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ORIGINAL ARTICLE

Reducing peripherally inserted central catheters in the neonatal intensive care unit

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OBJECTIVE: Our objective was to safely reduce the number of peripherally inserted central catheters (PICCs) inserted in infants with umbilical venous catheter using quality improvement methods.
STUDY DESIGN: In a tertiary neonatal intensive care unit, a questionnaire designed to prompt critical thinking around the decision to place a PICC, along with an updated standardized feeding guideline was introduced. PICC insertion in 86 infants with umbilical venous catheter (pre intervention) with birth weight 1000–1500 g were compared with 115 infants (post intervention) using Fisher's exact test.
RESULTS: PICC lines inserted after the intervention decreased by 37.5% (67/86; 77.9% vs 56/115; 48.7%; $P < 0.001$). The proportion of central line-associated blood stream infection were 2.49 vs 2.82/1000 umbilical venous catheter days; $P = 0.91$ in the two epochs, respectively.
CONCLUSION: Quality improvement methodology was successful in significantly reducing the number of PICCs inserted without an increase in central line-associated blood stream infection.

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INTRODUCTION

This project was undertaken, primarily, to reduce the number of peripherally inserted central catheter (PICC) lines in this subset of neonates who already had a central venous catheter (that is, UVC) and may not have needed a second central venous catheter (that is, PICC).

Early vascular access is often established in neonates with an umbilical venous catheter (UVC) placed either in the delivery room or in the neonatal intensive care unit.[1] A UVC is commonly utilized to administer fluids, nutrition and medications intravenously. A UVC provides a quick, easy and painless vascular access in the delivery room and the neonatal intensive care unit (NICU). The UVC, in our unit practice, is often removed by 5 (s.d. 2) days of age (irrespective of the UVC tip location) and is replaced with a PICC to provide total parenteral nutrition (TPN), and medications, if needed. If the neonate is able to meet the nutritional needs (100 ml kg^{-1} per day) by enteral feeds, the PICC line is discontinued. The preliminary data from our unit suggested that a subset of neonates especially those >1000 g or 27 weeks' gestational age (GA) at birth, who remain hemodynamically stable, are able to meet this nutritional goal by 7–10 days of age and may not need a central line beyond this period, making the procedure unnecessary. Our feeding protocol before this quality improvement (QI) initiative (introduction of enteral feeds at 10 ml kg^{-1} per day and advancement of feeds there after by 10 ml kg^{-1} per day) would not have made this possible.

There is literature supporting similar practice, that is, replacing primarily placed UVC with a PICC on day 4 (ref. 2) or later of age, but there is no literature reporting a similar effort to reduce the number of PICC in such babies.

In this QI project, we identified a population of preterm infants who might safely avoid a PICC insertion as they transition from TPN via UVC to enteral feeding. The ultimate goal of this project was to reduce the number of avoidable PICC lines inserted in this targeted population.

Specific aim

Reduce the number of PICC line placements by 20%, over a 24-month period, in a select population of neonates greater than 1000 g or 27 weeks' GA at birth, with a UVC on admission, and who are extubated and tolerating enteral feeds by 72 h of life

MATERIALS AND METHODS

The human research protection office determined that the project does not involve activities that are subject to Institutional Review Board oversight.

Planning the QI intervention: Baseline data

Duration of UVCs. The centers for disease control recommends that a UVC should be removed expeditiously, but can be left *in situ* for up to 14 days.[3] However, the UVCs were being replaced by PICCs at our hospital within an average of 5 (s.d. 2) days of admission. In addition, feeds were being started and advanced slowly, resulting in the need for TPN for a longer period. We also observed that there appeared to be a lack of urgency in the removal of PICC lines, once they were inserted, as opposed to the UVCs as the latter were considered to predispose to central line associated blood stream infection (CLABSI) but PICC lines were not.[4] Our NICU data indicated that the risk of CLABSI increased if UVC were left longer than 7 days. Hence we decided to use a cutoff of 7 days to define a 'safe' duration for UVC. We also noted that if an infant was tolerating 100 ml kg^{-1} per day of feeds by 7 days of life, he/she was likely to get to full fortified feeds by 10–14 days without additional need for a central line and TPN. In the current state of our practice, TPN is discontinued when an infant reaches 100 ml kg^{-1} per day of enteral feeds.

A retrospective review of 102 charts concluded that if replacing a UVC with a PICC was delayed up to a week in select neonates (>27 weeks' GA

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or >1000 g at birth, extubated by 3 days of age and were on enteral feeds by 2–3 days of age), a 20% reduction in PICC placement can be achieved in this patient population.

Updating the NICU feeding guideline. Per the existing feeding guideline, the initiating volume of enteral feeds and the subsequent advancement in the feed volume made it unlikely that the neonates would reach 100 ml kg^{-1} per day of feeds by 7 days of age. An evidence-based update to the feeding guideline was planned based on literature review that would help achieve this target (Table 1).[5]

Target population

The QI project targeted uncomplicated infants with birth weight >1000 g or 27 weeks' GA, without congenital anomalies, who were extubated by 3 days of age and were on enteral feeds by 2–3 days of age. Extubation at 3 days of age was a surrogate marker for the severity of the neonate's illness and derived from the previous chart review. We excluded neonates with birth weight <1000 g who were unlikely to achieve 100 ml kg^{-1} per day of enteral feeds by 7–10 days of age even with the new feeding guideline and hence would need central vascular access once the UVC was removed. Neonates with complex congenital heart diseases are transferred to the cardiac intensive care unit and no longer managed by neonatologists were hence excluded. Spontaneous intestinal perforation is generally treated with bowel rest for 10 days, delays enteral feeding, mandates the need for parenteral nutrition and hence a prolonged vascular access becomes unavoidable. Babies with spontaneous intestinal perforation were hence excluded. Similarly, neonates with birth weight >1500 g were excluded since they were likely to reach 100 ml kg^{-1} of enteral feeding by 7 days. Babies, who died within a week following redirection of care, did not meet the inclusion criteria and were excluded from the analysis.

Staff education and acceptance of the project

The updated feeding guidelines and results from the chart review were shared with all the groups of medical and nursing providers. A concern expressed by the dedicated PICC nursing team was that the specific aim of the project would decrease PICC lines and undermine their role in the NICU. Staff was concerned about an increase in CLABSI with the UVC left *in situ* longer than the existing standard of unit practice. Common staff perception was that PICC lines were safer and less likely to result in CLABSI. We decided to use the rate of CLABSI as our balancing measure for the QI project.

Barriers to the project

While accomplishing this QI project, we had to deal with the following barriers:

Fear of change. The most significant barrier was a change in practice from inserting a PICC line in babies with UVC by average of 5 days (s.d. 2) of age to considering not removing it until 7 days and not replacing if the baby was at or close to full feeds.

Fear of PICC team losing skills. The PICC team nurses initially misunderstood this initiative to be a means of eliminating PICC from the unit. This raised concerns that their skills would be lost. It was only after presentation of the data on multiple occasions that their fear was allayed.

Educational barriers. The centers for disease control recommendations that UVC can be left *in situ* for 14 days was not widely known.

Engagement of the team members. It was difficult to engage the team members initially because of above barriers but after the data from the pre-QI phase was disseminated, team members became convinced that the placement of PICC lines that seemed unnecessary in some babies could be indeed prevented. The idea that an unnecessary procedure and the pain/cost associated with it could be avoided/reduced helped to build team engagement.

Interventions

A questionnaire (Supplemental File 1) was devised that encouraged care providers to consider leaving the existing UVC *in situ* if the neonate met the criteria for this initiative. Exclusion criteria included neonates with abdominal wall defects, congenital heart defect, congenital diaphragmatic hernia, spontaneous intestinal perforation and neonates who required greater than 7 days of antibiotic therapy. The questionnaire also encouraged caregivers to remove the UVC and insert a PICC after day 7 if the neonate was not tolerating 60–70 ml kg^{-1} per day of feeds by 5–6 days of age. A new feeding guideline (Table 1) was introduced that initiated and advanced feeds at higher volumes compared with our previous feeding guidelines. Individual patient care teams were responsible for the decision to remove an existing UVC and replace it with a PICC. The clinical fellow on each team was responsible for completing the questionnaire as the QI process measure. Registered dietitians, who accompany the teams on rounds every day as a standard of our unit practice, reinforced the new feeding guidelines. The questionnaire was discussed at our monthly NICU handoff communication meetings as a means of reminding caregivers about our QI project.

The first Plan-Do-See-Act (PDSA) cycle began on 1 January 2014 (end of the last quarter for 2013) and ended on 30 March 2014 (end of first quarter for 2014, Figure 1). It included use of the questionnaire and standardization of feeding protocol. The number of PICCs inserted as a proportion of UVCs inserted increased at the end of 30 March 2014. The results were demonstrated on the run chart and shared with the caregivers (Figure 1). The second PDSA cycle started on 1 April 2014 and ended on 30 June 2014. It included sharing of the results obtained and analyzed from the first cycle and providing further education.

Table 1. Feeding guideline

Feeding preterm infants	*Birth weight ⩽1000 g*	*Birth weight ⩾1000 g*
Starting volume	10 ml kg^{-1}	20 ml kg^{-1}
Advance volume	10 ml kg^{-1} during morning rounds	20 ml kg − 1 during morning rounds
When to fortify	60–100 ml kg^{-1}	80–100 ml kg^{-1}

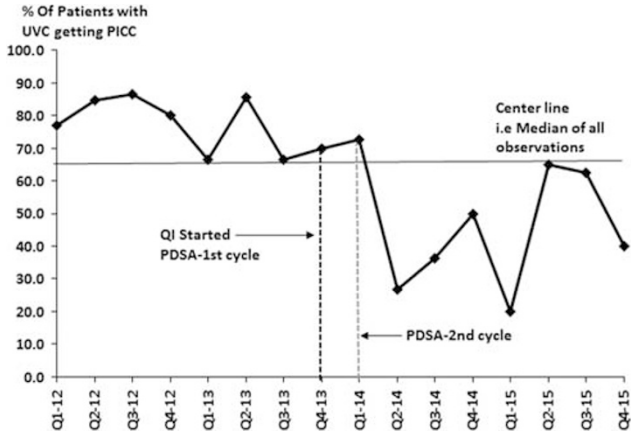

Figure 1. Run chart demonstrating percentage of umbilical venous catheters replaced with a PICC in each quarter of the pre- and post-QI period[11] (center line at median = 66.6%). First PDSA cycle and the QI intervention started on 1 January 2014, that is, the end of fourth quarter of 2013. It continued until 31 March 2014. Second PDSA cycle started 1 April 2014, that is, immediately after the first quarter of 2014 and ended on 30 June 2014.

Data management

A Microsoft Access database was created and maintained for this QI project. Demographic information for all eligible neonates was entered in the database. Chart review was performed and data collected included: (1) GA, (2) birth weight, (3) duration of invasive ventilation, (4) start date for

Table 2. Cohort comparison

	Pre intervention n = *86*	*Post intervention* n = *115*	P-*value*
Exclusions	16	18	
Incomplete charts	2	1	
Death	10	5	
Transfer to referring hospital	0	3	
Congenital anomalies	2	3	
Necrotizing enterocolitis	2	2	
Prolonged hospitalization due to infection (not CLABSI)	0	2	
Feeding intolerance needing a Broviac	0	1	
Not discharged when data analyzed	0	1	
Birth weight (g)	1237 (124)	1228 (147)	0.61
Gestational age (weeks)	28.9 (1.9)	28.9 (1.7)	0.40
Length of stay (days)	64 (20)	62 (24)	0.15
Ventilator days	3 (8)	3 (6)	0.81
Age at first feed (days)	4 (4)	3 (2)	0.01
Total parenteral nutrition days	11 (8)	9 (4)	0.01
Discharge weight (g)	2705 (573)	2696 (687)	0.92
UVC duration (days)	5 (2)	6 (3)	0.0001
PICC duration (days)	10 (11)	6 (8)	< 0.001

Data presented as mean (s.d.).

enteral feeds, (5) date at which 100 ml^{-1} kg^{-1} per day goal met, (6) date TPN was discontinued, (7) date of insertion and removal of UVC and PICC (if inserted), (8) date of discharge from NICU and (9) discharge weight. List of neonates with CLABSI was monitored by the infection control team of the hospital as a standard of care.

Data analysis

All statistical analyses were done using SPSS version 22 (IBM SPSS statistics, IBM Corporation, Armonk, NY, USA). Categorical variables, presented as N (%), were compared using Fisher's exact test. Continuous variables, presented as mean (s.d.), were compared using Mann–Whitney *U* test. Differences were considered significant at a *P*-value < 0.05.

Balancing measures

The number of CLABSI and the number of UVCs left *in situ* for >7 days in the two epochs were the balancing measures followed.

Short-term nutrition outcome was compared by comparing birth weight and discharge weight in the two epochs (as the new feeding guideline was introduced).

RESULTS

Patient characteristics

In the pre- and post-intervention epochs, total 1493 and 1718 babies were admitted to our NICU, respectively. Of those, 151 (10.1%) and 201 (11.7%) met the QI weight criteria. Sixteen and 18 neonates in the pre- and post-intervention groups were excluded leaving 86 neonates (out of 135, 63.7%) patients with UVC in the pre-intervention group and 115 (out of 183, 62.8%) in the post-intervention group to be included in our analysis. The two groups were similar for GA, birth weight, length of stay, number of ventilator days and discharge weight. Age at starting feeds and number of days on total parenteral nutrition were significantly different (Table 2).

Quality improvement process

At the end of the first PDSA cycle 8/11, 72.7% of babies with UVC had a PICC inserted. On further analysis 6/8, 75% of babies had their UVCs removed by 2 days of age. The babies were otherwise eligible for the QI intervention. This was the basis for further education with reinforcement of the questionnaire and the feeding guideline before the second PDSA cycle.

At the end of the second cycle, 4/15, 26.7% babies with UVC had a PICC inserted.

PICC insertion rate

Of the 86 patients with UVC in the pre-intervention period, PICCs were placed in 67 of these patients (77.9%) compared with 56 of 115 patients in the post-intervention period (48.7%). There was a (37.5%) reduction in the rate of PICC insertion in the post-intervention group compared with the pre-intervention group ($P < 0.001$).

Out of the total admissions to our NICU in the pre-QI and QI epochs, 151/1493 (10.1%) and 201/1718 (11.7%) babies weighed between 1000 g and 1500 g at birth, respectively. Of these babies in the two epochs, 86/151 (57.0%) and 115/201 (57.2%) had UVC inserted after birth ($P = 1.00$).

Secondary outcomes

Reduction in line utilization ratios. The umbilical line utilization ratio, (ratio of total umbilical line days to total number of patient days), was higher in the post-intervention phase (0.073 vs 0.104, $P < 0.001$). The PICC utilization ratio (ratio of total number of PICC days to total number of patient days) was lower in the post-intervention phase (0.160 vs 0.096, $P < 0.001$).

Dwell time for the UVCs increased significantly in the post-intervention period (range 1–11 days, average 6.3 days) compared with pre-intervention period (range 1–12 days, average 4.9 days) ($P = 0.0001$, Mann–Whitney test). Conversely, PICC line days significantly decreased to an average of 11.9 days (range 3–55 days) from an average of 13.2 days (range 2–82 days) ($P = 0.0001$, Mann–Whitney test).

Cost savings

Our PICC insertion team estimates an average of three radiographs following insertion of a PICC. Excluding the maintenance supplies, the cost of a PICC insertion was estimated to be $818. We estimate that without the QI, based on the data from the pre-intervention epoch, 90 (77.9% of 115) PICCs would have been inserted in the post-intervention period. Instead, we inserted 56 PICCs and avoided 34 PICCs. Thus we estimate a savings of 27 812 dollars from inserting 34 fewer PICCs in the post-intervention

period. No estimates on the cost savings on the maintenance supplies were available.

Balancing measures

In the pre-intervention phase 23/86; 27% UVCs were left *in situ* longer than 7 days; the recommended 'safe' period compared with 42/115; 36.5% left *in situ* in the post-intervention phase ($P = 0.045$).

The incidence rate ratio of UVC-associated CLABSI in the QI to pre-QI epoch was 1.13 (95% confidence interval 0.469–2.332, $P = 0.92$) indicating that there was no increase in the incidence of infection.

For the single CLABSI associated with UVC in the pre-QI intervention, the UVC were *in situ* for 8 days. In the two UVC-associated CLABSI in the post-intervention period, UVC was left *in situ* for 7 days and 10 days, respectively.

Age at first feed (4 vs 3 days) was significantly earlier and duration of TPN (11 vs 9 days) was significantly less in the post-intervention epoch.

Birth weight (1237 vs 1228 g, 0.61) as well as the discharge weight (2705 vs 2696 g, $P = 0.92$) in the pre- and post-QI epochs were not statistically different.

There were two cases of NEC in each of the epochs and they were excluded from the project. There were no additional cases of NEC during the post-intervention phase.

DISCUSSION

Our QI interventions reduced the number of PICCs inserted in neonates with UVC by 37.5%, the duration of PICC days, the PICC line utilization ratios and the duration of TPN days without an increase in CLABSI rates. The strengths of the project are that it was successfully conducted in a large tertiary NICU. In addition to the key benefits already mentioned, the interventions resulted in cost savings. Potential benefits include reduced exposure of the neonates to avoidable radiation, pain and narcotic analgesics.

The questionnaire promoted critical thinking among the caregivers and resulted in reduction in PICC lines and consequently reduction in the PICC line and central line days. The new feeding protocol led to early commencement of enteral feeds, shorter duration of TPN therapy and also helped reduce the need for a PICC. This was not associated with any short-term nutritional disadvantage.

Butler-O'Hara *et al*.[6] published a retrospective study demonstrating that UVCs left *in situ* more than 7 days were more likely to be associated with CLABSIs than PICCs. The risk of CLABSI increased significantly for UVC *in situ* for more than 14 days. No similar increase in CLABSI was associated with PICCs left *in situ* for more than 14 days. However, Shalabi *et al*.[2] did not find any difference in CLABSI rates with either UVCs inserted primarily and replaced with PICCs or PICCs inserted primarily and used as long as central venous access was indicated or UVCs inserted primarily and not replaced with PICCs. The UVCs inserted primarily in their study were replaced with a PICC at 4 days of age. Our CLABSI rates were associated with UVC *in situ* for over a week in both the epochs in contrast to the O'Hara study.

Our CLABSI rates did not change despite the decrease in PICC line days. Shahid *et al*.[1] had similar results to ours with no change in infection rates. Similar to Shahid *et al*., the goal of our QI project was not specifically to reduce CLABSI. This underlines the importance of continuing to follow the CLABSI prevention bundles in the unit.[7] Published evidence indicates that reducing the incidence of sepsis and CLABSI requires a multifaceted approach including adoption of best practices in skin preparation,[8] hand hygiene,[9] IV hub cleansing,[7] standardized processes for inserting and maintaining central lines.[10]

Estimated cost savings as a result of the interventions may be underestimated as the costs of the radiologists reading the films were not included. The reduction in the cost of TPN because of the reduction in the need for TPN by 2 days was also not estimated. Estimates of the reduction in the narcotic exposure of the neonates would have strengthened the study.

The project is unique and may be applicable in units with similar practice as outlined by Shalabi *et al*. The effect of this project on more mature neonates with higher birth weight is unknown. This initiative is unlikely to be effective at reducing the need for PICC lines in less mature neonates with lower birth weights in whom long-term central access is usually needed for total parenteral nutrition.

CONCLUSION

This QI project is beneficial in reducing the number of PICCs inserted in a subset of neonates with UVCs. It also reduces the central line days without increasing the CLABSI. It is sustainable as long as there is critical thinking around replacement of UVCs with PICCs. The effects of this project on more mature neonates with higher birth weight needs further evaluation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

AJV conceptualized and designed the study, drafted the initial manuscript, carried out the analysis and approved the final manuscript as submitted. AE and AMM reviewed and revised the manuscript, and approved the final manuscript as submitted. NAV designed the data collection instruments, critically reviewed the manuscript and approved the final manuscript as submitted. HM collected data, analyzed the data, critically reviewed the manuscript and approved the final manuscript as submitted. AN collected and analyzed the data, critically reviewed the manuscript and approved the final manuscript as submitted. DAL helped collect the data, critically reviewed the manuscript and approved the final manuscript as submitted.

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Supplementary Information accompanies the paper on the Journal of Perinatology website (http://www.nature.com/jp)