Assessment of the Reported Effectiveness of Five Different Quality-Improvement Initiatives for the Prevention of Central Line-Associated Bloodstream Infections in Intensive Care Units

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Abstract: Five studies that evaluated five different quality-improvement initiatives for the prevention of central line-associated bloodstream infections (CLABSIs) in adult, pediatric and/or neonatal intensive care units (ICUs) and that were published within the past two years in an infection-control and epidemiology journal were reviewed, assessed and compared. Each is a prospective cohort study that similarly concludes that the evaluated initiative was responsible for a significant and calculated reduction in the CLABSI rate, ranging from 30.3% to 85%. The soundness of these conclusions and calculations, however, like the legitimacy of several other common uses of CLABSI data, requires, in addition to satisfying a number of other criteria, that each study's CLABSI rates be accurate and complete. The primary goal of this analysis, therefore, was to confirm the hypothesis that each of these five studies had validated its CLABSI rates. The analysis found, however, that these five studies did not validate the accuracy and completeness of their CLABSI rates, which raises reasonable questions about each study's assessment of and conclusions about the initiative's effectiveness for the prevention of CLABSIs. In addition to their aims, calculations, and conclusions, these five studies share in common a number of features, as well as circumscribing qualities, which are discussed. The distinction between a qualitative assessment and a quantitative determination of an initiative's performance is also discussed. Both the circumspective use of CLABSI data that have not been validated and the cautious interpretation of conclusions about central-line care that are based on these CLABSI data are recommended.

Keywords: Central line-associated bloodstream infections, central lines, quality-improvement initiatives, prospective-cohort studies, confounding factors, biases, performance feedback, compliance data, data validation, outcome surveillance, process surveillance.

INTRODUCTION

Rates of central line-associated bloodstream infections ("CLABSIs") have many applications, several of which are listed in Table **1**. For example, the focus of many newspaper articles, medical studies, and governmental reports, state and federal agencies frequently study CLABSI rates to identify trends or deficiencies in health care; to set quality-improvement standards and goals, such as achieving a 50% reduction in CLABSIs, nationwide, by 2013; and as a metric to verify the effectiveness of targeted funding for the prevention of healthcare-associated infections (HAIs) [1-5]. In one recently published federal study, the Centers for Disease Control and Prevention (CDC) calculated that CLABSI rates in intensive care units (ICUs) in the U.S. had decreased dramatically from 2001 to 2009 [1]. The CDC concluded in this study that these calculated reductions were likely due primarily to state and federal efforts coordinated and supported by the CDC, the Agency for Healthcare Research and Quality, and the Centers for Medicare and Medicaid Services (CMS) [1]. Based on its calculations, the CDC further concluded that between 2001 and 2009 "the cumulative excess health-care costs of all CLABSIs prevented in ICUs could approach $1.8 billion, and the number of lives saved could be as high as 27,000" [1].

Table 1. Common Uses of CLABSI Data and Rates

CLABSI data and rates may be used by:

- Clinicians and researchers:
  - to manage the quality of central-line care; and
  - to evaluate and quantify the performance and cost-effectiveness of specific initiatives, such as a checklist or a bundle of "best-practices," for the prevention of CLABSIs in ICUs [6-14];
- Hospitals to advertise to the public their quality and safety [26, 27];
- State lawmakers to improve public health and enhance health care's transparency and accountability [5, 8, 15, 16, 21, 26, 28];
- Consumers to compare the relative safety of hospitals in different cities, states, and countries [1-5, 26, 28];
- Consumer organizations to rate hospitals and to label some "poor" or "top" performers [28];
- State and federal governmental agencies:
  - to evaluate trends in and to advance claims about the quality of health care and central-line care;
  - to set goals (e.g., a 50% reduction in CLABSIs, nationwide, by 2013 [1]); and
  - to evaluate the effectiveness of targeted efforts and funding, if not also, at times, to justify expenditures [1-5]; and
- Private and public healthcare insurers, as well as federal and state rules, programs and policies, to incentivize improved health care and the prevention of healthcare-associated infections (HAIs) by conditioning reimbursements, financial rewards, and other forms of compensation on the reporting of CLABSI and other HAI rates (e.g., CMS's pay-for-reporting programs) [1-5, 12, 14].

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Another popular use of CLABSI data, clinicians routinely perform studies to evaluate the effectiveness of an initiative, such as a checklist, for the prevention of CLABSIs in ICUs [6-14]. Like that of each of the other uses of CLABSI data (Table **1**), the soundness of these studies and their calculations and conclusions, however, requires that their CLABSI rates be accurate and complete [3,4,12,14-18]. For example, the CDC's published conclusion in its aforementioned study [1] that initiatives focusing on increased adherence to "best-practices" for the insertion of central lines (such as the Pittsburgh Regional Healthcare Initiative and the Michigan Keystone Project) successfully reduced CLABSI rates in ICUs by "roughly 70%" is only as legitimate as the CLABSI data on which this conclusion is based are valid. Therefore, because of the potential impact that these studies and their findings might have on quality improvements, central line practices, and health care policies [1-18], five studies evaluating a specific initiative's impact on CLABSI rates in ICUs were reviewed, assessed and compared. If this analysis found that any of these studies did not validate its CLABSI data for accuracy and completeness, then the soundness of its conclusions about the initiative's effectiveness, or of any actions or changes in practice that were based on the study's results, might be reasonably questioned. The primary goal of this analysis, therefore, was to confirm the hypothesis that each of these five studies had validated its CLABSI rates.

METHODOLOGY

Several studies that evaluated the effectiveness of an initiative for the prevention of CLABSIs in adult, pediatric or neonatal ICUs were randomly selected from a number of medical journals. To provide insight into the types of studies recently published specifically for the infection-control and epidemiology communities, only those studies that were published in the journal *Infection Control and Hospital Epidemiology* within the past two years were considered for further review. Of these remaining studies, five were randomly selected, and their aims, designs and methodologies, and conclusions were reviewed, assessed and compared [6-10]. Five studies were selected, because fewer than five might not be sufficient to resolve and reveal features and characteristics that these studies might share in common, and more than five studies was reasonably deemed to complicate the presentation of this analysis's findings and conclusions without likely providing additional insight.

In addition to confirming whether each study's CLABSI data and rates had been validated, this analysis identified a number of other features important to compare these studies and to assess the soundness of their conclusions about the initiative's effectiveness. Displayed in Table **2**, these features include: (*i*) the study's design (e.g., a prospective-cohort, retrospective-trend, or a randomized controlled design); (*ii*) its methodology (i.e., a qualitative assessment or a quantitative determination of the initiative's effectiveness); (*iii*) whether the study concluded that an identified relationship between the initiative's implementation and a measured change in the CLABSI rate was causal or limited to an association; (*iv*) whether the study confirmed adherence by ICU staff members to all of the initiative's elements; and (*v*) whether the study featured performance feedback (which is verbal communications among participating ICU staff members about the initiative's progress). This analysis also identified any limitations and circumscribing qualities that the five reviewed studies might share in common and that might affect their soundness.[1]

RESULTS

Each of the five reviewed studies evaluated the effectiveness of a different quality-improvement initiative for the prevention of CLABSIs in one or more adult, pediatric and/or neonatal ICUs. Displayed in Table **2**, these five initiatives were three different educational initiatives, a collaborative initiative, and the use a closed plastic intravenous (IV) container [6-10]. Other characteristics and features of these five studies that provide insight into the soundness of their conclusions about the implemented initiative's effectiveness are also provided in Table **2**. Table **3** focuses on a number of the limitations and circumscribing qualities that these five reviewed studies were found generally to share in common. For example, each is a prospective cohort study that is not controlled or randomized (or blinded). Nonetheless, although therefore limited to associations (and unable to display cause-and-effect relationships), each study provides a quantitative determination of the evaluated initiative's effectiveness, suggesting that the initiative causally reduced the CLABSI rate by a percentage ranging from 30.3%-85% (Table **2**) [6-10].

Also displayed in Table **2**, three of the five reviewed studies [6,7,10] feature verbal communications among participating ICU staff members during the *post*-intervention period (which is that period of time after the initiative's implementation) about, in general, not only the study's aim to reduce the CLABSI rate, but also about the initiative's progress and success toward achieving this goal (i.e., *outcome* surveillance) [1,6,7,10]. Such dialogue is often referred to as performance feedback [10, 12] (or, on occasion as "social interactions") [13].

Four of the five reviewed studies reported some compliance data (Table **2**) demonstrating that ICU staff members adhered, at least to some degree, to the evaluated initiative's prescribed elements (during the *post*-intervention period [i.e., *process* surveillance]) [7,8,10]. These compliance data are prone to biases [11,19-21], however, and for each study they were generally incomplete, self-reported and not validated.

One of the 5 reviewed studies reported having reviewed the patients' medical records to confirm the accuracy and completeness of the *number* of CLABSIs (Table **2**) [8]. Like each of the other four reviewed studies, however, this study did not report having similarly confirmed the accuracy and completeness of the *number* of central-line days, either before or after the initiative's implementation. Therefore, in short, none of these five studies validated the CLABSI rates on which their conclusions are based. (*Note*: The CLABSI rate

[1]A second analysis that will evaluate several, similar studies that aim to determine the effectiveness of an initiative, but that are broader in scope and were published in a number of different medical journals not specifically focusing on infection control and epidemiology, is planned by this article's author (LFM).

Table 2. Characteristics and Features of Five Studies that Report the Effectiveness of a Quality-Improvement Initiative for the Prevention of CLABSIs

Authors	Bizzarro *et al.* [6]	Jeffries *et al.* [7]	Maki *et al.* [8]	Parra *et al.* [9]	Rosenthal *et al.* [10]
Type of ICU:	NICU (Neonatal)	PICU (Pediatric)	ICU (Adult)	ICU (Adult)	NICU, PICU, ICU (Adult)
Location of study:	CT (U.S.)	U.S.	4 countries, including Mexico	Madrid (Spain)	15 developing countries
Type of study design:	A prospective cohort design	A prospective cohort design	A prospective cohort design	A prospective cohort design	A prospective cohort design
Number of facilities in the study:	One NICU (54-bed)	26 PICUs In 26 children's hospitals	15 adult ICUs in 7 hospitals	3 adult ICUs in one hospital	86 ICUs in 57 hospitals in 15 countries
Details of the studied initiative:	One hospital's educational initiative	A multi-center collaborative initiative	A closed plastic IV intravenous fluid container	One hospital's educational initiative	A multi-national educational initiative
Does the study provide a quantitative determination or qualitative assessment of the initiative's performance?	A quantitative determination	A quantitative determination	A quantitative determination	A quantitative determination	A quantitative determination
If a quantitative determination, what was the study's reported percent reduction of the CLABSI rate?	85%	32%[1]	67%	30.3%	54%
Does the study feature performance feedback? [2]	Yes	Yes	No	Not discussed in the article	Yes
Does the study collect and record compliance data?[3]	To some degree, but not entirely.[4]	To a limited degree.[5]	To a limited degree.[6]	No	To some degree, but not entirely.
Does the study validate its CLABSI data for accuracy and completeness?[7]	No[8]	No[8]	To a limited degree[9]	No	No
Does the study imply or suggest that the initiative caused a reduction in the CLABSI rate?	Yes. The initiative was "successful"; the authors state that their efforts, which featured the initiative, "resulted ... ultimately, in a decrease in the rate of CLABSI."[10]	Yes. This initiative "resulted in a reduction in (CLABSI) rates."	Yes. The data "strongly" suggest that switching from an open to a closed infusion container was the cause of "striking" reductions in CLABSI rates.	Yes. The initiative "resulted in" a reduction in the CLABSI rate.[11]	Yes. The initiative "significantly improved infection control adherence, reducing the CLABSI incidence."

[1]Based on their data and calculations, the authors estimate that their collaborative during a "12-month sustain period" prevented an estimated 198 CLABSIs, avoiding an associated cost of approximately $8,450,000.

[2]Performance feedback is defined herein as verbal communications among participating ICU staff members (during only the *post*-intervention period) about both the study's goal to reduce the CLABSI rate (e.g., by 50% or more) and the evaluated initiative's progress toward achieving this outcome. Refer to the main article.

[3]Compliance data are those that demonstrate that ICU staff members, first, adhered to all of the evaluated initiative's prescribed elements during the *post*-intervention period, and, second, adhered to none of these elements during the *pre*-intervention period. The establishment of a relationship between the initiative and a reduced CLABSI rate requires the collection of these compliance data; otherwise, assurances that the initiative was responsible for this outcome cannot be provided. Refer to main article.

[4]This study visually inspected the practices of ICU staff members during the *post*-intervention period and noted observed deviations, although the degree or percentage of staff compliance with the initiative's elements (possible range: 0% – 100%) was not reported.

[5]The authors acknowledge that their study did not collect data on *pre*-intervention process measure compliance, which, according to these authors, decreased the study's ability to measure the full impact of the initiative's bundles. Authors also acknowledge that there might have been variability in the measurement of process compliance across the collaborative's participating hospitals.

[6]The authors note that only open and closed infusion containers were used during the *pre*- and *post*-intervention periods, respectively, but whether audits were performed to confirm these claims (100% compliance with each respective type of container during the two studied periods) is unclear and was not reported.

[7]Data validation is defined as the process of auditing the participating patients' medical files and validating the CLABSI data (both numerator and denominator) used by the study during both the *pre*- and *post*-intervention periods. Refer to main article.

[8]The authors acknowledge that CLABSI data were incomplete, which could have affected the study's results.

[9]Each patient's case report was reviewed to confirm that every CLABSI during the *post*-intervention period was counted. But, like each of the others studies, this study's data are incomplete (e.g., the denominator during the *post*-intervention period was not reported to have been validated). Nor were any data provided confirming validation of the *pre*-intervention CLABSI data.

[10]The authors nevertheless acknowledge that "differences in unmeasured confounding variables between pre- and post-initiative patient populations could explain the observed results" and that "periodic fluctuations in (bloodstream infection) rates" could have contributed to the observed outcomes.

[11]The authors nevertheless aptly acknowledge that, due to the initiative's simplicity, it is "difficult to state with any degree of certainty that at (the intervention) was responsible for the observed reduction" in the CLABSI rate.

is determined by dividing the number of CLABSIs, which is the numerator, often by the number of central-line days, which is the denominator. The validity of the CLABSI rate requires the validity of *both* this numerator and denominator).

Table 3. Limitations and Circumscribing Qualities Shared by the Five Reviewed Studies (that may Also be Shared by Other Similar Types of Studies Evaluating the Effectiveness of a Quality-Improvement Initiative for the Prevention of CLABSIs)

1. *Study design:* Each of the five reviewed studies is of a prospective-cohort design that does not control, minimize or eliminate the effects of unrecognized biases and confounding factors.
2. *Causal relationships:* Although their designs limit their results to displaying associations, the five reviewed studies advance causal relationships between the evaluated initiative and a reduced CLABSI rate.
3. *Lack of data validation:* None of the five studies validated its CLABSI rates (i.e., the number of infections divided by the number of central-line days) for accuracy and completeness during the *pre*- and *post*-intervention periods.
4. *Feedback bias:* Three of the five reviewed studies feature performance feedback, which can introduce feedback bias and a second independent variable during the *post*-intervention period.
5. *Lack of compliance data:* One of the five reviewed studies did not provide any compliance data, which confirms that not every study assessing the effectiveness of an initiative for the prevention of CLABSIs necessarily monitors staff to confirm their complete adherence to all of the initiative's elements during the *post*-intervention period and to none of its elements during the *pre*-intervention, or baseline, period.

DISCUSSION

Based on this analysis's findings (Tables **2** and **3**), the cautious interpretation of a prospective-cohort study's quantitative determination of an evaluated initiative's effectiveness for the prevention of CLABSIs in ICUs is warranted. Further, the circumspective use of published CLABSI rates is advised (see: Table **1**) [3,4,9,15-19]. This analysis also yields some generalizations about studies evaluating the performance of such quality-improvement initiatives as those listed in Table **2** (at least about studies published specifically for the infection-control and epidemiology communities). Featuring similar aims and conclusions, each of the five is a prospective cohort study that is neither controlled nor randomized (instead, the studied patient populations are typically derived from small, targeted groups). Moreover, none of these studies validated its CLABSI rates for accuracy and completeness before and after the initiative's implementation. Although, therefore, being necessarily prone to the potentially complicating effects of unrecognized biases and confounding factors on its data, results and conclusions, each of these five studies, which is limited to displaying associations, nonetheless and similarly suggests that the evaluated initiative causally reduced the CLABSI rate by a calculated, marked and specific percentage, ranging from 30.3%-85% (Table **2**) [6-10]. This finding raises reasonable questions about each of these five studies' quantitative determination of the effectiveness of a quality-improvement initiative for the prevention of CLABSIs.

Similarly, this finding also has potentially significant implications to each of the many other uses of CLABSI data (Table **1**). Examples of the types of unrecognized biases and confounding factors that may be inadvertently introduced and adversely affect the results and conclusions of these five studies (and of other similar prospective cohort studies or, too, of retrospective trend analyses) are listed in Table **4**. They include: *sampling* bias, due to having not randomized the studied patient populations; *publication* bias, due to general concerns about publishing an unfavorable determination of the initiative's performance [15] or relatively high infection rates; and *measurement* bias [11], due to, among other factors, unrecognized changes in central-line care during the *post*-intervention period that favor a reduction in the CLABSI rate. Examples of such unrecognized changes in central-line care include the insertion of central lines by more skilled clinicians; more aggressive antibiotic therapy; and less aggressive surveillance (e.g., the reduced sensitivity of the methods used to detect, record, and report CLABSIs; or, the less rigorous application of the CDC's definition of a CLABSI)[3,4,7,19-21].

Prospective cohort study design: Studies evaluating the effectiveness of an initiative for the prevention of CLABSIs in adult ICUs, PICUs, or NICUs are generally not controlled (or blinded), and they typically do not randomize the studied patient populations (which is required to eliminate sampling, or selection, bias) (Table **4**). Instead, these studies are of a prospective-cohort design [6-14] (although these studies may also be retrospective trend analyses [1]) that is insufficiently robust not only to minimize the effects of these aforementioned biases, which are listed in Table **4**, but also to isolate the intertwined effects of the evaluated initiative from those of the aforementioned confounding factors, which are generally unrecognized and also listed in Table **4**. Although therefore limited to yielding associations, these studies, like the reviewed five, nevertheless routinely suggest that the evaluated initiative caused the calculated reduction in the CLABSI rate (Tables **2** and **3**). The advancement by these studies of this causal relationship, without assurances that no other independent variable had any effect on the study's finding and calculations, would seem, respectfully, to overstep the inherent constraints of their designs, warranting the caveat: *post hoc ergo propter hoc*. Indeed, none of the five reviewed studies can exclude the possibility, known as the *null hypothesis,* that the percent reduction in the CLABSI rate that each of these five studies calculated and published (Table **2**) was due, *not* to the evaluated initiative (to which each study ascribed and credited this result), but rather to one or more unrecognized (and unrelated) confounding factors (i.e., additional independent variables).

Performance feedback: In addition, studies evaluating the performance of a quality-improvement initiative for the prevention of CLABSIs routinely feature performance feedback (which, again, is verbal communications among participating ICU staff members about the initiative's progress) [6-8,10-14]. Although it may be clinically beneficial (indeed, it has been recommended to effect prompt improvements in central-line care) [8,10,22], performance feedback is manifestly associated with two potential "side effects" that are often under-appreciated and generally

Table 4. Biases and Confounding Variables that Might Cause: (A) the CLABSI Rate to be Under-Reported; (B) the Initiatives's Effectiveness to be Over-Exaggerated; and/or (C) a Reduced CLABSI Rate to be Misattributed to the Initiative [3,4]

1. *Measurement bias*, which may result from, among other factors, the employment of surveillance methods that lack the necessary sensitivity to detect, interpret, and report CLABSIs [20, 21, 27]. Such methods might "miss," or not count, a CLABSI due to, for example:
   - not culturing the blood samples of patients suspected of a CLABSI for all types of recognized pathogens, including fungi and both aerobic and anaerobic bacteria;
   - misinterpreting ambiguous definitions of CLABSIs [27];
   - using too low a blood volume for culturing [20]; and
   - misclassifying *primary* bloodstream infections associated with central lines, namely, *bona fide* CLABSIs, as false positives (e.g., a common skin contaminant such as coagulase-negative staphylococci) or as *secondary* infections attributed to another site [7, 15, 19, 20].
2. *Financial bias*, which may result from, for example, reimbursing or financially rewarding hospitals that report a reduced CLABSI rate (e.g., CMS's *pay-for-reporting* program) [4, 12, 14, 21]; or, from one or more potential financial conflicts of interest associated with a hospital reporting a reduced CLABSI rate [4, 16].
3. *Feedback bias*, resulting from clinicians and staff members being, not blinded, but instead provided with "feedback" about a study's intent and the success of their efforts to reduce CLABSI rates in ICUs [6, 7, 12, 14, 23, 25].
4. *Publication bias*, resulting from, for example, the tendency to report only favorable CLABSI data or to report or publish incomplete data [4, 6, 12, 25]. This type of bias may also be known as reporting bias [1, 3].
5. *Sampling bias*, resulting from treating in ICUs diverse patient populations that have not been randomized or adjusted for different risks of CLABSI (e.g., high-risk populations, varying birth weights in neonatal ICUs [6]).
6. *Confounding bias*, resulting from such factors as behavioral changes and [3, 4]:
   - the administration of antimicrobial therapy without having first obtained a blood culture to confirm a CLABSI (such therapy should be started, when possible, after a blood culture has confirmed infection);
   - the use of different medical supplies, such as catheter dressings or insertion-site antiseptics; or, the use of catheters impregnated with antimicrobial agents; and
   - other changes in infection-control techniques [23], including changes in the catheter's use [1]; use of more experienced physicians to insert and maintain central lines (as opposed to less skilled residents); or, changing catheter dressings more often.
7. *Confirmatory bias*, resulting from the inadvertent favoring of a specific outcome that is consistent with or confirms a study's hypothesis, such as a study's conclusion that an initiative was successful and reduced the CLABSI rate *without* the study's data having been validated or necessarily supporting this conclusion. Unless eliminated or controlled, confirmatory bias can cause a study to overlook or to ignore important factors that might invalidate or jeopardize its hypothesis [3].

incongruous with – in fact, they can compromise – a study's aim to determine the specific percentage by which an evaluated initiative might have reduced the CLABSI rate. First, performance feedback can be associated with unrecognized changes in central-line care (Table **4**) [23]. These changes, which are (of course) featured only during the study's *post*-intervention period, are confounding and necessarily introduce into the study's design another independent variable (in addition to the initiative's implementation) that can itself, independent of and unrelated to the initiative, reduce the CLABSI rate by an amount that these five studies (and others like them) cannot isolate or identify. Second, like discussions between clinicians and participants/patients during an "open-label" drug study that contravene the principle of "blinding," the types of dialogue between ICU staff members about the initiative's progress that define performance feedback may also be associated with a type of measurement bias known as "feedback bias" (Table **4**), which both is similar to a "placebo response" and favors reporting the initiative's success and a reduced CLABSI rate [10,19].

Nevertheless, three of the five reviewed studies, the designs of which cannot control, eliminate, or minimize the effects of unrecognized biases and confounding factors, feature performance feedback (Table **2**) [6,7,10], despite the potential impact that its two associated and aforementioned "side effects" can have (*not* on the patient's well-being and care but) on the validity of the study's determination of the calculated percentage by which an initiative might have reduced the CLABSI rate. In short, factors like performance feedback that are both confounding and associated with a bias (see: Table **4**) render studies, like the five reviewed studies, prone to under-reporting the actual CLABSI rate, to over-exaggerating the initiative's true effectiveness (and overstating its success) [10,19], and to misattributing to the studied initiative a significant percent reduction in the CLABSI rate that might have been caused instead, in part or in entirety, by performance feedback or an amalgam of other unrecognized confounding factors whose specific contribution to the outcome none of these five studies can isolate from the initiative's impact [10,12,14,15,19,23-25]. Therefore, although performance feedback may be clinically beneficial and introduced with intent to improve patient outcomes more promptly, its inclusion (not necessarily during a study's qualitative assessment of an initiative's success but) during a study's quantitative determination of an initiative's effectiveness for the prevention of CLABSIs in adult ICUs, PICUs, or NICUs warrants circumspection.

Compliance: Compliance data display whether ICU staff members adhered during a study both to all of the evaluated initiative's prescribed elements and bundles during the study's *post*-intervention period and, too, to none of these elements during its *pre*-intervention period (i.e., the baseline period, or the period before the initiative's implementation) [7-11,19-21]. One of the five reviewed studies provided no compliance data (Table **2**) [9], which indicates that, indeed, not every study evaluating a quality-improvement initiative for the prevention of CLABSIs, including studies published by the CDC [25], necessarily monitors or audits the practices of ICU staff members to confirm their complete adherence to every one of the studied initiative's prescribed elements [9,12,14,19] (the reasons for which have been reported to include limited resources) [14]. Moreover, whereas these types of studies may report some compliance data during the *post*-intervention period, rarely do any verify that none of the initiative's elements were practiced during the *pre*-intervention period. Without a study collecting, reporting and validating these compliance data, however, the study's advancement of an association, especially of a causal

relationship, between the studied initiative and a reduced CLABSI rate may be in questioned (even if all other aspects of the study were of unsurpassed rigor and quality), because the aforementioned null hypothesis is a possibility that cannot be ruled out [10,25].

Data validation: Studies that evaluate the effectiveness of an initiative for the prevention of CLABSIs ideally would have personnel independently confirm the validity of their CLABSI data, both before and after the initiative's implementation. Auditors, who would be both blinded from the study's specific goals and independent of its outcome (i.e., to avoid a measurement or confirmatory bias favoring a reduced CLABSI rate; see: Table **4**), would review the medical file of each of the study's participating patients with: (*i*) both a central line in place; and (*ii*) a positive blood culture. (Or, more feasibly, these auditors might instead review the files of a smaller, randomly selected, statistically significant sample of the participating patients). Based on the clinical data in these medical files, these auditors would independently assess each patient for a CLABSI, being also blinded to whether (or not) a clinician had previously determined and recorded the patient to have had a CLABSI. The validation of these data would confirm that during the study's *post*-intervention period: (*i*) every CLABSI (numerator) recorded in the patients' medical files was included in the study's calculations; (*ii*) all positive blood cultures meeting the CDC's definition of a "CLABSI" [7] were recorded as a CLABSI and similarly included in the study's calculations, with no *bona fide* CLABSIs being mistakenly misclassified or misattributed to an unrelated site or source (e.g., the skin) and therefore not counted; and (*iii*) the number of central-line days (denominator) used in the study's calculations was correct and not over-reported – any of these three of which would result in the study under-reporting the actual CLABSI rate and over-exaggerating the initiative's success and the percentage by which the initiative might have reduced the CLABSI rate.[2] Of equal importance, data validation would similarly confirm the accuracy and completeness (and the statistical soundness) of the CLABSI data during the study's *pre*-intervention period. (As previously noted, the CLABSI *rate* is determined by dividing the *number* of CLABSIs, which is the numerator, typically by the *number* of central-line days, which is the denominator.)

Displayed in Table **2**, none of the five studies validated the CLABSI rate before and after the initiative's implementation. Not only is this oversight surprising and a circumscribing quality that the five reviewed studies share, but a review of the medical literature indicates that the failure to validate CLABSI rates is also the rule, not the exception, and is a common feature of studies evaluating the effectiveness of a quality-improvement initiative for the prevention of CLABSIs [14]. While it does not by itself indicate that the study's paradigm is flawed or nullify the study's contribution to improving the management and quality of central-line care, a study's failure to validate its CLABSI data does, however, necessarily raise questions about the accuracy and completeness of the study's calculated CLABSI rates (Might the study's rates have under-reported the true incidence of infection?) and, therefore, about the study's assessment of the initiative's performance, which is based on these rates (Might the study's conclusions have over-exaggerated the initiative's true performance and success?) [16]. These are well-taken questions and concerns, because the public reporting of CLABSI data has been acknowledged to be "fraught with problems" [15] and may bias CLABSI rates "downward." [13] In fact, independent audits by state health departments have found published CLABSI rates to under-report the true incidence of infection [15-17], with one state's report (Connecticut's) finding that more than half of the CLABSIs among patients in several hospitals were "misclassified" and not counted (despite each of these hospitals having used the same definition of a CLABSI) [15].

Also consistent with this analysis of these five reviewed studies, a report by the U.S. General Accountability Office (GAO) similarly concluded that published infection data that have not been validated may be misleading, adding that the increasing use of these data to assess health care in the U.S. (see: Table **1**) may provide medical facilities with an incentive to under-report CLABSI rates [18]. According to another concurring report on initiatives to prevent HAIs, not only is the validation of infection data, including CLABSI rates, "essential" if these data are to be "credible," but also that mandatory reporting systems must consider a method of data validation, lest the reported HAI data be inaccurate and incomplete [16]. In some of its publications the CDC agrees, having acknowledged that CLABSI data that have not been validated lack quality and are prone to the effects of publication, or "reporting," [1,3] biases (Table **4**). Most notably, a review of the literature finds that the majority of all published CLABSI rates are self-reported and have not been validated [3,4,26]. This finding is consistent with this analysis's conclusions and review of these five studies (Table **2**), and it raises additional doubt, if not "serious concern," [18] about not only the credibility of the majority of published CLABSI rates, but also their use by (but not limited to) clinicians and researchers to evaluate and calculate the specific percentage by which an initiative might have reduced the CLABSI rate.

Concluding remarks: Most certainly, this analysis does not question the goals or commitment of these five reviewed studies. Their objectives, like their aims, are insightful, laudable, and impressive. Rather, this analysis, respectfully, advances an appreciation of the limitations imposed by a study's use of an uncontrolled (and not randomized) prospective cohort (or retrospective trend) design; of the importance of data validation; and of the distinction between a *qualitative assessment* and *quantitative determination* of an initiative's effectiveness. Indeed, incongruities, as well as an inadvertent mischaracterizations of an initiative's performance, can arise if the findings of a prospective cohort study, limited to yielding associations and qualitative assessments (e.g., "the initiative was effective and performed 'well'"), are used instead to advance a quantitative determination (e.g., "the initiative reduced the CLABSI rate by a calculated amount of more than 50%"), which is generally reserved for and derived from more rigorous and demanding study designs, such as randomized controlled studies. These

[2] When performed improperly or exercised with the intent to under-report the actual infection rate (due to, for example, publication biases; see: Table **4**), the subjective misattribution of a true CLABSI to an unrelated site or source has been referred to as "diagnostic tampering" and "gaming." [11].

concerns are especially well-taken if the prospective cohort study's conclusions are based on CLABSI data that have not been validated.

Table 5. Recommendations to Improve the Quality of Studies that Use CLABSI Data to Evaluate the Effectiveness of an Initiative

1. Use as rigorous a study design as possible; ideally, use a randomized, controlled study design that blinds clinicians and ICU staff members to the study's aim.
2. If the study is of a prospective-cohort (or retrospective-trend) design that cannot control, minimize or eliminate the effects of unrecognized biases and confounding factors, ensure that the study's conclusions are limited to associations and do not advance a causal relationship between the initiative and a reduced CLABSI rate.
3. Validate the CLABSI data, verifying for accuracy and completeness (and statistical soundness) the CLABSI rate's numerator (number of infections) and denominator (number of central-line days) during both the *pre*- (i.e., baseline) and *post*-intervention periods.
4. Reassess the importance of introducing performance feedback during a study's evaluation of an initiative's effectiveness. While such dialogue between participating ICU staff members may be appropriate to improve clinical outcomes or to feature during a study's qualitative assessment of an initiative's effectiveness, it can introduce both a measurement bias (feedback bias) and a confounding factor (a second independent variable) during the *post*-intervention period that may be incongruous with a study's quantitative determination of the specific percentage by which the initiative might have reduced the CLABSI rate.
5. Validate the compliance data, confirming that the practices of ICU staff members performed during the *post*-intervention period are in complete compliance with all of the initiative's elements (as well as ensuring that ICU staff members performed none of these elements during the study's *pre*-intervention period).

In closing, the clinical implications of the public reporting of CLABSI data being "fraught with problems"[15] and of published CLABSI rates, at times, lacking credibility and being prone to under-reporting the true incidence and risk of infection are not academic and may include: exaggerated depictions of an evaluated initiative's actual effectiveness, of the safety of ICUs, and of the quality of central-line care; a false sense of security and less vigilance; and reduced infection controls, thereby posing, paradoxically, an *increased* risk of patient infection, morbidity and mortality [3,4]. A number of recommendations, including the adoption of a circumspective approach to the study and assessment of an initiative's effectiveness for the prevention of CLABSIs in ICUs, PICUs and NICUs, are provided in Table **5**.[3] The possibility that the publication, use and advancement of inaccurate infection data might pose harm to patients underscores the importance of the validation of published CLABSI data and of the more cautious use and interpretations of CLABSI rates (Table **1**). Finally, other than having been published in the journal *Infection Control and Hospital Epidemiology* within the past two years, the five reviewed studies were otherwise randomly selected (refer to the *methodology section*, above). Therefore, the application of this article's analysis and findings to studies that are similar to these five reviewed studies in their aims, designs, and conclusions, whether published in this same medical journal or in another one, would seem valid.

[3] With respect for Voltaire's instruction, the study of CLABSIs can be improved without the best being incompatible with the good.

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CONFLICT OF INTEREST

Declared none.

REFERENCES:

[1] Srinivasan A, Wise M, Bell M, *et al*. Vital Signs: Central line-associated blood stream infections – United States, 2001, 2008, and 2009. MMWR Morb Mortal Wkly Rep 2011; 60:1-6.

[2] Centers for Disease Control and Prevention (CDC). First state-specific healthcare-associated infections summary data report. CDC's national healthcare safety network (NHSN). 2009;1-18.

[3] Muscarella LF. Review of a CDC Report about Healthcare-Associated Infections. The Q-Net Monthly 2011; 17(5-7): 9-14.

[4] Muscarella LF. Published Infection Rates: More Conjectural than Scientific? The Q-Net Monthly 2010; 16(10-12): 19-24.

[5] Centers for Disease Control and Prevention (CDC). Eliminating healthcare-associated infections. State Policy Options. March 2011 Association of State and Territorial Health Officials 2231 Crystal Drive, Suite 450, Arlington, VA 22202 202-371-9090.

[6] Bizzarro MJ, Sabo B, Noonan M, *et al*. A quality improvement initiative to reduce central line-associated bloodstream infections in a neonatal intensive care unit. Infect Control Hosp Epidemiol 2010; 31(3): 241-8.

[7] Jeffries HE, Mason W, Brewer M, *et al*. Prevention of central venous catheter-associated bloodstream infections in pediatric intensive care units: a performance improvement collaborative. Infect Control Hosp Epidemiol 2009; 30(7): 645-51.

[8] Maki DG, Rosenthal VD, Salomao R, *et al*. Impact of switching from an open to a closed infusion system on rates of central line-associated bloodstream infection: a meta-analysis of time-sequence cohort studies in 4 countries. Infect Control Hosp Epidemiol 2011; 32(1): 50-8.

[9] Parra AP, Menargues MC, Granda MJP, *et al*. A simple educational intervention to decrease incidence of central line-associated bloodstream infection (CLABSI) in intensive care units with low baseline incidence of CLABSI. Infect Control Hosp Epidemiol 2010; 31(9): 964-7.

[10] Rosenthal V, Maki D, Rodrigues C, *et al*. Impact of international nosocomial infection control consortium (INICC) strategy on central-line associated bloodstream infection rates in the intensive care units of 15 developing countries. Infect Control Hosp Epidemiol 2010; 31(12): 1264-72.

[11] Wheeler DS, Giaccone MJ, Hutchinson N, *et al*. A hospital-wide quality-improvement collaborative to reduce catheter-associated bloodstream infections. Pediatrics 2011; 128(4): 995-1007.

[12] Pronovost PJ, Goeschel CA, Colantuoni E, *et al*. Sustaining reductions in catheter related bloodstream infections in Michigan intensive care units: observational study. BMJ 2010; 340: 309

[13] Schulman J, Stricof R, Stevens TP, *et al*. Statewide NICU central-line-associated bloodstream infection rates decline after bundles and checklists. Pediatrics 2011; 127(3): 436-44.

[14] Pronovost P, Needham D, Berenholtz S, *et al*. An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med 2006; 355(26): 2725-32. Erratum in: N Engl J Med 2007; 356(25): 2660.

[15] Backman LA, Melchreit R, Rodriquez R. Validation of the surveillance and reporting of ventral line-associated bloodstream infection data to a state health department. Am J Infect Control 2010; 38: 832-8.

[16] Connecticut Department of Public Health. An act concerning hospital acquired infections. Status report on the healthcare association infections initiative. 2009;1-19.

[17] New York State Department of Health. New York State Hospital-Acquired Infection Reporting System: Pilot Year: 2007. Report to Hospitals - June 30, 2008.

[18] United States Government Accountability Office (GAO). Healthcare-associated infection in hospitals. An Overview of State Reporting Programs and Individual Hospital Initiatives to Reduce Certain Infections. 2008; 1-49.

[19] Jenny-Avital ER. Catheter-related bloodstream infections. N Engl J Med 2007; 356; 1267-8.

[20] Niedner MF, and the 2008 National Association of Children's Hospitals and Related Institutions Pediatric Intensive Care Unit Patient Care FOCUS Group. The harder you look, the more you find: Catheter-associated bloodstream infection surveillance variability. Am J Infect Control 2010; 38(8): 585-95.

[21] Lin MY, Hota B, Khan YM, *et al*. Quality of traditional surveillance for public reporting of nosocomial bloodstream infection rates. JAMA 2010; 304(18): 2035-41.

[22] McKibben L, Horan T, Tokars JI, *et al*. Guidance on public reporting of healthcare-associated infections: Recommendations of the healthcare infection control practices advisory committee. Am J Infect Control 2005; 33: 217-26.

[23] Warren DK, Zack JE, Mayfield JL, *et al*. The effect of an education program on the incidence of central venous catheter-associated bloodstream infection in a medical ICU. Chest 2004; 126: 1612-18.

[24] Passaretti CL, Barclay P, Pronovost P, *et al*. Public reporting of health care-associated infections (HAIs): approach to choosing HAI measures. Infect Control Hosp Epidemiol 2011; 32(8): 768-74.

[25] Muto C, Herbert C, Harrison E, *et al*. Reduction in central line-associated bloodstream infections among patients in intensive care units – Pennsylvania. MMWR 2005; 54: 1013-6.

[26] Muscarella LF. Avaialble at: www.mysndosite.com/articles/kitsapSun1210.pdf My Turn. Infection Rate Data: Science or Conjecture? The Kitsap Sun. December 12, 2010.

[27] Consumers Union. Deadly infections. Hospitals can lower the risk, but many fail to act. Consum Rep 2010. 16-21.

[28] Zingg W, Posfay-Barbe KM, Pfister RE, *et al*. Individualized catheter surveillance among neonates: a prospective, 8-year, single-center experience. Infect Control Hosp Epidemiol 2011; 32(1): 42-9.

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