HHS Public Access

Author manuscript

JPEN J Parenter Enteral Nutr. Author manuscript; available in PMC 2015 November 01.

Published in final edited form as:

JPEN J Parenter Enteral Nutr. 2015 November ; 39(8): 929–934. doi:10.1177/0148607114536580.

Utility of Electronic Medical Records to Assess the Relationship Between Parenteral Nutrition and Central Line–Associated Bloodstream Infections in Adult Hospitalized Patients

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Abstract

Background—Parenteral nutrition is associated with increased central line–associated bloodstream infections (CLABSIs). Electronic databases are important for identifying independent risk factors for prevention strategies. Our aims were to evaluate the utility of using electronic data sources to identify risk factors for CLABSIs, including parenteral nutrition (PN), and to assess the association between CLABSI and PN administration.

Methods—Data were obtained for all discharges of adult patients in whom a central line was inserted between September 1, 2007, and December 31, 2008, in a large, academically affiliated hospital in New York City. CLABSI was defined electronically using a modified definition from the Centers for Disease Control and Prevention. A manual chart review was also undertaken to assess validity/reliability of the electronic database and gather additional information. Risk factors for CLABSI were examined using logistic regression.

Results—Among 4840 patients, there were 220 CLABSIs, an incidence of 5.4 CLABSIs per 1000 central line days. Risk factors included PN (odds ratio [OR], 4.33; 95% confidence interval [CI], 2.50–7.48), intensive care unit stay (OR, 2.26; 95% CI, 1.58–3.23), renal disease (OR, 2.79; 95% CI, 2.00–3.88), and immunodeficiency (OR, 2.26; 95% CI, 1.70–3.00). Diabetes mellitus was associated with reduced CLABSI rates (OR, 0.63; 95% CI, 0.45–0.88).

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Conclusions—The utility of electronic medical records for determining risk factors is limited by such things as free-text data entry. Using a hybrid between fully electronic and manual chart review, reliable data were obtained. PN is associated with a high risk for CLABSI in a population highly selected for indications for PN.

Keywords

parenteral nutrition; nutrition; nutrition support practice; sepsis; life cycle; central venous catheter; central line–associated bloodstream infection; electronic medical records; risk factors

Clinical Relevancy Statement

Our study of a large cohort of adult hospitalized patients confirmed that parenteral nutrition (PN) is strongly associated with an increased risk of central line–associated bloodstream infections (CLABSIs). We found that electronic databases are not ready to be used for surveillance of PN-associated CLABSIs or other PN-related complications. Future studies can benefit from adjustments to these large databases and improved uniformity in the terminology and definitions of nutrition-related data elements across electronic health records.

Background

Healthcare-associated infections (HAIs) are a significant cause of morbidity and mortality around the world. In 2002, the Centers for Disease Control and Prevention (CDC) released a public report estimating that 1.7 million HAIs resulted in 98,987 deaths annually within hospitals across the United States.[1] Approximately 30% of these deaths were attributed to bloodstream infections (BSIs). These estimates are based on national surveillance systems using decade-old data and therefore do not accurately reflect current mortality attributable to BSIs. For more than a decade, hospitals have achieved significant reductions in central line–associated bloodstream infections (CLABSIs) through systems-level approaches. Most notably, these include enhanced hand hygiene among healthcare personnel and implementing a bundle of evidence-based interventions for care of indwelling devices.[2,3]

Compared with the predicted number of CLABSIs from 2006 to 2008, the National Healthcare Safety Network (NHSN) reported a 41% reduction in CLABSIs among adult, pediatric, and neonatal intensive care unit (ICU) patients in 2011.[4] Notwithstanding these efforts, the increasing use of central lines in non-ICU settings may generate new challenges to CLABSI prevention.[5,6] Understanding the individual-level predictors of CLABSIs may lead to improvements in prevention and surveillance strategies and provide important information when reporting risk-adjusted healthcare-associated infection per guidelines proposed by the Hospital Infection Control Practices Advisory Committee. As electronic medical records (EMRs) become more common, large electronic database systems are increasingly being used to monitor and study a variety of conditions among hospitalized patients. These systems must be validated as reliable epidemiologic tools for capturing these conditions and assessing potential risk factors. [7–9] In fact, a number of challenges have been identified with using EMR for this purpose.[10]

Evidence suggests that the use of central venous catheters for administration of parenteral nutrition (PN) is an independent risk factor for CLABSIs, with catheter-related sepsis occurring in 1.3% to 26.2% of the catheters used to administer PN.[11,12] A technical review of 57 randomized controlled trials published in 2001 reported that hospitalized patients who received PN had a 5% increase in overall infectious complication rates. In other words, PN resulted in 1 additional infection for every 20 patients who were treated.[13] Furthermore, in a recent randomized study of 4640 critically ill patients, those receiving early vs late PN had an increased incidence of BSIs (from 6.1%–7.5%; $P = .05$).[14]

Much of our understanding of the relationship between central line use for PN and incidence of CLABSI comes from studies conducted only in the ICU, even though these infections also occur in non-ICU acute care but are less likely to be systematically tracked.[15] Moreover, if surveillance systems for infections are to be cost-effective and provide data in real time, it will be necessary to take advantage of available patient data being collected electronically. Hence, the first aim of this study was to evaluate the utility of using electronic data sources to appropriately identify risk factors for CLABSIs. The second aim was to investigate the association between CLABSIs and administration of PN and to identify other potential factors that might be associated with a higher risk of CLABSIs.

Methods

Study Design and Setting

Data were obtained from all adult patient discharges between September 1, 2007, and December 31, 2008, in the two affiliated hospitals that comprise NYPresbyterian Hospital Columbia University Medical Center. The larger of these is a 745-bed tertiary-care hospital with an overall case mix index of approximately 2. In this facility are 6 ICUs, more than 40 operating rooms, and a surgical case mix index above 4. The second is a 220-bed community hospital. Both hospitals are within a large, academically affiliated hospital network in New York, NY. During this period, the EMR (Eclipsys Sunrise Clinical Manager 4.5 XA; Eclipsys Corp, Atlanta, GA) was used in conjunction with several other commercial and locally developed systems for computerized provider order entry. It was also the primary source for clinical documentation entered by nursing, physician, and ancillary staff. The medical center has a robust infection prevention and control program that covered both inpatient hospitals during the study period. The use of PN at both institutions was highly regulated during the study period. On average, 5 inpatients were receiving PN on any given day in the main adult hospital. Approximately 150–300 patient-days of PN are delivered per year in the smaller community hospital. A nutrition support team consisting of physicians and a dietitian in collaboration with pharmacists and nurses provided consultation and quality control of PN. Compounding of PN in both hospitals was outsourced to a large compounding pharmacy. The Columbia University Medical Center Institutional Review Board approved the use of data for this research study.

Definitions

CLABSIs were identified using previously validated computerized algorithms based on definitions used by the CDC and NHSN.[16,17] For the purposes of this study, CLABSI was

defined as a laboratory-confirmed BSI in a patient with a central line in place for at least 48 hours prior to the onset of symptoms, which was unrelated to an infection from another site. Days at risk for developing CLABSI was defined as the interval between the day of catheter insertion and the onset of CLABSI, catheter removal, or patient discharge if the central line was still in place. CLABSI was considered to be associated with PN if it occurred between the start of PN and within 3 days after stopping PN. We determined the temporal sequence of events using dates of occurrence for all procedure and infection variables.

Data Collection

As part of a larger study, "Distribution of the Costs of Antimicrobial Resistant Infections," funded by the National Institute of Nursing Research (5R01NR010822), data were collected retrospectively from various electronic sources shared by the 2 hospitals. Data sources included a clinical data warehouse, which combines information from various electronic sources; the admission, discharge, and transfer system; and the EMR as described above. The information extracted from these systems was compiled into the parent database and linked by patients' unique medical record numbers and admission dates using a technical process described in other published work.[17,18]

The following data were collected for discharges among 4840 adult patients who received a central line between September 2007 and December 2008: age, sex, dates of admission and discharge, hospital, ICU stay, dates and duration of catheter insertion and removal, PN start dates, Charlson comorbidity score,[19] pneumonia based on laboratory data, and immunodeficiency based on medication administration record. In addition, *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnoses and procedure codes were used for medical conditions, including human immunodeficiency virus (HIV), renal disease, transplant, diabetes, malignancy, and surgical site infection. Surgical site infection was also confirmed using previously suggested algorithms published in other literature.[20]

The database did not contain PN stop dates; therefore, we performed a manual review of the EMR to confirm PN duration, central line duration, and BSI dates in patients who were administered PN and to assess the validity and reliability of our electronic database. PN start and stop dates from the chart review were used to analyze duration of PN. CLABSI and central line dates from the parent database were used to analyze CLABSI incidence and duration of catheterization.

Statistical Analysis

Relevant variables were initially summarized, and univariate analyses, χ^2 test, or Student's t-test, as appropriate, were performed before building multivariable models. Variables with *P* values lower than .02 in univariate analyses were entered to build the final multivariable model. Multiple logistic regression was performed to evaluate the effect of PN on the occurrence of CLABSI after controlling for potential confounders, including demographic characteristics, ICU stay, duration of catheterization, Charlson comorbidity score, immunodeficiency, and medical conditions. We confirmed that multicollinearity was not a problem with these data. The effect of predictor variables on CLABSI rates was expressed

as odds ratios (ORs) with 95% confidence intervals (CIs). Effects with *P* values less than .05 were considered statistically significant in the multiple logistic regression analysis. The software package used for analysis was SPSS version 20 (SPSS, Inc, an IBM Company, Chicago, IL).

Results

Aim 1: Utility of Using Electronic Data Sources to Appropriately Identify Risk Factors for CLABSI

We searched the parent database for adults 18 years and older who were discharged between 2007 and 2008 and received a central line. PN stop dates had to be confirmed using the free text found in nursing notes, nutrition notes, and/or dietary flow sheets. The volume of PN delivered could not be determined from the chart review or parent database, and pharmacy records were not electronically available to review. In addition, central line insertion site or central line type could not be reliably determined from either the chart review or the parent database. In total, 122 patients received PN between September 2007 and December 2008 and were verified using either the parent database or the chart review. Central line duration and diagnosis dates of all patients with PN-associated CLABSIs were consistent (100%) between the parent database and the chart review, confirming the reliability and validity of these data.

Aim 2: Risk Factors for CLABSI in Patients With Central Venous Catheters

A total of 4840 patients were included in the analysis. During the study period, there were 220 CLABSIs, for an incidence density of 5.4 CLABSIs per 1000 central line days. There were 18 CLABSIs associated with PN, for an incidence density rate of 10 CLABSIs per 1000 PN days. Patients who received PN were similar to those who did not receive PN for characteristics including age, sex, comorbidity score, and ICU stay, but those who received PN had significantly longer average catheterization durations compared with patients who did not receive PN (Table 1).

In univariate analyses, PN, renal disease, admission to the ICU, immunodeficiency, pneumonia, duration of central line catheterization, and history of transplant were each associated with an increased risk of CLABSI. Diabetes was associated with a decreased risk of CLABSI (Table 2). In multivariable analysis, PN (OR, 4.33; 95% CI, 2.50–7.48), ICU stay (OR, 2.26; 95% CI, 1.58–3.23), renal disease (OR, 2.79; 95% CI, 2.00–3.88), and immunodeficiency (OR, 2.26; 95% CI, 1.70–3.00) were significant risk factors for CLABSI. Diabetes remained associated with a decreased risk of CLABSI (OR, 0.63; 95% CI, 0.45–0.88) (Table 3).

Discussion

Utility of Using Electronic Data Sources to Identify Risk Factors for CLABSI

As has been recently confirmed, data regarding HAIs from a variety of national electronic data systems are quite robust, as they were in our data set as well.[21] On the other hand, despite increasing efforts to prevent HAIs such as CLABSIs, data on central line insertion

site, type, date, and duration may be only partially or inaccurately documented in medical records, making it challenging to study these important variables. There are inherent methodological challenges with retrospective extraction of data from EMRs in such a way that the data can be reused for research purposes.[22] Natural language-processing tools that convert free text into structured data might help facilitate future data extraction; however, hospitals will need to rely on solutions that do not involve substantial capital investments in information technology. Important variables for research that are typically documented in a narrative could potentially be captured in a standardized way that does not increase the use of a clinician's time. Hospitals should engage clinicians in the design and testing of new structured formats for data entry and real-time dissemination of important data.

Other potential obstacles to reusing EMR data for epidemiological investigations include inaccuracies in electronic data, sparse data to examine causal relationships, and lack of standards for defining cases of disease and denominator populations. [23,24] These challenges and the work of improving the validity and reliability of electronically available clinical data must be addressed by researchers and by healthcare systems administrators. Efforts to improve these may include such improvements as direct input of objective data into analytic and decision support software, and improved uniformity and education as well as stricter adherence to definitions.

Risk Factors for CLABSI

Although major reductions in CLABSI have been reported in patients hospitalized in ICUs in the United States, a substantial number of CLABSIs continue to occur in other inpatient wards and outpatient centers. In 2009, the CDC reported CLABSI rates of 1.65 per 1000 central line–days in ICUs and CLABSI rates of 1.14 per 1000 central line–days in other inpatient wards.[25] An estimated 23,000 CLABSIs occurred among patients in inpatient wards in 2009.[25]

In addition, there is an increase in the use of central lines in non-ICU settings.[26] A 1-year descriptive review was conducted in a single tertiary center with a 1200-bed hospital and 209 adult ICUs. The authors reported that the non-ICU CLABSI rate was significantly higher than the concurrent ICU rate (2.1 CLABSIs per 1000 catheter-days vs 1.5 CLABSIs per 1000 catheter-days).[27] Our study results are consistent with a prospective cohort study comparing PN and enteral nutrition (EN) in patients admitted to the surgical ICU. In a multivariable logistic regression, PN was associated with a 4-fold increase in the OR for catheter-related bloodstream infections (OR, 4.48; 95% CI, 1.14–17.49).[28]

The rate of CLABSI in patients receiving PN in our study was low relative to rates reported in other studies. Yilmaz et al[12] reported a CLABSI rate of 18.8 per 1000 catheter days in patients receiving PN. O'Connor et al[29] reported a CLABSI rate of 14.5 per 1000 central line–days in patients receiving PN. Also, there was a higher rate of CLABSIs in the ICU population compared with the non-ICU population, 19.8 vs 9.3, respectively.[29] Renal disease and immunodeficiency were significant risk factors of CLABSI in our study, as has been reported in other studies.[25,30,31]

Limitations of our study include factors related to the use of electronic data such as missing data points or possible inaccurate or inconsistent recording. Specific reasons for missing data points might include the lack of catheter site assessment or failure to document the care. Diagnosis codes could be influenced by the billing context in which the clinician chose the coded diagnosis or by the feasibility of locating the appropriate code. Furthermore, clinical staff likely had disparate knowledge of use of the EMR.

Although the nutrition support team and dietitian regularly monitored and assessed all patients receiving PN during the study period, the odds of PN-associated CLABSI remained significantly high. It is likely that the patients were sicker than those included in prior studies due to the overall case mix, as well as the stringency with which our patients are selected for use of PN. It is possible that, with stricter adherence to protocols and a zero tolerance for CLABSI, this disparity may be reduced in the future.

Our finding that diabetes was associated with reduced risk of CLABSI was quite robust in the multivariable modeling. While this seems counterintuitive, it might be a result of increased vigilance among staff to use preventive care bundles and strategies, but it is more likely that diabetic patients may be at higher risk of having concurrent positive cultures at other sites. If that were the case, we would not have classified their BSIs as central line related.

Conclusion

Reducing HAIs has become a national priority with mandates for hospitals to improve patient safety and contain costs. Early identification of significant predictors may improve the ability of staff to target interventions to patients receiving PN who are at increased risk of CLABSI. Electronic health records should accurately depict independent risk factors of CLABSI, such as PN, to calculate and track hospital-associated infection rates over time.

We found that electronic databases are not ready to be used for surveillance of PN-associated CLABSI or complications associated with the implementation of PN. Future studies can benefit from adjustments to these large databases such as including records from the hospital pharmacy where PN orders are processed. We observed a strong association between administration of PN and an increased rate of CLABSI. Other risk factors for CLABSI identified in this study included renal disease, admission to an ICU, and immunodeficiency. These patients may benefit from efforts to avoid PN by maximal efforts toward use of EN support, which has been associated with a lower risk of infection than is PN[32] and an increase in tolerance for short-term undernourishment.

Causality cannot be inferred from this analysis. Irrespective of the limitations of the study and despite a highly selected PN patient population, PN continues to represent a significant risk factor for CLABSI.

Acknowledgments

Financial disclosure: This study was funded in part by grant 5R01NR010822 from The National Institute of Nursing Research, Distribution of the Costs of Antimicrobial Resistant Infections.

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Table 1

Clinical Characteristics of Patients With and Without Parenteral Nutrition (PN).

Characteristics	PN (n = 122)	No PN (n = 4717)
Age, mean (SD), y	60.7 (16.6)	63.5 (16.5)
Charlson comorbidity score, mean (SD)	2.9 (3.3)	2.5 (2.4)
Duration of catheterization, mean (SD), d	26.5 (29.8)	7.9 (11.9)
Male sex, %	54.9	55.1
Intensive care unit stay, %	52.5	60.6

Table 2

Univariate Analysis.

Risk Factors	CLABSI (n = 220)	No CLABSI (n = 4620)	*P* Value
Age, mean (SD), y	62.3 (16.2)	63.5 (16.5)	.27[a]
Charlson comorbidity score, mean (SD)	2.8 (2.4)	2.5 (2.4)	.19[a]
Duration of PN, mean (SD), d	10.7 (10.2)	15.5 (20.7)	.33[a]
Duration of catheterization, mean (SD), d	14.3 (15.3)	8.1 (12.8)	<.0001[a]
Male sex, %	58.2	55.0	.35
Underlying disease, %			
Malignancy	22.7	20.3	.38[b]
Diabetes mellitus	21.8	28.5	.03[b]
HIV	2.3	1.7	.43[c]
Renal disease	76.8	48.9	<.0001[b]
Surgical site infection, %	1.4	2.6	.24
PN, %	8.1	2.3	<.0001[b]
History of transplant, %	8.6	5.5	.05[b]
ICU stay, %	81.8	59.4	<.0001[b]
Immunodeficiency, %	60.0	34.3	<.0001[b]
Pneumonia, %	19.1	8.7	<.0001[b]

CLABSI, central line–associated bloodstream infection; HIV, human immunodeficiency virus; ICU, intensive care unit; PN, parenteral nutrition; SD, standard deviation.

[a] Student *t* test.

[b] χ^2 test.

[c] Fisher exact test.

Table 3

Significant Risk Factors Associated With CLABSIs (Multivariable Analysis).

Risk Factors	*P* Value	OR	95% CI
PN	<.0001	4.33	2.50–7.48
Renal disease	<.0001	2.79	2.00–3.88
ICU stay	<.0001	2.26	1.58–3.23
Immunodeficiency	<.0001	2.26	1.70–3.00
Diabetes	.007	0.63	0.45–0.88

CI, confidence interval; CLABSI, central line–associated bloodstream infection; ICU, intensive care unit; OR, odds ratio; PN, parenteral nutrition.