

American Journal of Medical Quality

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American Journal of Medical Quality 2006; 21; 7S
DOI: 10.1177/1062860606294631

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Economics of Central Line–Associated Bloodstream Infections

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Hospital-acquired infections add considerable morbidity and mortality to patient care. However, a detailed economic analysis of these infections on an individual case basis has been lacking. The authors examined both the hospital revenues and expenses in 54 cases of patients with central line–associated bloodstream infections (CLABs) over 3 years in 2 intensive care units and compared these financial data with patients who were matched for age, severity of illness on admission, and principal diagnosis. The average payment for a case complicated by CLAB was \$64 894, and the average expense was \$91 733 with gross margin of –\$26 839 per case and a total loss from operations of \$1 449 306 in the 54 cases. The costs of CLABs and the associated complications averaged 43% of the total cost of care. The elimination of these preventable infections constitutes not only an opportunity to improve patient outcomes but also a significant financial opportunity. (Am J Med Qual 2006; 21[suppl]:7S-16S)

Keywords: central line–associated bloodstream infections; hospital-acquired infections; hospital economics; payment methodologies

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American Journal of Medical Quality
Supplement to Vol. 21, No. 6, Nov/Dec 2006
DOI:10.1177/1062860606294631
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Increasing evidence suggests that central line–associated bloodstream infections (CLABs) are a common, morbid, and mortal form of hospital-acquired infections (HAIs).¹⁻⁶ The incidence and prevalence of these infections are largely unchanged despite nearly 3 decades of reporting and guidelines. Recently, regional collaboratives⁷⁻¹⁰ have reported reductions in the rates of this class of HAIs, yet considerable controversy remains as to whether these conditions are inevitable consequences of complex care^{11,12} or evidence of unreliable processes in care delivery.¹³ Several recent examples suggest that CLABs are preventable in intensive care units (ICUs) with the implementation of work standardization^{8,10} and/or strict adherence to established guidelines.^{11,12} Nonetheless, 5 years after the publication of the Institute of Medicine report calling attention to the issue of unsafe conditions in the health care system,¹⁴ progress in the elimination of harm in health care has been slow. Recently, within the quality community itself, the issue of safety in health care has been challenged as an epiphenomenon and sensationalism,¹⁵ correctable only if available evidence-based approaches are applied.

In the manufacturing industry, it is axiomatic that high quality is associated with lower costs, but the business case for such an assertion is lacking in health care. A tacit but potentially significant barrier to the eradication of HAIs in general, and CLABs in particular, rests in the complexities of the reimbursement system. There is a widespread but unsubstantiated belief that CLABs contribute to complexity of care, resulting in increases in the case mix index and increases in outlier payments. This is a product of a reimbursement system that pays for activity as opposed to outcome, such that factors that contribute to increased acuity, including

complications, result in coding modifications that increase payments to hospitals. There is evidence that patients who develop CLABs have higher costs, although these estimates arise from administrative billing data as opposed to clinical evaluation. There are little published data concerning the individual payments to hospitals in cases complicated by CLABs. Whether and to what extent CLABs contribute to the operating margins of hospitals is unappreciated. Moreover, the contribution of CLABs to the overall costs of hospital stays is highly variable depending on when in the course of care the infection occurs and complications that ensue. There are no diagnosis-related groups (DRGs) that identify CLABs; precise analyses of the operating margins in cases of CLABs are not readily available to hospital management teams. As a consequence, a detailed analysis of the contribution of CLABs to the costs of care and the impact on the operating margins of hospitals is lacking.

Accordingly, we examined the actual payments and expenses in clinical cases of patients whose care was complicated by a CLAB in 2 medical ICUs at Allegheny General Hospital during a 3-year period. These ICUs were actively engaged in the process of eliminating CLABs through the application of industrial systems redesign to care delivery during the past 3 years.¹⁰ As such, the economic analysis was important to consider in understanding the impact of care improvements not only on patient outcomes but also on the hospital margin. Do hospitals make money on cases complicated by CLABs? What is the economic impact on a hospital of eliminating unsafe conditions such as CLABs?

METHODS

The economic analysis was based on 54 CLABs confirmed in the medical intensive care unit (MICU) and coronary care unit (CCU) at Allegheny General Hospital between July 2002 and June 2005. The MICU and CCU are 28 contiguous beds under the direction of the Department of Medicine.

Since July 2003, the Department of Medicine has been engaged in the elimination of CLABs through the application of the principals of Perfecting Patient Care in collaboration with the Pittsburgh Regional Healthcare Initiative. The details of the process and the results on the rates of CLABs have been reported previously.^{9,10}

Calculation of the Net Operating Margins for Patients Whose Care Was Complicated by CLABs

There were 54 total CLABs in the MICU and CCU over a 3-year period of study (July 2002-June 2005). Clinical and financial data were available on all cases. The hospital revenues included in the model were the actual payments received by the hospital for care rendered as recorded in the Trendstar system and not accrued payments based on contractual allowances. The use of actual payment data also obviated the need to consider contracts and outlier payments and simply reflected what the hospital received in reimbursement. The period under consideration (2002-2005) ensured that all payments included any appeals and adjustments; all accounts were considered closed.

The hospital expenses were identified through the Financial Resources System of Allegheny General Hospital and were based on activity-based cost reports as opposed to estimates based on percentage of charges. The expenses entered into the model were the total direct costs, fixed (eg, ICU days) and variable (eg, costs of antibiotics, laboratory and radiological studies, diagnostic and therapeutic procedures). Labor costs for nursing care were included in the costs for an ICU day. Labor costs for other health care workers, such as respiratory therapists, were included in the daily costs of ventilator care. The hospital costs for procedures (ie, dialysis, endoscopy, radiological procedure, surgical procedures) included the labor costs for hospital personnel but not professional fees for physicians. Indirect costs (ie, debt service, corporate overhead) were not considered. The net hospital operating margin was calculated as the sum of the difference between payments and expenses for each individual case complicated by a CLAB. The average hospital revenues, expenses, and net operating margins were calculated as the mean of the 54 individual cases.

Calculation of the Costs of Care Attributable to the CLAB

A team composed of a clinician (B.P.) and financial personnel examined the daily clinical care and the daily cost reports to determine how much of the total cost of care was attributable to the CLAB or complications related to the CLAB. For example, the additional hospital days, antibiotics, and blood tests,

as well as complications attributable to the CLAB (eg, exploratory laparotomy, hemodialysis), were considered CLAB related. The activity-based costs of those procedures were assigned by the financial personnel. To verify that a specific cost was CLAB related, the assignment based on clinical care was reviewed by 2 other clinicians (Y.L., R.P.S.). The cost was attributable to the CLAB only if all 3 clinicians agreed that it would not likely have been part of usual care. For example, if the patient was not intubated before the CLAB but required ventilator support because of hypotension and acidemia that occurred following the CLAB, it was considered CLAB related. If the patient had normal renal function before the CLAB but developed renal failure in association with hypotension that occurred in proximity to the line-related bacteremia, it was considered CLAB related. The assigned costs were confirmed by a member of the finance team who assisted in the creation of the financial model. The reliability of the clinical assignment by the first reviewer was 84%, indicating that, on average, 16% of the costs considered to be CLAB related by the first clinician reviewing the case were not confirmed by subsequent review by the 2 other clinicians (Y.L., R.P.S.). Most of the differences were based on the assignment of the number of additional ICU days attributable to the CLAB or its complications rather than whether a complication and its treatment were CLAB related.

Comparison of Revenues, Expenses, and Net Operating Margins in Cases With and Without a CLAB

A nested case-control design was used in a subset of cases ($n = 5$) to establish a comparative group with the same age, admitting diagnosis, comprehensive clinical admission severity group (CC-ASG) score (Cardinal Health Inc, Marlborough, Mass), and payer (commercial, Medicare, Medicaid). The CC-ASG score is a validated risk adjustment methodology indicative of the severity of illness based on clinical conditions documented in the first 48 hours. The 5 cases were selected to determine the effects of 5 different payment methodologies on the respective financial outcomes. In addition, the examples highlighted differences in hospital economics based on whether case rates or per diem payment methodologies were employed. All comparative cases were drawn from the same fiscal

year to minimize the effects of changing payment contracts. It should be noted that in some cases, the principal diagnosis on which the payment was made differed from the admission diagnosis. This often occurred in patients who had multiple or serious complications from their CLABs. In these circumstances, the controls were matched to the patients with CLABs for both admission diagnosis and principal diagnosis. Similarly, when patients had multiple complications in addition to or as a consequence of the CLABs, attempts were made to compare them to similar cases with the same admission and principal diagnosis.

RESULTS

The average age of the 54 patients whose care was complicated by a CLAB was 56 years (range, 21-85), and 47% were male. The average length of stay was 34 days (range, 7-137 days). Twelve of the 54 patients (23%) suffered more than 1 CLAB. Notably, 22 patients died in the hospital (41% mortality) while only 9 (17%) were discharged to home. Interestingly, the most common principal diagnoses were acute myocardial infarction (AMI; $n = 9$), congestive heart failure ($n = 7$), respiratory failure ($n = 4$), and deep venous thrombosis ($n = 4$), diagnoses not commonly considered as risk factors for CLABs. Overall, 26 different principal diagnoses were represented among the 54 patients who developed a CLAB. The distribution of CC-ASG was random (ie, 17% grade 0-1, 24% grade 2, 39% grade 3, and 20% grade 4), indicating that severity of illness at the time of admission did not predict who was at risk for developing a CLAB. **Thus, neither age, severity of illness, nor principal diagnosis appeared to constitute risks for a CLAB, suggesting that process defects rather than clinical illness were more important predictors.**

Over the course of the study period, there was a dramatic shift in the types of line infections, reflecting process improvement and work redesign.^{9,10} In the first year, there were 49 infections in 37 patients; of these, 26 infections (53%) were related to femoral lines. In the next 2 years ($n = 17$), 2 (12%) were related to femoral lines and 5 (29%) were related to peripherally inserted central catheter (PICC) lines. In fact, PICC line use in the 2 ICUs more than doubled in the 3-year period from 212 lines per year to 478 lines per year. There was also a dramatic reduction in the rates of CLABs from

Table 1
Costs Directly Attributable to Central Line Infections and Associated Complications

	Case 1, Pancreatitis	Case 2, Gastroplasty	Case 3, CHF	Case 4, CHF	Case 5, Respiratory Failure
CC-ASG	1	2	3	3	4
Total charges, \$	828 847	359 315	98 717	69 850	112 265
Total expenses, \$	241 844	117 626	30 786	21 828	37 075
Total LOS, d	86	48	16	15	15
Hospital day on which CLAB occurred	6	22	3	6	9
Expenses before CLAB, \$	12 463	53 048	5052	9611	20 437
Expenses after CLAB, \$	229 381	64 579	25 734	12 217	16 638
Total expenses attributable to CLAB, \$	170 565	41 009	22 001	9419	13 520
% Total expenses attributable to CLAB	71	35	72	43	37

CHF = congestive heart failure; CC-ASG = comprehensive clinical admission severity group, severity of illness present on admission; LOS = length of stay; CLAB = central line-associated bloodstream infection.

10.5/1000 line-days in fiscal year 03 to 1.6/1000 line-days in fiscal year 05. These results have been detailed previously.¹⁰

The actual payments and expenses in the cases complicated by a CLAB varied widely, consistent with the random distribution of principal diagnoses and the severity of illness. The average payment was \$64 894 (range, \$4546-\$299 318), and the average expense was \$91 733 (range, \$15 565-\$353 205) with an average gross margin of -\$26 839 (range, +\$5145 to -\$265 426) and a total loss from operations of \$1 449 306. Most important, there were only 4 cases (7.4%) in which the gross margin was positive when clinical care was complicated by a CLAB. The cases included 2 AMIs, 1 case of chronic obstructive pulmonary disease, and 1 case of deep venous thrombosis. In each of these 4 cases, there were no end organ complications resulting from the CLAB, and the average length of stay was only 8 days.

Hospital payments are known to vary by insurer and principal diagnoses. Most patients were insured through Medicare (43%), 22% were insured commercially, and 22% were insured through Medicaid programs, including Medicaid managed care. In 14%, the payment was made by another party or by the patients themselves. For comparable principal diagnoses, payments varied more by length of stay than by payer. For example, in the case of a principal diagnosis of AMI complicated by a CLAB, the payment from a commercial payer was \$24 805 for 16 days; the payment for Medicare with a commercial secondary payer was \$27 238 for a 14-day hospital stay. The average loss from operations was -\$15 194 and -\$13 499, respectively. For a patient

with a principal diagnosis of AMI covered under Medicaid whose care was complicated by a CLAB, the payment was \$54 597 for a 30-day hospitalization with a loss from operations of -\$11 217. Thus, the payments were comparable across 3 different payers for the same principal diagnosis complicated by a CLAB and were influenced to a greater extent by length of stay than payment methodology. The increased payments that accompanied care complicated by CLABs and associated hospital losses were observed with all payers examined.

The Attributable Costs of a CLAB

To determine the contribution that CLABs and related complications made to the total cost of care, we conducted an analysis of the daily clinical activity and the attributable costs before and after the CLAB. The actual costs attributable to the CLAB and its complications averaged 43.8% (range, 21%-71%; average attributable: \$40 179) of the total expenses (Table 1). The following are case illustrations of the economic impact of CLABs when compared to cases in the same period matched for payer, age, CC-ASG, and principal DRG but not complicated by a CLAB.

Patient 1: Acute Pancreatitis

A 37-year-old video programmer was admitted with acute pancreatitis secondary to hypertriglyceridemia. On presentation to the emergency room, his blood pressure was 90/60 mm Hg, and a femoral venous catheter was placed for volume resuscitation.

Table 2

Comparison of Hospital Economics in Patient 1: Pancreatitis Complicated by a CLAB

	n = 2	n = 2	n = 2	Patient 1
Admission diagnosis	Pancreatitis	Pancreatitis	Pancreatitis	Pancreatitis
CC-ASG	1	1.8	1.5	1
Age, y	30-40	41-50	27-37	37
Principal diagnosis	Pancreatitis	Pancreatitis with surgical complications	Tracheostomy following pancreatitis	Tracheostomy following pancreatitis + CLAB
Payer	Commercial	Commercial	Commercial	Commercial
Revenue, \$	5907	99 214	125 576	200 031
Expense, \$	5788	58 905	98 094	241 844
Gross margin, \$	+119	+40 309	+27 482	-41 813
Costs attributable to CLAB, \$				170 565
LOS, d	4	38	41	86

CLAB = central line-associated bloodstream infection; CC-ASG = comprehensive clinical admission severity group, severity of illness present on admission; LOS = length of stay.

On day 5, he developed fever (39.4°C), progressive hypotension, and respiratory failure and was transferred to the MICU where he was intubated and supported with mechanical ventilation. On day 6, the 3 sets of blood cultures drawn on day 5 were positive for methacillin-resistant *Staphylococcus aureus* (MRSA). The same organism (>25 colony-forming units [CFU]) was cultured from the tip of the femoral line placed on admission.

He was persistently hypotensive, requiring 2 to 3 different pressor agents, and developed renal failure requiring dialysis on day 13. He developed multiple intra-abdominal abscesses with MRSA requiring 3 laproscopic surgical procedures to drain the infected abscesses. Because of his persistent hypotension and bacteremia, he was unable to be weaned from the ventilator, and on day 19, he underwent tracheostomy. He was discharged on day 86 to an acute long-term care facility. He was insured by a large commercial payer.

Table 1 illustrates the breakdown of hospital costs for this patient. The total cost of care was \$241 844; \$12 463 in costs occurred prior to the development of the CLAB, and \$229 381 were incurred after the CLAB. The total cost attributable to the CLAB or its attendant complications was \$170 565.

Table 2 illustrates the payments and the gross margins associated with this patient. The total payment was \$200 031, and the gross margin represented a loss from operations of -\$41 813. Most of the additional costs attributable to the CLAB and its complications were due to increased ICU stay. To determine the range of payments and operating margins in patients with an admitting diagnosis of

pancreatitis, we identified additional patients in the same fiscal year who were within 10 years of age of the patient with the CLAB, had comparable CC-ASG scores, and were insured similarly. In these uncomplicated patients (n = 3), the average payment for pancreatitis was \$5907, with a gross margin of +\$119 and an average length of stay of 4 days. We also compared our patient with 3 other cases of patients with pancreatitis on admission but who were billed under a principal diagnosis of acute pancreatitis with surgical complications. We performed this comparison because our patient required several surgical procedures that may have influenced both payments and expenses. The average payment in control cases of pancreatitis requiring surgery was \$99 214, and the average operating margin was +\$40 309. Notably, these patients typically had pancreatic pseudocysts or ductal obstruction requiring complex surgical procedures as opposed to intra-abdominal abscesses, which may explain the significant increase in payments. Each of the control cases of pancreatitis with surgery also had at least 1 complication such as renal failure, similar to our patient, but not an HAI. We also identified 2 cases in the same fiscal year in which acute pancreatitis was complicated by respiratory failure and subsequent requirement for tracheostomy, resulting in the reimbursement being based on a principal diagnosis of tracheostomy. In these cases, the average payment was \$125 576, with a positive operating margin of +\$27 482. Nonetheless, in our patient with a principal diagnosis of tracheostomy, the addition of a CLAB to already complex care resulted in a substantial loss from operations of -\$41 813, as compared

Table 3
Comparison of Hospital Economics in Patient 2: Obesity Surgery Complicated by CLAB

	n = 5	n = 3	Patient 2
Admission diagnosis	Obesity surgery	Obesity surgery	Obesity surgery
CC-ASG	2	2.2	2
Age, y	42	52	49
Principal diagnosis	Surgical procedure for obesity	Tracheostomy following obesity surgery	Tracheostomy following obesity surgery + CLAB
Payer	Medicaid	Medicaid	Medicaid
Revenue, \$	18 023	153 566	101 521
Expense, \$	12 100	148 969	117 626
Gross margin, \$	+5923	+6597	-16 105
Costs attributable to CLAB, \$			41 009
LOS, d	6	51	47

CLAB = central line-associated bloodstream infection; CC-ASG = comprehensive clinical admission severity group, severity of illness present on admission; LOS = length of stay.

to these other examples of complex care uncomplicated by a CLAB in which positive margins ranged from +\$27 482 to +\$40 308. These variances occurred despite comparable ages, severity of illness on admission, principal diagnosis, and payer.

Patient 2: Elective Surgical Gastroplasty

A 49-year-old African American woman was admitted for elective surgical gastroplasty. She had a history of obstructive sleep apnea treated with continuous positive airway pressure at night. Her surgical procedure was uncomplicated, but she developed hypercarbic respiratory failure postoperatively and was reintubated on the second postoperative day. On day 22 of her hospital stay, she developed fever (38.9°C), had persistent leukocytosis, and had purulent drainage from a right femoral venous catheter that had been in place for 16 days. Blood cultures were positive for coagulase-negative staphylococcus, *Enterococcus faecalis*, and a *Candida* species. All 3 organisms were also cultured for the line tip. She required tracheostomy because of persistent requirements for mechanical ventilation and was discharged to an acute long-term care facility on hospital day 48. The patient was insured through Medicaid managed care.

Table 1 illustrates the breakdown of hospital costs and the relationship to the CLAB. The total cost of care was \$117 626, of which \$41 009 was attributable to the CLAB and the associated additional length of stay.

Table 3 outlines the payments and operating margin in the case under review and compares these

data with similar cases studied during the same fiscal year. In this particular case, the payments received by the hospital were \$101 521, and the operating margin included losses of -\$16 105. To compare this financial outcome to other cases of elective surgical gastroplasty unassociated with a CLAB, we identified 5 additional cases with the principal diagnosis of obesity surgery matched for payer, age, and CC-ASG score. In contrast to what was observed in our case of surgical gastroplasty complicated by a CLAB, the average revenues for uncomplicated cases were \$18 023, and the gross margin included operating margin gains of +\$5923, with an average length of stay of 6 days. When we compared the revenues and gross margin in our case complicated by a CLAB to other cases of surgical gastroplasty with a principal diagnosis of tracheostomy, we observed average revenues of \$153 566 and an operating margin gain of +\$6597, with an average length of stay of 51 days. Thus, in circumstances in which there was the desired outcome and even in the case in which there were postoperative complications requiring tracheostomy, there were significant positive financial gains. However, when this elective surgical procedure was further complicated by a CLAB, the case was associated with significant losses.

Patients 3 and 4: Congestive Heart Failure

A 66-year-old woman with a history of ischemic cardiomyopathy was transferred from an outlying hospital with respiratory failure secondary to pulmonary edema. On admission, she had a right radial artery line placed and an introducer placed

in the right internal jugular vein. On the second hospital day, a pulmonary artery catheter was passed through the right internal jugular introducer for measurement of cardiac filling pressures. On day 3, she developed fever and hypotension, and 3 sets of blood cultures (ie, 2 peripheral and 1 drawn through the pulmonary artery [PA] catheter) were positive for methacillin-sensitive *S aureus*. On day 4, the PA catheter was removed, and the tip subsequently grew the same organism (>25 CFU). She was subsequently extubated, but a cardiac echo on day 9 revealed a tricuspid valve vegetation not noted on a similar study performed on admission. She was discharged to a skilled nursing facility on day 16 to complete a 6-week course of antibiotics. The insurance was Medicare fee for service (FFS).

Table 1 illustrates the total costs of hospital care and the component attributable to the CLAB. The total cost of care was \$30 786, of which 72% (or \$22 011) was attributable to the CLAB, its complications, and additional length of stay (11 days).

Congestive heart failure is a common diagnosis. We also examined the economics under circumstances of a different payer methodology, namely, Medicare managed care.

A 78-year-old man (patient 4) was transferred from an outlying hospital with decompensated congestive heart failure in the setting of an extensive history of ischemic cardiomyopathy. A right femoral catheter and left radial arterial line were placed at the outside hospital prior to transfer. On hospital day 6, the man developed fever and hypotension associated with metabolic acidosis. Blood cultures were drawn and were positive for methacillin-sensitive *S aureus*. The femoral venous catheter tip was positive for the same organisms (>25 CFU). The patient experienced nonoliguric renal failure but recovered without requiring dialysis. On day 15, the patient was transferred to a skilled nursing facility. The insurance was a Medicare managed care product that paid based on per diem rates.

Table 1 delineates the total cost of hospital care and the component attributable to the CLAB. The total cost of care was \$21 828, of which \$9419 (43.2%) was attributable to the CLAB, its complications, and increased length of stay (+10 days).

Table 4 compares the gross margin in the 2 cases of congestive heart failure complicated by a CLAB, based on the 2 different payment methods. In patient 3, the insurance carrier was Medicare FFS using a case rate payment methodology. The payments were

Table 4

Comparison of Hospital Economics in Patients 3 and 4: Heart Failure Complicated by CLAB

	n = 30	Patient 3	Patient 4
Admitting diagnosis	CHF	CHF	CHF
CC-ASG	2.8	3	3
Age, y	75	69	78
Principal diagnosis	CHF	CHF	CHF
Payer	Medicare FFS	Medicare FFS	Medicare managed care
Revenue, \$	5740	5595	20 250
Expense, \$	5683	30 786	21 828
Gross margin, \$	+57	-25 191	-1578
Costs attributable to CLAB, \$	—	22 011	9419
LOS, d	5	16	15

CLAB = central line-associated bloodstream infection; CHF = congestive heart failure; CC-ASG = comprehensive clinical admission severity group, severity of illness present on admission; FFS = fee for service; LOS = length of stay.

\$5595, and the loss from operations was -\$25 191. In case 4, the patient was part of a Medicare managed care product that employed a per diem payment methodology. In this case, the payments were higher, at \$20 250, while the loss from operations was -\$1578. By comparison, we found 30 cases with the principal diagnosis of congestive heart failure that were similar in age, CC-ASG score, and payment methods (Medicare FFS) in which the average payment was \$5740 and the operating gain was +\$57. Thus, when congestive heart failure was complicated by a CLAB, hospital operating losses varied widely from -\$1578 to -\$25 191, depending on the payment methodologies.

Patient 5: Acute Respiratory Failure

A 75-year-old woman was transferred from an outlying hospital with a 1-day history of right lower lobe pneumonia and worsening respiratory distress. She had an extensive smoking history and chronic emphysema, requiring supplemental oxygen at home. She was intubated and mechanically ventilated for hypoxemia and hypercapnia upon arrival. Sputum samples obtained from the endotracheal tube revealed that hemophilus influenza pneumonia and intravenous antibiotics were initiated. On the first hospital day, a right femoral arterial and a left femoral venous catheter were placed. On hospital day 5, she became febrile and hypotensive,

Table 5
Comparison of Hospital Economics in Patient 5: Respiratory Failure Complicated by CLAB

	n = 20	Patient 5
Admitting diagnosis	Respiratory failure	Respiratory failure
CC-ASG	3.8	4
Age, y	71	75
Principal diagnosis	Respiratory failure	Respiratory failure
Payer	Medicare + commercial secondary	Medicare + commercial secondary
Revenue, \$	20 792	20 417
Expense, \$	19 501	37 075
Gross margin, \$	+1291	-16 658
Costs attributable to CLAB, \$		13 696
LOS, d	10	15

CLAB = central line-associated bloodstream infection; CC-ASG = comprehensive clinical admission severity group, severity of illness present on admission; LOS = length of stay.

despite antibiotics. Blood cultures drawn at the time were subsequently positive for *E fecaelis*. The same organisms grew from the tip of the left femoral venous catheters. Despite extensive critical care support, she remained hypotensive and required increasing ventilator support. At the point at which dialysis and tracheostomy were required, the family decided to withdraw support and maintain measures designed for care and comfort. She died on hospital day 15. She was insured with Medicare as her primary and a commercial secondary insurer.

Table 1 illustrates the total cost of hospital care and the components attributable to the diagnosis and treatment of the CLAB and its complications. The total costs of hospital care were \$37 035, of which \$13 520 (37%) was attributable to the CLAB, its treatment, and additional length of stay (+5 days). Notably, these costs were limited by the fact that her family decided to withdraw support.

Table 5 illustrates the revenues and expenses in this case of acute respiratory failure compared to 20 additional cases with the principal diagnosis of respiratory failure matched for payer (Medicare + commercial secondary), age, and severity of illness on admission. In our case, the payments were \$20 417, with a gross hospital margin of -\$16 658. In contrast, the average payments for matched cases of acute respiratory failure with secondary diagnoses of bacterial pneumonia and chronic lung disease were \$20 792, with an average positive margin of \$1291. The financial analysis is influenced heavily by the fact that critical care was withdrawn at the request of the family. Nonetheless, the hospital losses were considerable.

DISCUSSION

What society pays for HAIs in general and CLABs in particular have been the subject of speculation and controversy. In the present study, we demonstrate the staggering costs attributable to CLABs and complications attendant to them in individual case analysis. In 54 patients whose care was complicated by a CLAB, the loss from operations averaged -\$26 885 per patient, despite a sizable increase in payments to the hospital. The negative impact on operating margins was driven by greater increases in hospital expenses, 43% of which were attributable to the treatment of the CLAB or its complication. The losses were not specific to a given payer and were observed for commercial and government insurers. Moreover, the most common principal diagnosis in which CLABs were observed included cardiovascular diagnoses such as myocardial infarction, congestive heart failure, or deep venous thrombosis, conditions not typically recognized as posing increased risks of infection because of biological factors such as burns, trauma, or an immunocompromised state. Nor did the severity of illness on admission predict the risk of CLABs in that as many patients (17%) admitted with low-severity grades (grade 0-1) as those (20%) with high-severity grades (grade 4) were represented.

Importantly, the economics that we examined pertain only to the hospital stay and did not include physician costs. However, a proportional increase in physician payments can be inferred from the increase in length of stay as physicians

are typically reimbursed on a per diem basis using evaluation and management or procedure codes. More important, we did not calculate the considerable costs of additional long-term care or rehabilitative care that most certainly accounted for significant additional costs, as only 4 patients were discharged to home.

There has been considerable controversy concerning the economics of these infections, as most studies have examined only expenses¹⁻⁵ and have not analyzed case-specific payments. While there has been a general consensus that CLABs cost more for additional care, it has been unclear whether the increased costs are fully recovered by hospitals through mechanisms such as increased case-mix index or outlier payments. In general, hospital-specific payment data for individual cases have been difficult to access. Our data demonstrate that when payments and expenses are considered, such cases have a significant negative impact on hospital operating margins. Notably, our analysis indicates that while payments escalate for care required as a consequence of CLABs, regardless of the payment methodology, even those sizable increases are insufficient to cover the additional costs when complex care is further complicated by this class of HAIs.

An additional important question has been the relative difference in payments and costs between care compromised by a CLAB and comparable levels of care for patients of similar age, admission severity index, principal diagnosis, and payer. There have been no economic analyses that have risk-adjusted for severity of illness. To address this concern, we performed case control analysis in which patients with CLABs were compared to age- and severity-matched patients with similar DRG and payer. When cases billed under the same principal diagnosis and matched for age, severity of illness, and payer were examined, patients whose care was compromised by CLABs commanded higher payments but cost hospitals more, leading to the overall negative economic impact. This understanding can only come from individual case review, given the wide variations in age, severity of illness, and principal diagnoses observed in our setting.

Our findings of an average payment of \$64 894 in these 54 patients with CLABs is in keeping with recently public reports¹⁶⁻¹⁸ by the Pennsylvania Healthcare Cost Containment Council (PHC4) demonstrating that HAIs were more costly by a factor of 6. Notably, we did not find any significant relationship between different payers and the

magnitude of operational losses, suggesting that these findings are not specific to a given payment methodology. However, our study has the advantage of demonstrating actual payments and expenses from clinical cases as opposed to using charges or administrative billing data, adding significant credibility to the assertion that CLABs are costly errors. The PHC4 public reports have been criticized as being insensitive to whether the infection was truly hospital acquired. In our study, we confirmed that all reported infections were hospital acquired, and our data are very much in keeping with those reported by PHC4 for this class of HAI. Moreover, the argument that certain classes of infections, such as CLABs and ventilator-associated pneumonia, may be present on admission and not hospital acquired is unsubstantiated by our data and seems unlikely given that central line and ventilator use are generally hospital based.

Our study is a single-center experience and was limited to analysis of cases in an MICU and CCU. The economic analysis may differ in other patient populations enriched with surgical cases. We restricted our economic analysis to cases presenting in the same time period to avoid the influence of changes in payment contracts. We focused on actual payments and did not assess the component of the payments attributable to modifiers, such as outlier payments. Finally, we did not perform a formal cost-effectiveness analysis but estimate that the investment required to reduce CLABs¹⁰ in our hands is approximately \$18 000 per year in the first year and \$8000 per year thereafter. The prevention of 1 average CLAB with operating losses of -\$26 839 would result in savings that would cover the costs of process improvement for a full year.

Our study suggests that the price of central line infections is considerable and that neither patients, payers, nor hospitals benefit. Given that these infections are largely preventable,¹⁰ the elimination of CLABs carries moral and economic imperative. However, this analysis should be repeated on a national scale to confirm the true magnitude of the economic opportunity.

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