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Improving central line infection rates in the neonatal intensive care unit: Effect of hospital location, site of insertion, and implementation of catheter-associated bloodstream infection protocols

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Abstract

Introduction—Catheter associated blood stream infections (CABSI) are morbid and expensive for all ages, including neonates. Thus far, the impact of CABSI prevention protocols, such as insertion and maintenance bundles, in the neonatal intensive care unit (NICU) is largely unknown. We hypothesized that lines placed in the operating room (OR) would have a lower infection rate due to established insertion protocols and a more sterile environment.

Methods—Retrospective chart review of NICU patients who received a percutaneous or tunneled central venous catheter between 2005 and 2012. ECMO cannulas, PICC and umbilical catheters were excluded. Variables of interest included demographics, anatomical site, hospital location, line days, and line infection. Line infection was defined as a positive blood culture drawn through the catheter.

Results—A total of 368 catheters were placed in 285 NICU patients. Majority of catheters (65.5%) were placed in OR. Saphenous and femoral veins were most common anatomical sites (50.8%). Twenty-eight catheters were infected (7.6%). After adjusting for pre-operative antibiotics, anatomical site, and SNAPPE-II scores, lines placed in OR were three times less likely to become infected (Odds Ratio=0.32, $p=0.038$). Although implementation of CABSI prevention protocols resulted in statistically significant reductions in infection (Odds Ratio=0.4, $p=0.043$), lines placed in the OR remained less likely to become infected.

Conclusions—NICU line infection rates decreased with implementation of CABSI prevention protocols. Despite this implementation, catheters placed in the NICU continued to have higher infection rates. As a result, when patient status allows it, we recommend that central lines in newborns be placed in the operating room.

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Keywords

Catheter associated blood stream infections; insertion bundles; central venous catheter

Background

Centers for Disease Control and Prevention (CDC) reported in 2002 that 1.7 million healthcare associated infections resulted in 99,000 deaths annually.[1] In 2009, 18,000 CABSIs occurred in ICU patients with another 23,000 occurring in patients admitted to other areas of the hospital.[2] In 2010, it was estimated that a CABSIs in the pediatric intensive care unit (PICU) increased hospital costs by just over \$33,000 per patient.[3] The Center for Disease Control and Prevention estimates that for all patients over 1 year of age between 2001 and 2009 there was a 58% reduction in line infections which resulted in an estimated \$1.8 billion in health care cost savings.[4] Because of these numbers, an even more drastic decrease in infection rates is believed to be possible.

Many institutions have made efforts to decrease CABSIs incidence through placement of catheters at different anatomic sites (e.g. saphenous vein versus jugular vein) and at different locations in the hospital (e.g. NICU versus OR). Furthermore, the impact of implementation of CABSIs prevention protocols in the NICU, such as insertion and maintenance bundles is largely unknown for neonates. We hypothesized that if a line were placed in the OR, then it would have a lower chance of infection due to performance in more sterile surroundings and in a more standardized order.

Methods

After exemption was received from the Institutional Review Board at C.S. Mott Children's Hospital, a retrospective chart review was done of all NICU patients who received a percutaneous central venous line or a tunneled central venous catheter from 2005 to 2012 from the pediatric surgery service. PICC lines, umbilical lines, and ECMO cannulas were excluded because they require different insertion and maintenance protocols.

Variables of interest included demographic information, anatomical site of line placement (external jugular, facial, femoral, internal jugular, saphenous, or subclavian vein), hospital location at the time of procedure (NICU or OR), dosing of pre-operative antibiotics, total line days, line infection, and line days to infection. Pre-operative antibiotics were credited if given 30 minutes or less prior to the documentation of the surgical start time. Patients were given IV cefazolin unless they were allergic to cephalosporins or were on antibiotics at the time of placement. If the patient was allergic, clindamycin was given. For those on antibiotics, they were continued as per their scheduled dosing if they covered skin flora; otherwise an additional dose of cefazolin was used as per our protocol.

Total line days were defined as the number of days the line was in the patient. Line infection was defined as a positive blood culture drawn through the catheter with a temporally associated negative peripheral blood culture as per our institution's policy. Line days to

infection were defined as the number of days from line placement to day the positive blood culture was drawn.

Health status of each patient for each line placement was evaluated and standardized with the Score for Neonatal Acute Physiology (SNAP-II) and the SNAP Perinatal Extension (SNAPPE-II) score using values immediately prior to line placement as clinical documentation allowed to assist with risk stratification.[5] SNAP-II uses mean blood pressure, temperature, PO₂/FIO₂, serum pH, seizure activity, and urine output to calculate an in-hospital mortality risk. SNAPPE-II includes the SNAP-II criteria as well as Apgar scores, birth weight, and if the infant is small for gestational age (<3rd percentile). Scores for the SNAP-II can range from 0 to 115. Scores for the SNAPPE-II can range from 0 to 162. Lower scores convey a lower mortality risk. These scores were used in the logistic regression to account for injury severity and gestational age differences between patients.

From a procedure standpoint, tunneled lines placed in the OR and NICU are both performed with OR staff, full draping of the patient, and a sterilized minor procedure tray. Percutaneous lines placed in the OR and NICU use the same standardized insertion kit with chlorhexidine skin prep and full patient draping. The only difference is the lack of OR staff for the NICU percutaneous procedure. Ultrasound is used to visualize the vein prior to saphenous/femoral placement as well as during EJ and IJ placement regardless of hospital location. Fluoroscopy is typically utilized for line placement only in the OR. We do not have the capabilities to use fluoroscopy in the NICU due to the types of NICU beds we use and the walls not designed to be radio-protective. Saphenous, EJ and facial vein lines are placed by a cutdown technique. Subclavian and IJ vein lines are placed by a percutaneous technique. Femoral vein lines are placed by a cutdown technique (if the saphenous cutdown is unsuccessful) or, more commonly, via a percutaneous technique.

Statistical analysis was performed with Stata version 12.1 (StataCorpLP, College Station, TX) using student's t-test and logistic regression with infection as the dependent variable. Independent variables included SNAPPE-II scores, gestational age, birth weight, anatomical site of line, hospital location, total line days, antibiotic dosing, and days to line infection. P values less than 0.05 were considered significant. Values are expressed as a count, percent, or mean $\pm$ standard deviation.

Results

During the study period, the pediatric surgery service placed 368 percutaneous central lines and tunneled catheters into 285 unique patients who were being cared for in the NICU. Table 1 shows the descriptive information including birth weight, average gestational age at procedure, SNAPPE-II score at procedure, mortality rate, infection rate, line days, line days until infection, and CABS rate per 1000 line days for the entire cohort as well as for each of the two patient groups. The 83 "repeat" lines were for replacement after cleared infection or for replacement due to a malfunctioning line (i.e. leaking due to line breakage or unable to flush/draw back appropriately). There were no differences in complications associated with line placement (i.e. pneumothorax, bleeding, etc.) between the two groups. In addition, no complications occurred during transportation to OR.

Out of these 368 central lines, 28 (7.6%) were found to have a positive blood culture and were classified as infected. The absolute number of line infections was evenly divided between NICU and OR placed lines (n=14), which translates to 1.69 CABSIs per 1000 line days. A majority of lines (85.1%) were tunneled catheters. There were no differences in infection rates between tunneled and non-tunneled catheters. There were 77 mortalities in the patient cohort, only five of which had a documented line infection. Of the five patients with documented line infections during their hospital course, all ultimately died from complications of their primary diagnosis (i.e. respiratory failure secondary to CDH, Tetralogy of Fallot, pulmonary hypertension, etc.), not due to their line infection. In fact, all 5 lines had been removed more than two weeks prior to death. Additionally, 4 of the 5 had been removed more than a month prior to death.

With regard to anatomical location, as shown on Table 2, the saphenous and femoral veins were the most common sites (50.8%) for line placement, followed by the internal jugular vein (20.1%), then subclavian (12.0%), external jugular vein (9.0%), and finally the facial vein (8.2%). Although there was no statistically significant difference in infections based on site of placement ($p=0.37$), the saphenous and femoral sites accounted for 67.8% of the infected lines. Saphenous/femoral lines were the most likely to become infected (10.2%). This was closely followed by external jugular lines (9.1%). Internal jugular lines had the lowest infection rate (2.7%).

Figure 1A illustrates the total number of lines placed each year (whole bar) as well as the number of lines per hospital location (OR black, NICU gray) per year. A majority of catheters (65.5%) were placed in the operating room, while the rest were placed bedside in the NICU. The large increase in the number of lines placed in 2007 is due to an unclear etiology.

As shown in Figure 1B, when the line infections were separated by year of placement, a sharp reduction in line infection rate was noticed in 2009 (decrease from 9% in 2008 to 4% in 2009, noted by the black arrow). Upon further review of NICU protocols, CABSIs prevention protocols were first implemented in the late fall of 2008. In early 2009, indication and hand hygiene checklists were implemented. At the end of 2009, line insertion checklists were implemented with 95% compliance within 4 months. Overall, these protocols resulted in statistically significant reductions in infection (Odds ratio=0.40, $p=0.043$).

Interestingly, when the infection rates were divided by hospital location at placement, the majority of the decline in CABSIs rates seems mostly attributable to lines placed in the OR (Figure 1C). After adjusting for pre-operative antibiotics, anatomic site of insertion, and SNAPPE-II scores, there was a three-fold reduction in infection rates when catheter insertion took place in the operating room when compared to the NICU (Odds Ratio=0.32, $p=0.038$). This decrease in infection rate persisted even after implementation of CABSIs protocols (Odds Ratio=0.30, $p=0.03$; Table 3).

Discussion

Our CABSIs insertion and maintenance protocols seem to be effective in decreasing preventable infections. Although NICU line infection rates decreased with implementation of CABSIs prevention protocols, higher rates of infection of catheters placed in the NICU when compared to OR placed catheters persisted over time. We believe that this is due to the OR providing a more sterile environment as well as a more standardized way of sterilizing, draping, and placing the central line.

Although NICU placed lines have not been previously directly compared to OR placed lines in the published literature, the Central Venous Catheter Initiative Committee has previously shown that in NICU placed lines, infection rates were decreased from 8.40 infections per 1,000 central line days to 1.28 infections per 1,000 central line days with implementation of standardized education and competency assessments for those placing lines, maintenance of aseptic technique during insertion and all dressing changes, minimizing dressing changes, and minimizing total line days.[6] Our institution is a tertiary referral center and as a result, we have a comparatively ill NICU population. While other studies have shown a NICU line infection rate similar to our OR infection rate, our data does not show this lower rate.[6, 7] While this lower rate is our ultimate goal, it has not yet been achieved with our patient cohort.

CABSIs are associated with increased severity of illness, anatomic location of line, lack of line insertion and maintenance protocols, and decreased pre-operative antibiotic administration. As expected, our patients who received lines bedside in the NICU had a younger gestational age and higher SNAPPE-II score at placement since it is common practice to place central lines bedside in an unstable or critically ill patient rather than risk the patient decompensating during transportation to the OR. In addition, this group had an overall mortality rate of 34.6% and accounted for a higher proportion of the mortalities of the entire cohort. As a result, the average total line days (and infection rate) for this group may be deceptively low due to patient mortality.

Our data show that the venous site of central catheter placement does not impact the rate of CABSIs in NICU patients. A recent study completed in the Netherlands looked at NICU CABSIs incidence and risk factors.[8] They found that the highest infection rates were associated with umbilical catheters, which were excluded from our study due to the usage of different insertion and maintenance bundles for those lines. When only looking at the central venous lines in their data, they had an 8% infection rate (2 infections in 25 total central lines) that were in place for a median of 6 days (range 4–13.5 days).[8] While our overall infection rate is similar (7.6%), our central lines stay in over seven times longer (45.2 days) which lends itself to the argument that while sterile insertion is important, proper maintenance bundles are also crucial in decreasing the incidence of CABSIs.

Mortality rate from CABSIs is traditionally quoted as being 12–40%, which is based on data from prior to 1995, however, this number has not been updated since the implementation of insertion and maintenance bundles.[9] In our study, we had a 0% mortality rate from CABSIs, which may be a more accurate estimation of the modern CABSIs mortality rate.

While we see a lower infection rate with OR placed lines, transportation to the operating room alone is not without risk. A recent study of intra-hospital transfer of ICU patients for diagnostic tests showed a 25% rate of unexpected events and a 2.2% rate of cancellation of transfer due to serious changes in oxygenation, blood pressure, or mental status.[10] As a result, we emphasize that unstable patients should receive a NICU placed line to avoid deterioration and resultant adverse events (such as coding) during transport.

Another alternative for some patients would be a PICC line. These were excluded from our study due to the fact that they have different insertion staff as well as different insertion and maintenance protocols from the ones used for tunneled and non-tunneled central catheters. PICC lines are nice options for access for selected patients with published infection rates of 1.66 per 1000 line days, similar to our infection rate of OR placed lines.[11] However, in patients who have difficult line access (inability to place PICC or umbilical line), need for serial blood draws, or long term access, placement of a central (tunneled or non-tunneled) catheter would be preferred.

The Committee to Reduce Infection Deaths (RID) as well as the CDC have both published several checklists and recommendations to ensure decreases in CABS rates. These include cleaning hands before (and after) placement, wearing full barrier precautions (masks, gowns, gloves, and full sterile drapes) during insertion, using chlorhexidine to clean the skin, using pre-packaged insertion bundles, and assessing daily the need for the line.[2, 12]

In 2009, Steinberg et al published a large multicenter (44 hospitals) study that showed that skin infection rates when antibiotics were administered within 30 minutes were 1.6% and increased to 2.4% when given between 31 and 60 minutes. Infection risk continued to increase with increasing time between dosing and incision.[13] Although our study only used the more stringent cut off of 30 minutes, we did also note a sharp decrease in infection rates with antibiotic dosing.

One limitation of our study is that it is a single institution retrospective chart review with a relatively small number of infectious events, although this did allow for a single individual to review all charts to ensure consistent evaluation of data during the creation of the database. Even though it is a small number of events, our line infection per 1000 catheter days is similar to other published studies.[3] We also recognize that late infections are usually related to maintenance rather than insertion and cannot fully explain why our data shows a difference in infection rates based on hospital location. Perhaps, the lines are seeded and the low-grade infection festers in this sicker cohort of patients. A prospective study would help delineate this better.

Another limitation is that due to the retrospective nature of this study, these patients were not randomized. We adjusted for severity of disease as well as use of preoperative antibiotics to minimize the effect of this limitation through logistic regression, but this adjustment is not perfect.

In addition, due to the retrospective nature of our study, it is difficult to surmise what drove the decision between placement of a tunneled vs non-tunneled line. In general, we try to place a UVC/PICC as they can be used to draw blood, check labs, and can be left in during

the hospital course. However, clearly there was a clinical indication for each of these patients to be escalated to a surgically placed line which is not obvious on chart review of the medical record.

Since the review of our data, we have not placed any elective central catheters in the NICU. We placed one emergently via femoral cutdown in a 480 gram baby that had no IV access, was septic, and non-transportable. In the past, we would routinely place lines in the NICU in children to avoid having to wait for OR availability and transporting the baby with added risks of hypothermia, line dislodgment, etc. For those lines placed in the NICU, we established the same format we follow in the OR, such as antibiotics within 1 hour of incision, use of ultrasound, a timeout, and nursing scrub assistance as possible as these may play a role in the infection rates.

In conclusion, our results show a decrease in CABSIs when lines are placed in the operating room. As a result, when patient status allows it, we recommend that central lines in newborns be placed in the operating room.

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Figure1.

Graphs of Lines Placed and Infection Rates Per Year. **Panel A** shows the total number of lines placed each year as well as lines placed in each hospital location each year. **Panel B** shows the percentage of lines placed each year that became infected. Black arrow demonstrates the initiation of line insertion and maintenance protocols. **Panel C** shows the number of line infections per 1000 line days for each year of the study period.

Table 1

Descriptive information of the entire cohort and each patient group.

	All Patients (n=285)	OR Placed Lines (n=201)	NICU Placed Lines (n=107)	P values
Number of Lines	368	241	127	
Number of Tunneled Catheters	313	219	94	
Birth Weight (range)	2.11±0.52 kg (0.46–4.49)	2.30±0.47 kg (0.52–4.17)	1.76±0.57 kg (0.46–4.49)	<0.0001
Gestational Age at Procedure (range)	39.7±3.9 wks (23.4–73.3)	40.9±3.8 wks (26.1–73.3)	37.6±3.8 wks (23.4–56.9)	<0.0001
SNAPPE-II score (range)	19.8±7.8 (0–83)	17.3±6.9 (0–83)	24.6±8.9 (0–79)	<0.0001
% Mortality	27.0%	13.7%	34.6%	
% Infected	7.61%	5.81%	11.0%	
Line days (range)	45.2±39.3 (1–974)	52.6±46.5 (1–974)	31.2±17.7 (1–213)	0.01
Line Days Until Infection (range)	53.3±17.3 (4–149)	50.4±17.5 (8–116)	56.2±17.7 (4–149)	0.67
CABSI rate per 1000 line days	1.69	1.11	3.53	0.038

Table 2

Anatomical Location of Lines Placed. Infection rates by anatomic location of placement was not significant ($p=0.37$).

Venous Location of Line	All Patients (n=285)	OR Placed Lines (n=201)	NICU Placed Lines (n=107)
Saphenous/Femoral	187	92	95
Internal Jugular	74	49	25
Subclavian	44	40	4
External Jugular	33	32	1
Facial	30	28	2

Table 3

Variables used in logistic regression. Odds ratio and p values given for each variable.

	Odds Ratio	P value
SNAPPE-II	0.98	0.16
Anatomic Site	1.05	0.77
Hospital Location	0.30	0.03*
Pre-operative Antibiotics	0.79	0.72
CABSI protocol	0.55	0.23