The Cost of Catheter-related Bloodstream Infections: Implications for the Value of Prevention

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Catheter-related blood stream infections (CRBSI) are frequently observed in the intensive care unit and are a serious cause of morbidity and mortality in the U.S. This paper reviews the literature and summarizes what is currently known about the cost of CRBSI in the ICU to hospitals. In the general adult ICU the cost of CRBSI is between $33,000 and $44,000. In the adult surgical ICU the cost is between $54,000 and $75,000. In the pediatric ICU the cost of CRBSI is approximately $49,000. In the single multicenter study that pooled the ICU and general hospital wards, the cost of CRBSI was estimated to be $20,647. Finally, CRBSI is associated with reimbursement that is more than $26,000 less than costs. Hospital and clinical decision makers should be aware of the high cost of CRBSI in the ICU, the relatively poor reimbursement, and the implied high value of prevention efforts.

1 Background

There are approximately 500,000 cases of hospital-acquired bloodstream infections in the U.S. each year, which makes BSI an important cause of morbidity and mortality [1, 2]. The majority of serious BSIs are associated with central venous catheters [3, 4]. These catheter-related blood stream infections (CRBSI) are most frequently observed in the intensive care unit because of the high use of central venous catheters, but are also observed in other settings and other hospitalized populations [1, 3]. Strictly defined, CRBSI is a primary bloodstream infection in a patient with a central venous catheter, at least one positive blood culture from a peripheral vein, and at least one of the following [3]:

- Differential time period of central venous catheter culture versus peripheral blood culture positivity of more than two hours
- Simultaneous quantitative blood culture with a ≥5:1 ratio (central venous catheter versus peripheral)
- A positive semi-quantitative (>15 CFU/catheter segment) or quantitative (>10(3) CFU/catheter segment) culture with the same organism isolated from the catheter segment and peripheral blood.

Risk of CRBSI is determined by such factors as hospital size, hospital ward, and type of device [5, 6]. In U.S. hospitals, these infections occur at a rate of approximately 3 per 1000 line days [7]. Wisplinghoff et al. performed an analysis of the Surveillance and Control of Pathogens of Epidemiologic Importance (SCOPE) database and found that between 1995 and 2002, about half of CRBSI occurred in the ICU and intravascular devices were the most common risk factor [8]. There are also other patient specific risk factors, such as age, severity of underlying illness, malnutrition, poor skin integrity, and immunocompromization [4].

Relatively little is currently known about the excess costs and length of stay (LOS) associated with CRBSI in the US. There are some studies in the literature that provide estimates, but many come from other countries and therefore may not be generalizable to a US population, and many are small studies from single institutions. This paper will review the literature and summarize what is currently known about the cost of CRBSI to hospitals. Our primary emphasis will be on the ICU and we will review what is known about costs in the adult ICU, the adult surgical ICU, and the pediatric ICU. We will then briefly review the attributable cost of CRBSI in the non-ICU setting.

Studies reviewed here are summarized in Table 1. Most of these studies define cost as an excess attributable cost, which is the incremental cost that is directly related to the infection. Most of this cost comes from prolonged length of hospital stay and additional medication, but most studies do not

parse out the specific cost components. Also, most of the studies include direct costs and overhead, although this also varies from study to study. Studies also differ in other respects. Each study focused on a different population, used a different study design, and used different statistical methods. Each of these choices would have an impact on the estimated excess cost of case of CRBSI.

2 Adult ICU

Two U.S. studies report the cost of CRBSI among adults in the ICU. Digiovine et al. performed a retrospective pairwise matched cohort study. They matched 68 ICU patients with CRBSI to 68 ICU patients without. Matching was done on severity of disease, admission diagnosis, demographics, and other factors. They report an attributable cost of CRBSI of $34,508 in 1999 US dollars. This would be roughly $44,015 in current year (2009) dollars. Warren et al. performed a retrospective cohort study of 1,132 (medical and surgical) ICU patients at a community medical center (41 patients with CRBSI and 1,091 without). Because the patients were not matched, we used statistical models to control for patient severity and other characteristics. In the baseline analysis, the estimate of the attributable cost of CRBSI was $11,971 in year 2000 dollars. This would be roughly $14,767 in current year (2009) dollars.[1] As a sensitivity analysis, we also performed a propensity score matching analysis, which is akin to retrospective matching. This analysis estimated the attributable cost of CRBSI to be $26,241 in 2000 dollars, or approximately $32,370 in current year (2009) dollars.

The large difference between these two estimates is striking. There are some possible explanations for the difference. First, the Digionvine study was performed at a large academic medical center, while the Warren study was from a smaller community medical center. Second, both studies included patients from both the medical and the surgical ICU, but no data was provided in either study about the distribution of patients between them. If one study had a higher proportion of infections in, say, the surgical ICU, and costs were larger in the surgical ICU, then this may account for part of the difference. Finally, the statistical methods themselves might be partially responsible for the difference in cost estimates. Digiovine used a simple mean difference comparison combined with a Wilcoxon rank sum test for statistical inference. This was appropriate given the matching study design. But this approach would also lead to a very liberal estimate of attributable cost. Warren et al. used multivariate regression models that controlled for the skewness of the dependent variable. This approach would lead to a much more conservative estimate.

A third study by Shannon et al. used a very different methodology to estimate the attributable cost of CRBSI among patients in the medical and cardiac ICU [9]. They study a series of 54 patients with CRBSI (with no controls) and performed an activity-based review of resources used during each day of admission. The costs of resources used specifically to treat the CRBSI were parsed out. This approach led to an estimate of the attributable cost of CRBSI of $40,179. The dollars do not appear to have been normalized in this study to a specific year, but were collected between 2002 and 2005. If we assume costs were reported in 2005 dollars, the attributable costs would be $43,770 in 2009 dollars. This estimate is remarkably consistent with the other reported estimates, particularly given the very different cost estimation methodology.

These three studies suggest that the attributable cost of CRBSI in the adult ICU is between $33,000 and $44,000 in 2009 dollars.

3 Surgical ICU

In what appears to be the first study of the cost of CRBSI in the surgical ICU, Pittet et al. performed a pairwise matched case-control study at a large academic medical center [5]. They matched 86 surgical ICU patients who developed CRBSI with 86 surgical ICU patients who did not. Matching was done on severity of disease and other factors. They did not use any sophisticated statistical model but simply compared the mean difference in cost between the two groups. While not wrong, this method is expected to provide a more liberal estimate of attributable cost. The excess cost of CRBSI was estimated to be $33,268 in 1990 dollars. In

[1] Adjustments to current year dollars use the consumer price index (CPI) for all urban wage earners and not the medical care component of the CPI only.

current year dollars this would be nearly $53,919

Dimick et al. also studied the cost of CRBSI in the surgical ICU at a large urban academic medical center. Their data came from an earlier clinical trial comparing fluconazole to placebo for prevention of fungal infection in critically ill surgical patients. They had 260 total patients (130 who received fluconazole and 130 who received placebo). They fit these data to a regression model of (log) total costs, controlling for age and patient severity. This yielded an estimate of the attributable cost of CRBSI of $56,167 in 1998 dollars. In current year dollars this would be $74,886.

The attributable cost of CRBSI in the surgical ICU is between $54,000 and $75,000 in current year dollars.

4 Pediatric ICU

Only one paper reports attributable cost of CRBSI among children in the ICU. Elward et al. studied a prospective cohort of children at an urban academic medical center. Of 911 patients admitted to the ICU between September 1999, and May 2000, 57 developed a CRBSI. The Elward study was unique in that it focused on estimating the attributable direct costs of CRBSI, that is, only those extra costs that went for direct care of the patients. Similar to Warren et al., Elward used a linear regression approach that not only controlled for patient severity of illness and other characteristics, but also the skewness of the dependent variable [6]. Our results gave an estimate of the attributable cost of CRBSI among children in the ICU of $39,219 in year 2000 dollars. In current year dollars this would be $48,379.

While this estimate seems large compared to the other settings, it is actually a very conservative estimate. First, it includes only direct costs, which are much lower than fully loaded operating costs, which are usually what is reported in the literature. Fully loaded costs include indirect costs—costs for items and services that are not used directly in the care of the patient (e.g. laundry and janitorial services)—and also overhead costs. Second, the statistical model, which transforms the dependent variable to reign in large outliers, and also controls for a host of patient and disease characteristics, tends to produce smaller estimates since it is better able to parse out cost of care into constituent components.

The costs of CRBSI among children in the ICU is approaching $49,000 in current year dollars.

5 Multicenter Studies

There is one multicenter study of the cost of CRBSI. Kilgore et al. used an enormous database from Cardinal/MedMined that included 1,355,647 admissions and 12,578 BSIs from 54 different hospitals. All patients were admitted between March 2001 and January 2006. To control for confounding from different hospital, patient, and disease characteristics, they used a sophisticated absorbing regression model. Although several estimates are presented, the estimate of the attributable cost of CRBSI that is most similar to the others reviewed here is $19,427 in year 2006 dollars. This would be approximately $20,647 in 2009 dollars.

While this estimate is somewhat lower than other estimates, there are key differences between this study and others reviewed here. First, the measure of bloodstream infection is not limited to those that are catheter-related. Second, the bloodstream infections are not limited to the ICU. This is not a limitation per se, since not all CRBSI occurs in the ICU. However, the majority do, and most studies focus on populations to the ICU. Finally, the measure of CRBSI is an electronic measure that, while it has a high sensitivity and specificity for CRBSI, is not a perfect measure. Still, this is an important paper because of the very large sample size, the inclusion of multiple hospitals, and the rigorous statistical models used.

6 Reimbursement Issues

The conclusion that must be reached thus far is that CRBSI is costly to providers. Enormous amounts of resources are required to treat patients who develop this infection. This fact by itself, however, does not provide a strong incentive to invest in preventing them. Decisions about investment in prevention must be made knowing both costs and reimbursement. If reimbursement for CRBSI more than covers the additional costs then this reduces the financial incentive to prevent them.

Very little is known about relative reimbursement for CRBSI. The Centers for Medicare and Medicaid Services (CMS) estimates that it currently reimburses providers $103,027 per case [10]. But CMS also ruled that it would no longer pay beyond the prospective DRG patient for admissions

with a CRBSI, which means that average reimbursement for CRBSI started going down 2009.

A study by Shannon et al. provides the only known estimates of relative reimbursement for CRBSI that presents both average costs and average reimbursement. Shannon et al. found that payments for patients with CRBSI were, on average, much lower than costs. Their hospital lost on average $26,839 on each case of CRBSI. Across the entire sample of 54 patients, this represented a loss of $1,449,306. This suggests that for this hospital there is a strong financial incentive to prevent CRBSI.

7 Discussion

This paper has reviewed the literature on the cost of CRBSI in the ICU setting. We have covered studies that have focused on the cost of CRBSI in the general adult ICU setting, the adult surgical ICU setting, and the pediatric ICU setting. We also described work done in a large multicenter study of patients at 54 hospitals, presumable treated both in the ICU and in the general wards. Cost estimates are remarkably consistent across studies and across settings. In the general adult ICU the cost of CRBSI is between $33,000 and $44,000.[2] In the adult surgical ICU the cost is between $54,000 and $75,000. In the pediatric ICU the cost of CRBSI is approximately $49,000. In the single multicenter study that pooled the ICU and general hospital wards, the cost of CRBSI was estimated to be $20,647.

This literature review is not comprehensive; there are many other studies that focus on other populations, such as patients on dialysis. There are also many other excellent studies that were performed in countries other than the U.S. These were excluded not for any weakness in study design, but only because of the additional complexity of translating currencies and the fact that practice patterns in many European countries differ substantially from those of the U.S.

Clinical decision makers should be aware of the high cost of CRBSI in the ICU. They should also be aware that in addition to being costly, CRBSI has been reported to be associated with reimbursement that is substantially lower than expected costs. The good news is that there are methods for prevention of CRBSI that are available and are likely to be cost-effective given the stylized facts about costs and reimbursement reported here.

[2] In current year (2009) dollars.

Authors	N	Population	Design	Setting	Year	Cost	Reference
Digionvine et al.	Cases = 30; Controls = 30	Critically ill adults	Retrospective pairwise matched cohort study	ICU	1999	$34,508	[11]
Warren et al.	N=1,132	Critically ill adults	Prospective cohort study	ICU	2000	$11,971	[6]
Shannon et al.	N=54	Critically ill adults	Cohort series	ICU	2006	$40,179	[9]
Dimick et al.	N=260	Critically ill surgical patients	Prospective cohort study	Surgical ICU	1998	$56,167	[12]
Pittet et al.	Cases = 86; Controls = 86	Critically ill surgical patients	Pairwise matched case-control study	Surgical ICU	1990	$40,000	[5]
Elward et al.	Cases = 57; Controls = 30	Critically ill children	Prospective cohort study	Pediatric ICU	2000	$39,219	[13]
Kilgore et al.	N=1,355,647	Hospitalized adults	Retrospective cohort	Multiple centers	2006	$12,774	[14]

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