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Research Article

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Reduction in Central Line Days, Central Line Utilization Ratio, and Central Line Associated Blood Stream Infections Through Hospital Based Intensivist Program

Michael Wilson

Director, Mobile Infirmary, Intensivist Program, Infirmary Health System, Diagnostic Medical Clinic, Mobile, AL, United States

Corresponding author
Michael Wilson, Director, Mobile Infirmary, Intensivist Program, Infirmary Health System, Diagnostic Medical Clinic, Mobile, AL, United States.

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ABSTRACT

Purpose: We tracked the effect that a newly implemented intensivist program following a restrictive venous access policy emphasizing mid-lines and peripheral IVs over central lines had on central line days, central line utilization ratio, and central line associated blood stream infections in a non-academic hospital.

Methods: Prior to June 2021, Mobile Infirmary's intensive care units (ICU) were open units staffed with physicians with combined ICU, ward, and outpatient responsibilities. In June of 2021, an intensivist program was started to transition the hospital to a closed ICU model with intensivists whose sole responsibility was the ICU. Concurrently, a policy was implemented that emphasized avoidance of central lines unless indicated by defined criteria (MICAR Criteria). We tracked central line days (CLD), central line utilization ratio (CLUR) and central line associated blood stream infections (CLABSI) rates and compared it to these same unit for the 2 years prior to the start of the program.

Results: There was a reduction in CLD from 628 per month to 425 per month (RRR of 32%), a reduction in CLUR from 0.62 to 0.46 (RRR of 26%), and a reduction in CLABSI rate from 1.65 to 0.78 (RRR of 51%). When looking at the number of central line infections per expected line days, there was a reduction from 20.2 to 6.6 (P=0.04). The central line infection rate relative to patient days showed a reduction from 10.3 to 3.6 (P=0.04).

Conclusions: Over utilization of central lines and the subsequent increase in central line infections represents a major complication of ICU care. By combining an intensivist program with a venous access policy designed to reduce dependence on central lines, we showed a clinically significant reduction in central line infections and a reduction in central line days and central line utilization ratio without any significant increase in IV extravasations.

Introduction

A central line is defined as an intravascular catheter that terminates at or close to the heart, or in one of the great vessels and is used for infusions, withdrawal of blood, or hemodynamic monitoring which includes central lines, peripherally inserted central catheters (PICC lines), and hemodialysis catheters [1-6]. Historically they were placed when a patient needed vascular access when a peripheral IV could not be obtained or when a more secure form of access was needed for a medication with high risk of complications from accidental extravasations, such a vasopressors, Total Parenteral Nutrition (TPN), or chemotherapy [7-10].

Access for the administration of medications through large veins using central lines has been around in some form for over a century. The modern technique for placing central access developed by Dr. Sven-Ivar Seldinger in 1953 has been the standard for placement of central lines for over 70 years. While the use of central lines remains a routine part of healthcare in the United States and are frequently necessary for the care of critically ill patients, it can have deadly complications. CLABSI are associated with up to a 25% increase in mortality [11-15]. Like pulmonary artery catheters, the routine placement of central lines in critically ill patients without a clear indication can lead to more harm than benefit. It can, therefore, no longer be viewed as routine or required in critical care units. We must use central lines on an individual basis with careful consideration of the risks versus benefits on a case-by-case basis [1,3,5,6,10,11].

The primary complications from central lines use to be viewed only in terms of complications during placement of the line. These typically included bleeding, hematoma, local tissue injury and pneumothorax. However, these complications occur less than 1% of the time when placed by experienced operators, and

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with the advent of ultrasound these complications occur even less frequently [16,17].

The complication from central lines that occur with a much higher frequency and frequently with far greater implications for morbidity and mortality are infections in the blood stream introduced through the central lines, referred to as central line associated blood stream infections or CLABSI. CLABSI is defined as a primary laboratory confirmed blood stream infection (BSI) in a patient that had a central line placed within the 48-hour period before the development of the BSI and is not related to an infection from another site. According to the Centers for Disease Control (CDC), in the United States, there were 27,201 CLABSI's reported in 2021. On average they occur at a frequency of 0.8 per 1,000 central line days. Since the CDC first started tracking reportable CLABSI dating back to the initiation of the infection reduction program in 2008, there has been a gradual reduction in CLABSI of around 85% of the 2008 average. However, with the advent of COVID-19, there has been a slight increase in the number of CLABSI bringing the national average back up to around 91% of the rate that it was at in 2008. This trend in the number of CLABSI since COVID-19 likely reflects a combination of a greater number of critically ill patients with a higher severity of illness combined with lack of adequate staffing for the sudden influx in such a large volume of critically ill patients [18-23].

Each CLABSI is associated with an average increase in hospital length of stay and cost per hospitalization of $48,108. If you take the number of CDC reported CLABSI of 27,201, that equates to a total of 1.31 billion dollars in health care cost in 2021. The average reported mortality rate for CLABSI was 15% with reported ranges of 10-25% in various studies. Extrapolating from 27,201 CLABS's in 2021, that equates to roughly 4,080 deaths [18,21-25]. While central lines remain essential in the care of critically ill patients, it is clear that reducing unnecessary central lines improves patient morbidity and mortality.

Additionally, prior to June 2021, Mobile Infirmary's ICUs were not intensivist run units. Prior to that time, they were open units staffed with Pulmonary consultants covered by physicians and advance care practitioners with combined ICU, hospital, and outpatient clinic responsibilities. In June of 2021, an intensivist program was started to transition part of the hospital to a 24-hour closed ICU critical care model with coverage by in-house board-certified critical care physicians with no other duties or responsibilities outside the ICU. Since July of 2021, the Surgical ICU and the Medical ICU, representing 38 out of the 70 total critical care beds, were converted to a closed ICU model covered by the newly formed intensivist department, staffed by 2 intensivist and one advanced practitioner by day and 1 intensivist at night. These units run by the intensivist program were the focus of this study.

Operating under the premise that the best way to prevent a CLABSI is to not place a central line in the first place, we decided to develop a specific criteria for when central lines should be used that would be implemented by the new Intensivist program. A literature search was performed to see the standard of care under what conditions it would be safer to avoid central lines and infuse medications through peripheral IVs (PIV) or midlines. In doing so we had to weigh the risk of extravasation of caustic medications from non-central line access points against the risk of CLABSI in an attempt to find the breakpoint where risk of CLABSI outweighed the risk of extravasation. For example, it has been shown in several recent studies that the temporary administration of lower doses of levophed through a PIV or midline for up to 72-hours was found to be effective and safe. In that situation, the rate of extravasation of lower doses of levophed was negligible and certainly lower than the risk of central line infections [26-36]. Based off of this literature review we developed the Mobile Infirmary Central Access Criteria (MICAR) for when a central line is required. All patients that did not meet MICAR criteria were treated without central access.

This was the first time that a restrictive venous access policy was combined with a new intensivist program at the same time. We hypothesized that combining the MICAR criteria and the implementation of an intensivist program with a closed ICU model would reduce the dependence on central lines and the number of CALBSI in a non-academic private hospital.

Methods

Intervention

If a patient did not meet the MICAR criteria below, we avoided placement of a central line.

Mobile Infirmary Central Access Requirements (MICAR)

- Medications with a pH of less than 5 or greater than 9
- Medications with an osmolality greater than 500
- Use of Levophed over 15 mcg/min, phenylephrine over 100 mcg/min, or epinephrine over 7 mcg/min
- Use of multiple pressors (2 or more) at anytime
- Use of vasopressin or dopamine
- TPN
- Chemotherapy
- Inadequate IV access (should be the exception, not the rule)
- Hemodynamic Monitoring (CVP, ScvO2, PA catheters)
- Need for dialysis or other central access required procedures (ECMO, Plasmapheresis)
- Use of pressors for more than 72 hours

For example, based off of this, levophed infusion rates up to 15 mcg/min through PIV or midlines for up to 72 hours was considered standard care unless a secondary indication arose. Following this, in all other situations, when MICAR criteria was not met, patients received either peripheral IVs or midlines.

The additional component in this plan was the implementation of the intensivist program. Prior to the intensivist program, Mobile Infirmary functioned as an open ICU. In this model, anyone could be admitted to the ICU and serve as the primary attending for the patient, and Intensivists were just consultants. This meant that physicians without critical care training and expertise were often functioning as the primary treating physicians. As is typical in such models, ICU patients had several consultants caring for them, often one physician for every organ system, and care was not coordinated and frequently contradictory. No one physician had direct ownership over the central lines and, consequently, the lines tended to stay longer.

By implementing the Intensivist Program, ICU care changed to a closed unit model with trained, board certified critical care

physicians being the attending of each intensive care unit patient and having direct control over the coordination of the care of each patient including their venous access. Consultations were less frequent and targeted to answer specific questions. While consultants' opinions were carefully listened to and frequently implemented, the final care plan each day was coordinated through the intensivist to reduce unintended contradictions in care. Therefore, the decision on when to place and remove central lines were under the control of the intensivist program which made a targeted effort to not place them unless necessary and then to remove them as soon as they were no longer necessary [37-40].

As part of the intensivist program multi-disciplinary rounds (MDR) were implemented in the care of our patients. MDR are a proven daily patient rounding model that includes the intensivist and all ancillary services that help care for ICU patients [41-42]. Members of an ICU MDR include speech and nutrition therapy, pharmacy, nursing, respiratory therapy, physical and occupational therapy, case management, wound care, and other services as needed. The goal of MDR is to coordinate the care of the entire treatment team towards common goals and improve the outcomes of patients. During these MDR, we included daily nursing reports of the type of vascular access. If a central line was present, its continued utilization was reviewed, and it was removed if it no longer met MICAR criteria. In addition, we empowered nurses to continuously review the need for central lines and to request removal of central lines at any time when patient no longer met MICAR criteria.

We studied the results that the new intensivist program running a closed ICU model using the new venous access policy had on central line days, central line utilization, and central line infection rates at Mobile Infirmary. We obtained approval for this study from the Mobile Infirmary Institutional Review Board which also granted a HIPPA wavier for authorization of access for medical records.

We calculated the number of central line infections occurring during two time periods: April 1, 2020-April 1, 2021 (pre-intervention), and June 1, 2021-June 1, 2022 (post-intervention). Additionally, we summed together the frequency of central line infections occurring in the period before the intervention was introduced (April 1, 2019-April 1, 2021). We calculated the rate of central line infections with corresponding 95% confidence intervals using three denominators: central line days, expected central line days, and patient days.

In order to determine whether there was a significant change in the rate of central line infections we calculated rate ratios (RRs) along with corresponding 95% confidence intervals and p-values comparing the rate of central line infections using all three denominators between the pre and post intervention time periods. We used Poisson regression with a log link in SAS Version 9.3 to calculate these RRs. In these models, the log of the denominator (central line days, expected central line days, and patient days) was treated as the offset. The exponent of the coefficient from these models were the RR. These RRs represent how many times lower the central line infection rate was in the time period after the intervention was introduced compared to pre-intervention period.

Additionally, in order to determine whether differences in the characteristics of the patients seen in the period before and after the interventions were introduced may have impacted our findings, we compared the number and percentage of patients according to gender, age group, race/ethnicity, COVID-19 diagnosis, and admitting diagnosis in the period before the intervention was introduced and the period after. In order to determine whether these frequencies in the two time periods were significantly different, we performed chi-square analysis.

Results

As shown in table 1, there were 25 central line infections between April 1, 2019 -April 1, 2021, and 4 between June 1, 2021-June 1, 2022. Across the three denominators used for calculating rates, infections rates were lower in the post-intervention time period compared to the pre-intervention period (figure 1).

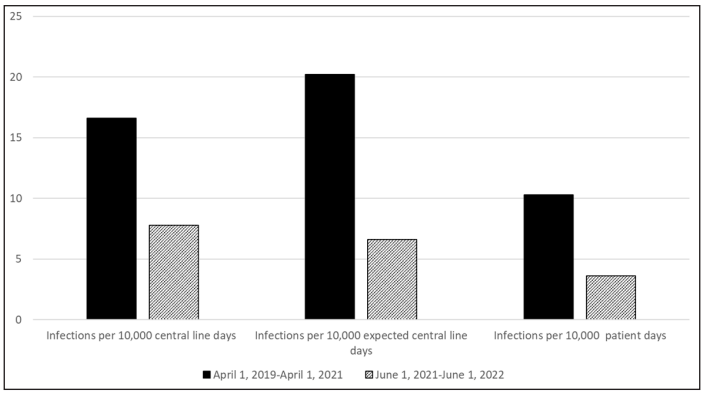

Figure 1: Central line rates, and rate ratios compared across time periods and denominator, April 1, 2019, to June 1, 2022

Table 1 shows the rate ratios (RRs) comparing difference in rates between the pre and post intervention time periods. When central line days are the denominator, the RRs is less than 1, consistent with the lower rate in the post-intervention time period (P-value=0.16, RR=0.47, 95% CI=0.16, 1.36). When expected patient line days are the denominator, the infection rate was 68% lower in the post-intervention time period (**P-value=0.036**, RR=0.32, 95% CI=0.11, 0.93). Similarly, when patient days are the denominator, the infection rate was 65% lower in the post-intervention time period (**P-value=0.049**, RR=0.35, 95% CI=0.12, 1.00).

Table 1: Central line Infections, infection rates, and rate ratios compared across time periods by denominator type, April 1, 2019, to June 1, 2022

	Pre-intervention: April 1, 2019-April 1, 2021	Post-intervention: June 1, 2021-June 1, 2022	Pre-intervention/Post-intervention	
			Rate ratio (95% CI)	P-value
Central line infections	25	4		
Central line days	15,062	5,108		
CLABSI Rate (CLABSI/central line days x 1000)	1.65	0.78		
Infections per 10,000 central line days (95% CI)	16.6 (10.1, 23.1)	7.8 (0.2, 15.5)	0.47 (0.16, 1.36)	0.1630
Expected central line days	12,350	6,097		
Infections per 10,000 expected central line days (95% CI)	20.2 (12.3, 28.2)	6.6 (0.1, 13.0)	0.32 (0.11, 0.93)	0.0364
Patient days	24,290	11,178		
Infections per 10,000 patient days (95% CI)	10.3 (6.3, 14.3)	3.6 (0.1, 7.1)	0.35 (0.12, 1.00)	0.0498

Table 2: Comparison of demographic characteristics between the pre- intervention and post-intervention time periods

	Pre-intervention		Post-intervention		
	n	%	n	%	P-value
Total	2,105	100	2,463	100	
Gender					
Female	973	46.2	1,127	45.8	0.7527
Male	1,132	53.8	1,336	54.2	
Age Group		-			
11-20	9	0.4	12	0.5	0.7664
21-30	60	2.9	80	3.2	0.4396
31-40	109	5.2	140	5.7	0.4527
41-50	207	9.8	211	8.6	0.1388
51-60	358	17.0	463	18.8	0.1161
61-70	586	27.8	670	27.2	0.6314
71-80	518	24.6	611	24.8	0.8764
81-90	227	10.8	243	9.9	0.3088
91-100	31	1.5	33	1.3	0.7033
Race/ethnicity					
Asian	10	0.5	6	0.2	0.1869
Black	798	37.9	941	38.2	0.8374
Hispanic	4	0.2	1	0.0	0.1279
Other	14	0.7	27	1.1	0.1235
White	1278	60.7	1482	60.2	0.7088

Table 3 shows comparisons of the admitting diagnoses between the pre-intervention and post-intervention periods. Only diagnoses with 10 or more patients in each of the two time periods are shown. In general, there were not significant differences in the admitting diagnosis between the two time periods except for COVID-19. The distribution of COVID-19 was significantly different. In particular, 14% of participants were COVID-19 positive in the pre-intervention time period, while 9% were COVID-19 positive in the post-intervention time period.

Table 3: Comparison of admitting diagnosis between the pre-intervention and post-intervention time periods

ICD-10 Admitting Diagnosis	Pre-intervention		Post-intervention		
	n	%	n	%	P-value
Total	2105		2463		
Shortness of breath	161	7.6	149	6.0	0.0322
COVID-19	153	7.3	90	3.7	<0.0001
Chest pain unspecified	89	4.2	98	4.0	0.6554
Sepsis unspecified organism	78	3.7	106	4.3	0.3053
Altered mental status unspecified	56	2.7	106	4.3	0.0028
Unspecified abdominal pain	54	2.6	39	1.6	0.0192
Pneumonia unspecified organism	47	2.2	61	2.5	0.5887
Atherosclerotic heart disease of native coronaries w/o angina	47	2.2	57	2.3	0.854
Acute respiratory failure with hypoxia	32	1.5	41	1.7	0.698
Gastrointestinal hemorrhage unspecified	32	1.5	55	2.2	0.0789
Acute respiratory distress	29	1.4	40	1.6	0.4692
Nonrheumatic aortic (valve) stenosis	28	1.3	22	0.9	0.1571
Nonrheumatic mitral (valve) insufficiency	26	1.2	22	0.9	0.2586
Weakness	23	1.1	45	1.8	0.041
Syncope and collapse	22	1.0	32	1.3	0.4283
Non-ST elevation (NSTEMI) myocardial infarction	22	1.0	28	1.1	0.7665
Dyspnea unspecified	20	1.0	14	0.6	0.1346

Type 2 diabetes mellitus with ketoacidosis without coma	20	1.0	26	1.1	0.7218
Nausea with vomiting unspecified	17	0.8	27	1.1	0.3195
Heart failure unspecified	17	0.8	15	0.6	0.4225
Hematemesis	16	0.8	14	0.6	0.424
Unspecified atrial fibrillation	15	0.7	19	0.8	0.8176
Atherosclerotic heart disease of native coronaries with unstable angina	15	0.7	15	0.6	0.6657
Other pulmonary embolism without acute cor-pulmonale	15	0.7	15	0.6	0.6657
ST elevation (STEMI) myocardial infarction	14	0.7	26	1.1	0.1579
Urinary tract infection site not specified	14	0.7	16	0.6	0.9486
Other chest pain	14	0.7	14	0.6	0.6765
Hypotension unspecified	13	0.6	26	1.1	0.1124
Acute and chronic respiratory failure with hypoxia	13	0.6	16	0.6	0.8919
Anemia unspecified	13	0.6	17	0.7	0.7619
Fever unspecified	13	0.6	23	0.9	0.2282
Abdominal aortic aneurysm without rupture	12	0.6	10	0.4	0.4247
Acute kidney failure unspecified	11	0.5	22	0.9	0.1441
Cardiac arrest cause unspecified	11	0.5	29	1.2	0.179
Other	943	44.8	1128	45.8	0.4987

Discussion

The results of combining the intensivist program with the MICAR criteria was a clinically significant reduction in central line days, central line utilization ratio, and central line associated blood stream infections. Our findings supported the hypothesis that combining an intensivist program using a closed ICU model with MICAR criteria for central lines appropriateness reduced dependence on central lines and significantly lowered the incidence of CLABSIs.

As discussed above, reducing the number of CLABSIs has a significant impact on both morbidity and mortality. Specifically, each CLABSI carries with it an increase in per hospitalization cost of approximately $50,000 and an increase in mortality of up to 25%. By reducing the utilization of central lines, and thereby reducing the number of CLABSIs at our institution, we effectively reduced cost and mortality.

Interestingly, this reduction in CLD, CLUR, and CLABSIs occurred despite an overall increase of 15% in total number of patients treated in the first year after the intervention. We attributed the 15% increase to a reduction in both ventilator days and ICU length of stay related to the greater efficiency of care under the intensivist program and closed ICU model.

In terms of potential negative effects, during the post intervention period, there were 2 cases of extravasation of a caustic medication into the skin, both times around a PIV site. In both cases, the treatment was standard, and harm was minimal. The 2 years prior to the initiation of the program, there were 5 reported cases of extravasation. There was not a significant increase in reported extravasation cases after the start of the program [9].

In comparing the two groups looking for potential demographic bias, we found no significant difference between the two groups in regard to demographics. When comparing the two groups to assess for any differences in the medical conditions treated during the study periods, we found no clinically significant difference between the two study periods except for COVID-19.

When COVID-19 was listed as one of the primary ICU treatment diagnoses, COVID-19 was found in 14% of the preintervention group compared to 9% in the post intervention group (P-value<0.0001). How this difference in COVID-19 numbers affected the data is unknown. While it has been shown in other studies that the number of CLD and CLABSIs did go up in the first year of the COVID-19 pandemic, the total number of COVID-19 patients was high in both groups. In addition, the total number of patients treated was higher in the post-intervention group. Based on this, an argument can be made that the use of a full-time intensivist team in a closed ICU model using a restrictive central line placement criteria is what lead to such a significant decline in CLD and CLABSI post intervention despite continued high number of COVID-19 patients.

Potential limitations of this study include that the study was a single center retrospective study comparing data from pre-intervention time frame to data collected for 1 year post intervention. In addition, while there was a significant trend towards reduction in CLD and CLUR, the power of the study was insufficient to show statistical significance, though it did show statistically significant reductions in CLABSI rate for actual and expected line days.

Conclusions

Over utilization of central lines and the subsequent increase in central line infections represents a major complication of ICU care directly impacting morbidity and mortality. By combining an intensivist program using a closed ICU model with a restrictive venous access policy designed to reduce dependence on central lines, we showed a significant reduction in central line days, central line utilization ratio, and central line infections without any significant increase in IV extravasations. Closed intensive care units managed by board-certified intensivist using a restrictive central line access policy can significantly reduce central line use and infections without secondary adverse events in non-academic private sector hospitals.

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