated a striking improvement in normothermia rates, from 75 to 85%. An increase in the percentage of premature babies with hyperthermia from 8.8 to 12% was observed. Of note, 3/9 of these neonates were hyperthermic at birth, with temperatures above 37.8°C. After the implementation of a strategy of not empirically using Transwarmers unless the baby was hypothermic in June 2017, the use of Transwarmers decreased from 35% to 10%. Thirty-six percent of babies managed with Transwarmers from January to June 2017 were hyperthermic, while none of the babies managed with Transwarmers from June to December 2017 was hyperthermic. Table 2 demonstrates that the use of continuous temperature monitoring was associated with elimination of hypothermia and a reduction in Transwarmer use in 2017. None of the infants managed with Transwarmers combined with continuous temperature monitoring were hyperthermic. There were no significant differences in important baseline characteristics between the two groups.

A run chart with interventions shows the improvements in the rates of hypothermia and hyperthermia with the interventions made from January to December 2017 (Figure 3).

Phase 3 – Results

In 2018, we reached a normothermia rate of 94%, complying for the first time with the NNAP audit standard of 90% normothermia. This high rate was maintained in 2019, although it dropped to just below the national standard (Table 1).

Discussion

Despite the importance of normothermia in preterm infants during stabilisation, the UK's rates of admission normothermia have remained persistently below the national audit standard (5). The problem is not limited to the UK. A total of 12.9% of neonates in a large cohort study of 11 European countries had temperatures below 35.5°C (29). To date, there are no quality improvement strategies that have incorporated continuous temperature monitoring in their resuscitation practice. Billimoria et al. (20) measured axillary temperatures before transfer in their initiative in a setting that was similar to ours and eliminated hypothermia. Other work has focused on developing novel algorithms for achieving temperature stability in an incubator after admission to the neonatal unit, with significant improvements in thermal outcomes during the first day of life (30). Our data demonstrate that using a delivery room thermal care package that involves SNRP with a dedicated person monitoring temperature continuously from birth can improve normothermia rates and prevent hypothermia in neonates under 30 weeks gestation.

The high rate of hyperthermia in 2017 is likely explained by the combined use of plastic bags and Transwarmers. Indeed, there was a decreasing trend in the rates of hyperthermia from June to December 2017 once the use of servo-controlled temperature monitoring was introduced and Transwarmers were only used in response to hypothermia. We also took an iterative approach, characterised by continuous audit and revision of QI methods in response to monthly thermal outcomes. These results were relayed to staff and may have influenced behaviour and performance in Phase 2.

There have been challenges with implementing both this thermal care package, reflected by the fact that 25% of babies did not have continuous temperature monitoring during Phase 2. Multidisciplinary feedback from staff included anxieties about longer stabilisation times and worries about an increased focus on temperature rather than on the other elements of stabilisation. A significant benefit of the QI process was identifying and correcting system issues, including changing the batteries on the transport incubator, using larger plastic bags, and ensuring that all Resuscitaires had temperature probes.

This work is likely to be relevant to many NNUs in the UK, and this project has been shared via the British Association of Perinatal Medicine (BAPM) normothermia toolkit (31).

Careful consideration must be given to the ability to implement this QI package in different environments, especially if using a different temperature monitoring method. For example, studies in low- and middle-income tropical countries demonstrate a very different pattern of hypothermia and hyperthermia (32).

There are limitations to this work. We did not routinely gather data on the compliance of stabilisation teams with SNRP. Not all neonates had continuous temperature monitoring, and Transwarmers were used unnecessarily in a significant number of neonates. This limits the power of our work to define the impact of individual measures on thermal care outcomes. Furthermore, quality improvement initiatives are not necessarily generalisable to different settings. This work took place in a centre in which transport incubators are available, there is a short distance from delivery rooms to the neonatal unit and four staff are generally available to attend preterm deliveries. Centres which do not share these properties would need to implement their own iterative quality improvement programmes to identify relevant changes and assess impacts in their setting.

In conclusion, standardised resuscitation practices alongside implementing a thermal care package can be beneficial to centres looking to increase normothermia rates amongst preterm neonates soon after birth. The application of continuous temperature monitoring during preterm stabilisation allows interventions that can address hypothermia and prevent hyperthermia.

Acknowledgements

We would like to acknowledge our Data officer Matthew Davies for helping with the data collection.

Conflict of Interest and Funding

There are no conflicts of interest to declare, and this study did not need any funding

Data Accessibility Statement

The data from national studies (National Neonatal Audit Project) has been referenced within the article where appropriate.

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Figure Legends

Figure 1. Standardised neonatal resuscitation practice and supporting quality improvement tools for Project SHIP

Figure 2. Example of monthly run chart for feedback

Figure 3. Run chart of monthly thermal outcomes for neonates under 30 weeks gestation

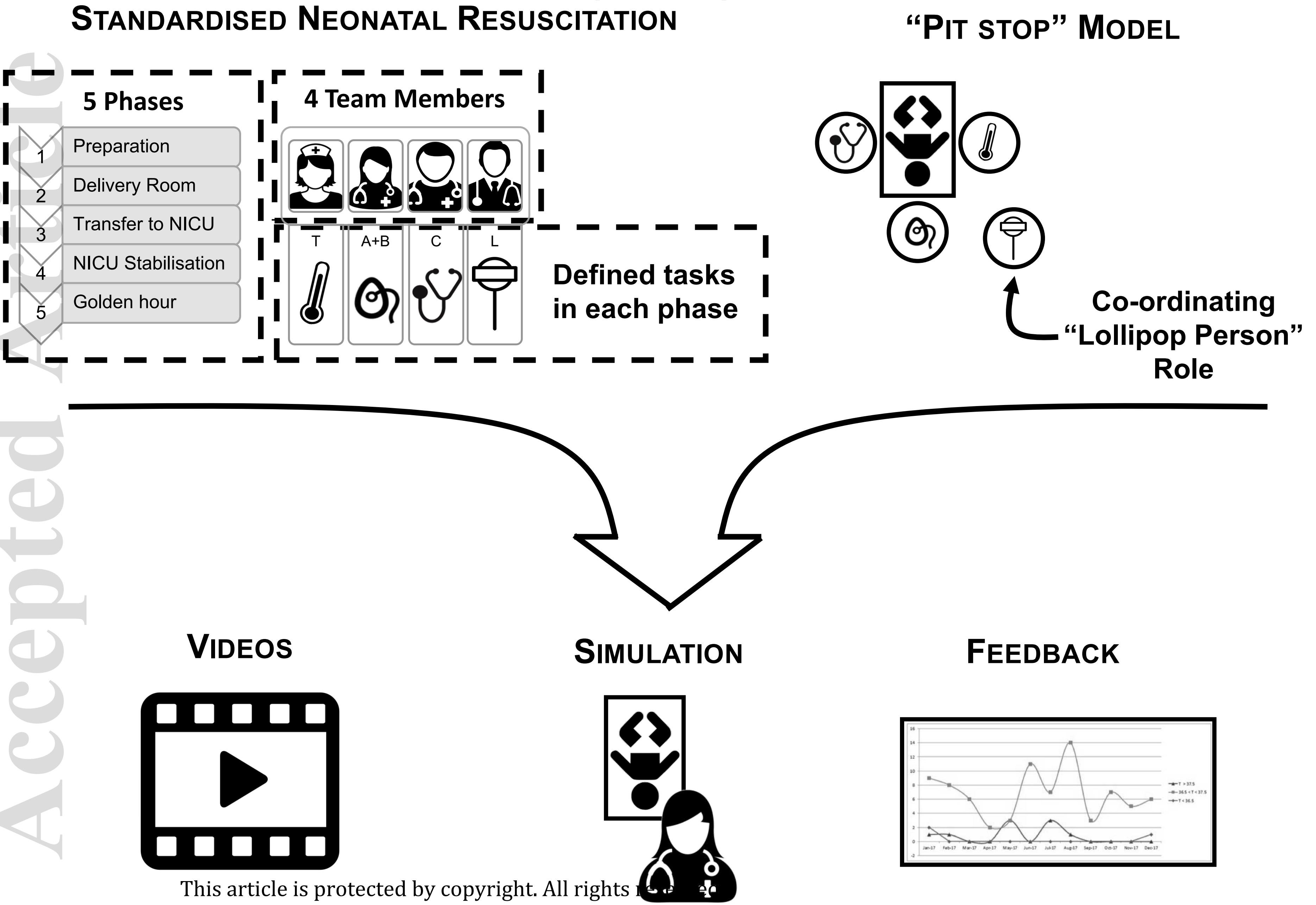
Table 1. Rates of admission hypothermia, normothermia and hyperthermia for infants born under 30 weeks' gestation

Phase	Phase 1 (P1)							Phase 2 (P2)	Phase 3 (P3)	
	n=415							n=72	n=112	
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hypothermic (<36.5°C) (%)	21 (33%)	16 (25%)	9 (17%)	8 (13%)	5 (11%)	5 (8%)	11 (16%)	2 (3%)	2 (4%)	4 (6%)
Normothermic (36.5-37.5°C) (%)	37 (58%)	38 (59%)	39 (75%)	47 (76%)	33 (75%)	48 (79%)	51 (75%)	61 (85%)	45 (94%)	55 (86%)
Hyperthermic (>37.5°C) (%)	5 (8%)	10 (16%)	4 (8%)	7 (11%)	6 (14%)	8 (13%)	6 (8.8%)	9 (12%)	1 (2%)	5 (8%)
Total number of infants	64 *1 NA	64	52	62	44	61	68	72	48	64
Weeks gestation (mean± SD)	26.7±1.81							27.0±1.71	26.6±1.63, (p=.03)	
Weight (mean± SD)	951±265							997±262	910±281, (p=.09)	
Sex (Male)	55%							66% (p=.08) P2 vs P1	55% (p=1.0) P3 vs P1	
Mode of delivery VD	29%							37% (p=.17) P2 vs P1	31% (p=0.6) P3 vs P1	
Apgar 1	4.6±2.4							4.3±2.3	4.1±2.1, (p=0.1)	
Apgar 5	6.7±2.1							6.4±2.1	6.5±1.8, (p=0.3)	

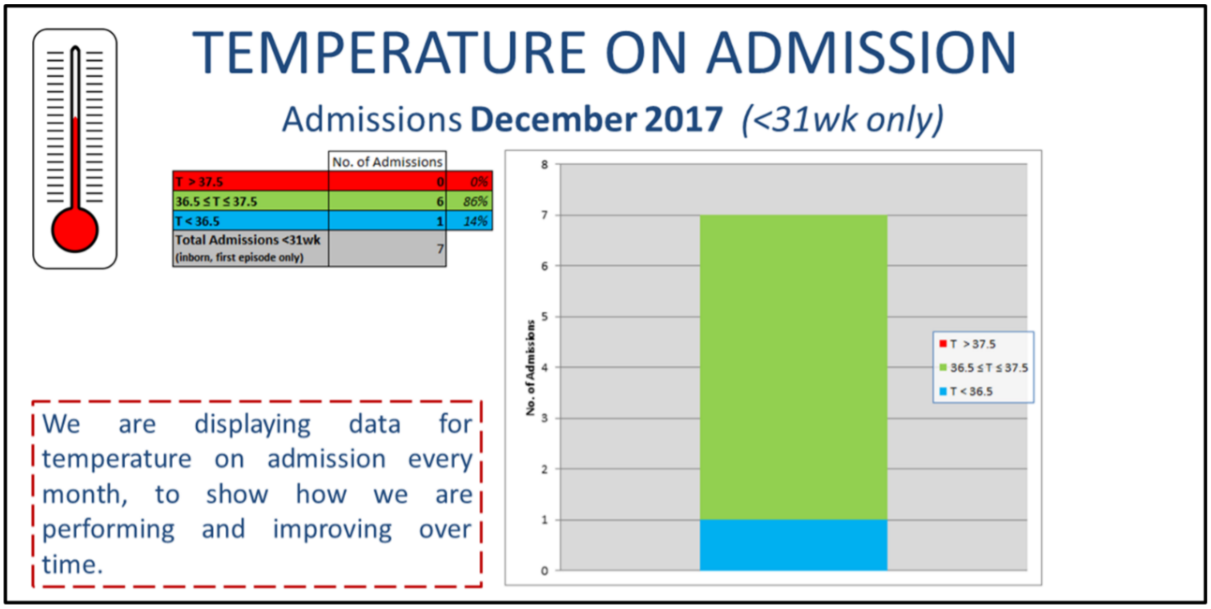
Antenatal steroid	96%	94% (p=0.4) P2 vs P1	90% (p=.01) P3 vs P1

Table 2. Rates of admission hypothermia, normothermia and hyperthermia for infants born under 30 weeks' gestation in 2017 after the implementation of Project SHIP

Group	Continuous monitoring of temperature	Temperature not monitored continuously	P-value
n=72	48	24	
Hypothermia (<36.5°C) (%)	0 (0%)	2 (8.3%)	0.10
Normothermia (36.5-37.5°C) (%)	42 (87.5%)	19 (79.2%)	0.40
Hyperthermia (>37.5°C) (%)	6 (12.5%)	3 (12.5%)	1.0
Gestational Age (mean± SD)	26.6±1.8	27.5±1.5	0.14
Weight (mean± SD)	974.5±270	1047.9±249	0.26
Mode of Delivery (LSCS)	73%	67%	0.59
Apgar 1	4.3±2.4	4.3±2.2	1.0
Apgar 5	6.3±2.3	6.6±2.1	0.61
Maternal age	28.8±6.5	31±7.4	0.17
Antenatal steroid	100%	92%	0.10
Chorioamnionitis	33%	29%	0.79
Transwarmer	27%	8.3%	0.07
Stabilisation Time *minutes	31.8±9.7	31.2±11.3	0.80



STANDARDISED NEONATAL RESUSCITATION
5 Phases
1 Preparation
2 Delivery Room
3 Transfer to NICU
4 NICU Stabilisation
5 Golden hour
4 Team Members
T
A+B
C
L
Defined tasks in each phase
"PIT STOP" MODEL
Co-ordinating "Lollipop Person" Role
VIDEOS
SIMULATION
FEEDBACK



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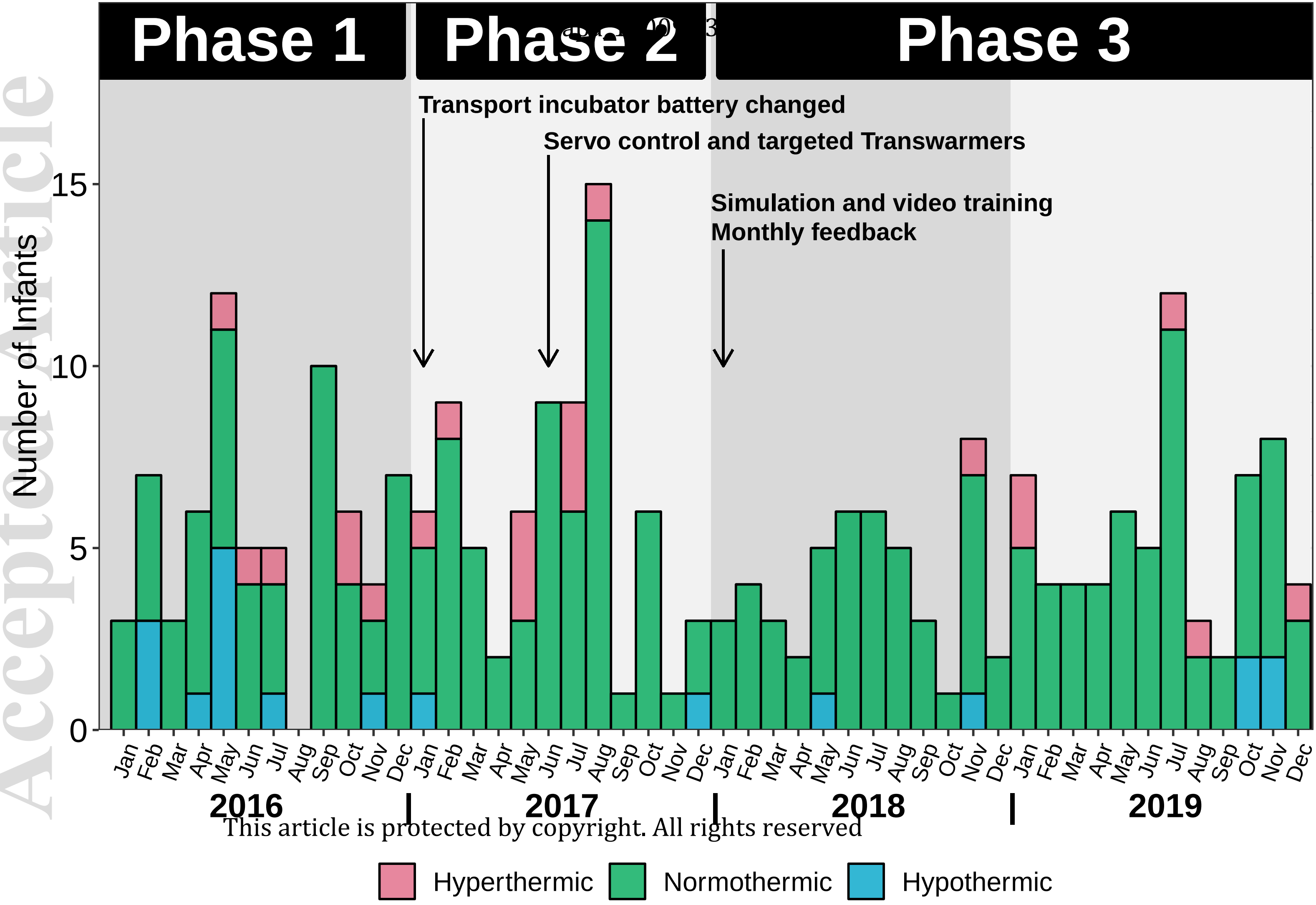
Phase 1
Phase 2
Phase 3
Transport incubator battery changed
Servo control and targeted Transwarmers
Simulation and video training
Monthly feedback
Number of Infants
0
5
10
15
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2016
2017
2018
2019
Hyperthermic
Normothermic
Hypothermic