While society would benefit from a reduced incidence of nosocomial infections, there is currently no direct reimbursement to hospitals for the purpose of infection control, which forces healthcare institutions to make economic decisions about funding infection control activities. Demonstrating value to administrators is an increasingly important function of the hospital epidemiologist because healthcare executives are faced with many demands and shrinking budgets. Aware of the difficulties that face local infection control programs, the Society for Healthcare Epidemiology of America (SHEA) Board of Directors appointed a task force to draft this evidence-based guideline to assist hospital epidemiologists in justifying and expanding their programs. In Part 1, we describe the basic steps needed to complete a business-case analysis for an individual institution. A case study based on a representative infection control intervention is provided. In Part 2, we review important basic economic concepts and describe approaches that can be used to assess the financial impact of infection prevention, surveillance, and control interventions, as well as the attributable costs of specific healthcare-associated infections. Both parts of the guideline aim to provide the hospital epidemiologist, infection control professional, administrator, and researcher with the tools necessary to complete a thorough business-case analysis and to undertake an outcome study of a nosocomial infection or an infection control intervention.

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Despite the fact that nosocomial infections pose a significant risk to patient safety, resources targeted to prevent these infections are limited. Although society would benefit from a reduced incidence of nosocomial infections, there is currently no direct reimbursement to hospitals for the purpose of infection control, which forces healthcare institutions to make economic decisions about funding infection control activities. Unfortunately, one current perception is that investments to improve quality might actually financially penalize the hospitals that make these improvements.1 Because infection control programs are often seen as cost centers and not as revenue generators, they are often identified as potential areas for budget cuts.2 In fact, many infection control programs have faced downsizing in recent years.3,4 Demonstrating value to administrators is increasingly important as healthcare executives are faced with the need to support many initiatives with limited resources.5 A recent survey of Society for Healthcare Epidemiology of America (SHEA) members showed that hospital epidemiologists already provide expertise in a wide variety of areas beyond traditional infection control (eg, antimicrobial stewardship, patient safety, employee health, and emergency preparedness), but compensation for these services occurs in less than 25% of cases.6 Increasingly, directors, managers, and infection control professionals (ICPs) must develop a business case to initiate a new intervention, justify continuing a program during budget negotiations, or fend off downsizing.

Because US national health expenditures were estimated to be $2.08 trillion in 2006, or 16% of the gross domestic product,7 there is no inherent reason that infection control interventions must save society money. Ideally, society should be willing to spend money to prevent either a myocardial infarction or a surgical site infection. To make a policy case for additional investment in infection control interventions or changes in reimbursement practices, many more quality cost-effectiveness analyses must be completed and published.8 Thus, a business case for infection control requires both the use of existing literature to make optimal decisions at an individual institutional level and support for the completion of more comprehensive analyses.
of additional cost-effectiveness analyses to guide future societal decisions and improve public health.

In part 1 of this article, we describe the basic steps needed to complete a business-case analysis for an individual institution. A case study using a representative infection control intervention is provided. In part 2, we detail important basic economic concepts, including types of economic analyses and their strengths, as well as the different perspectives of various analyses (eg, hospital vs societal). We also describe approaches used to assess the financial impact of infection prevention, surveillance, and control interventions, and approaches used to measure the attributable costs of specific healthcare-associated infections. All of these additional considerations provide the hospital epidemiologist, ICP, or administrator with the tools necessary for a thorough and accurate business-case analysis. This article outlines important considerations regarding the economic measurement of healthcare-associated infection and related interventions, although more detailed texts about the design and analysis of healthcare economic research are available. Infection control has been at the forefront of improving patient safety. The aim of this article is to assist infection control specialists and hospital epidemiologists in their understanding and use of economic analyses to help justify the need for and benefits of effective infection control interventions and programs.

PART 1: BUSINESS-CASE ANALYSIS

A business-case analysis is a type of cost analysis performed from a business’s perspective, in this instance, that of the hospital. Broadly defined for use in an intervention to improve health care, a business case “exists if the entity that invests in the intervention realizes a financial return on its investment in a reasonable time frame.” The reasonable return can occur through profit, reduction in losses, or cost avoidance. In this case, the purpose is to look purely at the dollar costs and benefits of an infection control intervention or an entire infection control program to justify its existence to hospital administrators. In the business case, patient outcomes such as infection-associated morbidity and mortality are not considered unless they impact the hospital economically, either positively or negatively.

The difficulty in making a business case cannot be overlooked, because many infection control programs often lack the economic expertise necessary to complete such an analysis on their own. Anyone considering a business-case analysis should contact their local institution’s finance administrators for assistance in using the available local cost data. Importantly, most (90%) of published studies of studies that claim to be cost-effectiveness analyses of infection control interventions actually adopt the hospital perspective and are more correctly called business-case analyses, with only 3% of the studies adopting a societal perspective.

Often, an infection control intervention program has existed for several years and has kept infection rates low. If hospital-acquired infections are now rare and no longer perceived as a problem, administrators might want to cut a program focused on controlling the infections, not realizing that the program is highly effective and even cost saving. The same difficulty arises when trying to initiate a new intervention program, because it is easy to quantify the extra costs of a new program but often difficult to estimate the incremental benefits, particularly when there are very few clinical trials available to convince administrators and likely even fewer resources available to complete studies at an individual institution.

One partial, although usually suboptimal, solution to facilitate saving an existing program is to examine areas where the intervention is not in place and compare infection rates there with rates in areas where the intervention is used. An example would be comparing central venous catheter–associated bacteremia rates in a medical intensive care unit (ICU) where a prevention program exists to rates in a surgical ICU that does not have a prevention program. Alternatively, if cost reductions force the elimination of a specific program, it would be helpful to stagger the elimination, so that as infection rates rise in certain units where an intervention is eliminated, this evidence could be used to support reinstatement of the program.

When an identified problem, new mandate, or new technology leads to the desire to introduce a new infection control intervention, it is important to remember that this is the time to collect outcome, cost, and implementation data. Careful review of these data will help justify the intervention in the future if it faces elimination when the institutional will supporting it dissipates. To that end, it is often helpful from an analysis perspective, and more importantly, from an implementation perspective, to roll out a new intervention in a stepwise or randomized fashion. This allows comparison of the intervention’s effects with results in control populations (eg, wards or ICUs where the intervention has not yet been implemented) by use of a higher-level quasi-experimental design. Importantly, when completing a business-case analysis, it is important to make an honest assessment of the situation. Most hospital epidemiologists or infection control specialists want to increase the resources available for infection control activities, but it is important to avoid overestimating benefits or underestimating staff and time costs. Overestimation in an initial analysis may improve the situation in the short term, but it will hinder efforts and necessary trust in the long term after actual resource audits are performed.

Business-case analyses conducted from a hospital perspective are important to local decisions; however, these types of analyses are not useful at the level of public health decision making because they typically do not include the health impact of infection-associated morbidity and mortality. It has become increasingly important to justify the importance of funding infection control activities at a broader level through the completion of cost-effectiveness analyses conducted from the societal perspective.
Cost-shifting issues can become even more problematic when through lower reported infection rates and lower costs? The new ICP because it will see the benefits of the added staff infection control or microbiologic analysis. In this example, not always where the cost of the intervention arises (eg, in- always clear who should pay for an intervention, because the reason it is difficult to initiate interventions is that it is not saving, initiation is often difficult in hospitals. One of the a business-case analysis. Third, the administrators can help identify the individuals and departments who may be affected by your pro- gestion, chief medical officer, and/or chief operating officer) who oversee hospital epidemiology and other groups who will be involved in the program or intervention. The purpose of this meeting is threefold. First, it is important to obtain agreement that the issue that you are addressing is of institu- tional concern and has the support of hospital leadership. Second, the administrators can help to identify critical in- dividuals and departments who may be affected by your pro-posal and whose needs should be included in the business- case analysis. Third, the administrators can help identify the critical costs and factors that should be included in the anal- ysis, including administrative data.

Even for interventions that estimates suggest would be cost saving, initiation is often difficult in hospitals. One of the reasons it is difficult to initiate interventions is that it is not always clear who should pay for an intervention, because the cost center that benefits (eg, patient care or surgical care) is not always where the cost of the intervention arises (eg, in- fection control or microbiologic analysis). In this example, should the cardiothoracic surgery service contribute to hiring a new ICP because it will see the benefits of the added staff through lower reported infection rates and lower costs? The cost-shifting issues can become even more problematic when interventions are effective but not cost saving. It is often the case that strong institutional support and understanding of cost-sharing is needed to initiate effective interventions, even when they are cost saving.

Step 3: Determine the Annual Cost

In the current example, the cost is the salary of an FTE plus the price of benefits for that individual. This information is available from many sources, including your own institutional budgets or surveys available online.17 As an example, a full-time ICP might earn $60,000, and benefits may cost the in- stitution 28% of that total, which brings the hospital’s cost for the FTE to $76,800. Other interventions may involve more wide-ranging costs. For example, an intervention that uses surveillance cultures will include the costs associated with nurses on the floor obtaining the culture samples and the costs associated with culture processing by the microbiology laboratory; similarly, an intervention that requires increased gown use will include additional costs for waste disposal.

Step 4: Determine What Costs Can Be Avoided Through Reduced Infection Rates

Optimally, the up-front cost of hiring a new ICP can be recouped over a reasonable period, usually the current fiscal year. Ideally, you might have data from your own institution that can be analyzed to determine whether C A B G - associated SSIs decreased after hiring an ICP. Alternatively, the medical literature may be reviewed to see whether others have publish- ed data regarding a similar issue (Table 1). For example, if 500 C A B G operations are completed at your institution annually and the current SSI rate is 5%, then 25 C A B G - related SSI occur per year. Your experience or a literature review might suggest that hiring an ICP would be expected to reduce SSI by over 35% through targeted interventions, including improved prospective surveillance, increased reporting of rates to surgeons, and improved timing of perioperative antibiotics.18 Thus, if 25 C A B G - related SSIs occur annually in your hospital, an effective ICP could prevent 9 of these SSIs.

Step 5: Determine the Costs Associated With the Infection of Interest at Your Hospital

If hospital administrative data are readily available, the attributable cost of an SSI could be calculated as described...
below. Alternatively, if they are not available, a literature re-
view might be performed, which, in this case, reveals that the
mean CABG-associated SSI costs approximately $18,000 (Ta-
ble 1).

At this point, it might be tempting to multiply the number
of SSIs expected to be prevented by the estimated cost per
SSI and state that hiring an ICP will save $162,000 (ie, $9 ×$18,000) in CABG-related SSI costs alone. If calculated
in this way ($162,000 in savings minus $76,800 for the new
ICP), the resulting figure suggests that the hospital will save
$85,200 overall. However, from the hospital’s financial per-
spective, a certain percentage of these costs are currently re-
imbursed by third-party payers. Therefore, the emphasis in
a business-case analysis should be on the attributable costs
(and attributable complications) of excess complications, in-
fected or otherwise. An attributable cost or complication is
one that would not have occurred during a hospital stay that
is identical to the one being analyzed except for the absence
of the complication or infection of interest. For example, a
recent study found that profits on surgical cases fell from
$3,288 when there were no complications to $755 when com-
plications, such as infections, occurred. Assuming that the
individuals in whom complications occurred were identical
to those without complications, except for the presence of
the complication, one would say that the approximately
$2,500 in hospital revenues that were not received during the
treatment of individuals with complicated stays constituted
the attributable cost of this particular complication. As a
result of preventing 9 SSIs, then, the hospital revenues would
be $22,797 (ie, $2,533 × 9) higher. In our example, if only
50% of costs are reimbursed, the cost savings from preventing
9 SSIs would be estimated at $81,000 instead of $162,000.
After subtracting the cost of the ICP (ie, $76,800), the overall
savings would be $4,200 annually.

An additional problem with the use of hospital adminis-
trative data or literature estimates of infection costs in an
analysis is that most hospital costs are fixed costs. Fixed
costs include buildings, equipment, and salaried labor, which
are difficult to eliminate in the short term. It has been es-

timated that as much as 84% of hospital costs are fixed. Thus,
if only 16% of the costs attributable to infections are
variable costs (eg, medication, supplies, or tests), our estimate
of costs might be $25,920 instead of $162,000. In this case,
then 59 new patients could be admitted, and the associated
revenue gained by filling the additional bed-days available,
because patients who do not develop infections are discharged
sooner. In the example, the question becomes how many new
patients could be admitted to the hospital without additional
investment in new buildings and equipment, given that we
estimate SSI prevention will reduce overall length of stay by
234 days? If the mean length of stay in the hospital is 4 days,
then 59 new patients could be admitted, and the associated
profits from these admissions could offset the investment in
the new ICP.

Step 6: Calculate the Financial Impact
To complete the business-case analysis, we must take the
estimated cost savings or additional profits and subtract the
costs of the up-front outlay, in this case the salary and benefits
for an ICP. In this example, the total economic impact at the
hospital for CABG-related infections as a result of hiring an
additional ICP is estimated to range from an annual cost of
$50,880 to an annual savings of $63,700. Although this is
quite a range, by thinking through all the possible permuta-
tions and assumptions and presenting the different sce-
narios, the administrator is able to make a thoughtful deci-
sion. Furthermore, all of these estimates assume that the ICP’s
activities are focused only on preventing CABG-associated
SSI, which is highly unlikely.

Step 7: Include the Additional Financial or
Health Benefits
Many infection control interventions have multiple benefits.
For instance, a contact isolation program developed in re-
sponse to an outbreak of Acinetobacter baumannii infections
would also be expected to reduce the rate of methicillin-
resistant Staphylococcus aureus (MRSA) infections and van-
comycin-resistant Enterococcus (VRE) infections. In this ex-
ample, the efforts of the new ICP could also be expected to
reduce the incidence of catheter-related bloodstream infec-
tion, prevent other SSIs, and improve compliance with hand
hygiene. All of these factors need to be included in a proper
business-case analysis. To further make the business case for
an additional ICP, one must include the reduced costs ex-
pected to be associated with these other types of preventable
infections. After these are included, it would be expected that
hiring an additional ICP would save the hospital money.
Even though business-case analyses do not typically include the adverse consequences of nosocomial infections, such as patient mortality, hospital administrators do respond to these important issues as well. Thus, some calculation of the patient safety improvement associated with the intervention should be included. If mortality associated with CAVG-related SSI is 20%, then preventing 9 of these infections would be estimated to prevent approximately 2 deaths. In this example, these 2 deaths could be prevented with an estimated maximum cost of $50,880 per year. Additionally, preventing complications, such as SSI, might be associated with reduced legal costs. Furthermore, with the increased call for regulations requiring mandatory reporting of healthcare-associated infections, there may be other benefits to the hospital that have not yet been considered (eg, pay-for-performance or an enhanced reputation for the institution). These benefits must be included in a proper business-case analysis and may be used to influence hospital administrators with respect to the importance of infection control programs. Thus, a hospital’s risk management group should be involved early on in any business-case analysis for a quality improvement program.

Because of the transmissible nature of communicable diseases, it is possible that an intervention used in one group of patients (eg, identification and isolation of ICU patients who are colonized with VRE) benefits another group to whom the intervention is not directly applied (eg, patients on a general medical floor who reside with VRE-colonized patients after they are transferred to that floor). Clearly, an ideal business-case analysis would capture such additional benefits (and potential cost savings). In reality, it may be difficult to identify such indirect effects (or “externalities,” as they are sometimes called) with infection control data. More sophisticated analyses may attempt to identify externalities through the use of mathematical modeling.

Step 8: Make the Case for Your Business Case

The completed analytical portion of a business case must be complemented by effective communication of its findings and your recommendations to critical stakeholders at your institution. Once a business-case analysis has been completed, the first instinct may be to immediately schedule an executive-level group meeting to present your findings and recommendations. That may work in certain instances, but it may be best to meet again with key stakeholders individually (eg, the chief medical officer, chief operating officer, and/or nurse-managers on affected units). These discussions can serve several purposes, including the presentation of initial findings, the development of an implementation plan, and the determination of current support for the initiative. Additionally, when the results are formally presented at a committee meeting, the key administrators will have had most of their questions answered already and will, more often than not, provide critical support during the final discussion before approval of the initiative.

Often, more attention is given to the formulation of an initiative than to its actual implementation. After the individual discussions, it is likely that the key findings of the analysis will need to be presented at an executive-level meeting. Importantly, successful implementation requires consensus building, which leads to higher levels of commitment even if it slows implementation speed. Much has been written about the successful implementation of initiatives in healthcare settings, including developing action plans, setting budgets, and measuring performance improvement.

Step 9: Prospectively Collect Cost and Outcome Data Once the Program Is in Effect

If an infection control intervention program has been in existence for several years and has kept infection rates low, administrators might be tempted to eliminate or reduce the program even though associated costs would have been higher in its absence. Therefore, it is imperative that intervention-specific outcome data and costs be collected after the intervention is implemented. It is important to show stable outcome rates or continued improvement associated with the intervention, to maintain consensus support and organizational momentum.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Benefit measurement unit</th>
<th>Formulation of final reported outcome</th>
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<tr>
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<td>Most natural unit of comparison*</td>
<td>Cost per unit</td>
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<td>Cost-utility</td>
<td>QALYs</td>
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<td>Cost-benefit</td>
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<tr>
<td>Business-case</td>
<td>Monetary units</td>
<td>Net financial benefit (or loss)</td>
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**Note.** QALY, quality-adjusted life-year.

* For example, infections prevented or life-years saved; final outcome is then reported in terms of that unit (eg, cost per infection prevented or cost per life year saved).
blurred, yet it is important to consider what is included in and excluded from each specific analysis so that informed decisions can be made. A recent review of the infection control literature found that of 30 publications that claimed to be economic analyses, only 8 were cost-effectiveness or cost-consequences analyses. Cost-effectiveness analysis. Cost-effectiveness analysis compares interventions or products that have different costs and different levels of effectiveness. If a new intervention costs more and is less effective than an existing intervention, or if the new intervention costs less and is more effective than an existing intervention, then the choice is easy. However, if a new intervention delivers more benefit at an increased cost, which occurs frequently in the setting of rapid technological innovation, then the choice is often difficult. In cost-effectiveness analysis, the benefits of an intervention are measured in the most natural unit of comparison, such as the number of lives saved or infections prevented. Programs are then compared in terms of cost per unit (eg, dollars per life-year gained or dollars per infection prevented). Cost-utility analysis. Cost-utility analysis is very similar to cost-effectiveness analysis, except that benefits of a specific intervention are adjusted by health preference scores or are utility weighted. In this type of analysis, programs are compared in terms of quality-adjusted life-years (QALYs) gained. The rationale behind this approach is that it not only values life, but it also allows the analysis to take account of disability or morbidity associated with the condition being treated or with adverse effects from the treatment. For instance, a year spent in an ICU would be valued differently by a patient, compared with a year spent at home with their family. Perhaps 4 years spent in an ICU would be equal in value to 1 year spent healthy, so 4 years spent in an ICU would equal only 1 healthy year, or rather, 1 QALY. A good example of a cost-utility analysis (and a cost-effectiveness analysis) in the infection control literature studied the use of vancomycin in perioperative prophylaxis during coronary-artery bypass surgery. Cost-benefit analysis. A cost-benefit analysis is one in which all aspects of the analysis, including the consequences of the intervention, are valued in monetary or dollar terms. If an intervention’s benefits measured in dollars exceed its costs, then this analysis considers it worthwhile. The major impediment to the use of cost-benefit analysis in healthcare decision making is the requirement to set a monetary value on human life or health benefits, such as setting a human life-year equal in value to $250,000. Of note, most economic analyses of infection control interventions that claim to be cost-benefit analyses are mislabeled, because they do not include a dollar value for the important outcomes of interest (eg, they do not place a dollar value on a human life or quality of life and they do not include dollars saved as a result of saving a life or improving quality of life in the analysis.) Which type of analysis is preferred? Over the past 10 years, cost-effectiveness analysis and the closely related cost-utility analysis have emerged as the preferred methods for economic evaluation in health care. Importantly, it is recommended that researchers compare new interventions to a reference case whenever possible, using standard units such as cost per lives saved or per QALYs saved. If an agency wanted to choose between funding a hand-hygiene promotion initiative and a cancer screening program, it would be difficult to compare the cost per infection prevented with the cost per cancer detected. However, if the comparison was cost per life-year saved or cost per QALY saved for each program, then an informed decision could be made. What is considered cost-effective? A standard threshold for calling a program cost-effective stipulates that the intervention should cost less than $50,000 per QALY saved; however, some suggest the threshold has increased to $100,000 per QALY saved. The World Health Organization recommends that the threshold for calling an intervention cost-effective should be 3 times a country’s gross domestic product per capita, and this threshold is $94,431 in the United States. Frequently, but incorrectly, researchers will only state that an infection control intervention is cost-effective or cost-beneficial if it is cost saving from a hospital perspective. Most healthcare interventions are not cost saving. A review of all cost-effectiveness analyses published between 1976 and 2002 found that only 130 (9%) of 1,433 cost-effectiveness ratios reflected cost saving, in which the interventions saved lives and money at the same time. Perspective The economic impact of nosocomial infections and infection control interventions can be assessed from various perspectives: that of society, that of the hospital, that of a third-party payer (eg, a health maintenance organization or the Centers for Medicare and Medicaid Services), that of a government agency (eg, the Veterans Health Administration), or that of the patient. Studies that examine a nonsocietal perspective can underestimate the full economic effect of an infection or intervention. Thus, it is important to recognize the perspective of a study to interpret its results appropriately. In addition, it is important to design the study so that it evaluates the issue from the perspective of interest (Table 3). For instance, outpatient physician visits to treat an SSI would be important to include in an analysis for the Centers for Medicare and Medicaid Services but would not be included in a typical acute care hospital business-case cost analysis. The societal perspective incorporates all costs and all health outcomes, regardless of who incurs the costs or who receives the benefits. The US Panel on Cost-Effectiveness in Health and Medicine states that even when an analysis from a nonsocietal perspective is requested, a complete societal perspective analysis should also be completed. Importantly, an analysis from the societal perspective will inform broader comparisons of programs and could lead to more equitable distribution of resources to improve public health. It is possible that the current lack of cost-effectiveness analyses of
infection control interventions from the societal perspective has facilitated the current underfunding of infection control programs and the continued incidence of preventable healthcare-associated infections.

Stating Monetary Values in Constant Dollar Terms

Adjusting for inflation: using published cost estimates from prior years. When the cost estimates used in an economic analysis come from different years, the data should be converted to current-year values. For instance, if you wanted to include the cost of a CABS-associated SSI in a business-case analysis for your hospital and you only had access to an estimate of the costs associated with such an SSI in 2002, then you would need to inflate that amount to reflect costs incurred in the current year. The typical method for handling these adjustments is to inflate the dollar amounts by use of a standard price index, such as the medical care services component of the Consumer Price Index. Alternatively, a simpler method for use in a business-case analysis is to use the Bureau of Labor Statistics Consumer Price Index calculator. This calculator allows a researcher to enter a value and select the year of the study, and the calculator then accurately inflates the value to that of the current year. Although this method is easy to use, it will likely underestimate costs because the rate of inflation in medicine is far higher than standard inflation rates. Therefore, it should be used only for convenience.

Discounting: incorporating future benefits and costs in a cost analysis. It is widely accepted that in economic analysis, all future costs and future health consequences should be stated in terms of their present value. The process of converting both future dollars and health outcomes to their present value is called discounting. The US Panel on Cost-Effectiveness in Health and Medicine recommends using a discount rate of both 5% and 3%. For example, if you assume that you will save $10,000 for preventing an MRSA infection next year if you decolonize a patient with intranasal MRSA colonization this year, then, by use of a 3% discount rate, the discounted savings would be $10,000/(1 + 0.03)^n, or $9,709, where n is the number of years in the future the benefit is accrued. Although counterintuitive to some, it is often recommended that the future health benefits of disease control programs (such as life-years gained) also be discounted to the present value at the same rate as costs. Failure to do so may result in the misleading impression that the most attractive strategy is simply to defer the initiation of the program indefinitely.

Measuring the Attributable Cost of Nosocomial Infections

Obtaining data on the incidence and attributable cost of a nosocomial infection allows an individual institution to understand the financial burden created by the infection. Many studies have been published that aim to define the attributable cost of nosocomial infections. Generally, these studies involve a set of patients who develop the infection of interest and a reference group who do not develop the infection. Outcomes such as attributable mortality, length of hospitalization, and costs are then compared between the 2 groups. These studies are, by definition, cohort studies because the outcomes of interest (ie, morbidity, mortality, and/or cost) occur after the exposure of interest (eg, nosocomial infection). Examples of these studies include examinations of the mortality and costs associated with catheter-associated bloodstream infection and SSI.

Studies that aim to assess the impact of infection with a specific antibiotic-resistant organism may have 2 reference groups, one with infection due to the susceptible form of the same organism and another without infection. For example, the outcomes for patients with SSI caused by MRSA can be compared with the outcomes for patients with SSI caused by methicillin-susceptible S. aureus to determine the incremental cost associated with methicillin resistance; the outcomes for patients with MRSA SSI can also be compared with the outcomes for patients without infection to determine the cost associated with MRSA SSI. The latter comparison results in a much higher estimate of costs attributable to resistance.

Important concepts to consider when determining the attributable costs and outcomes of nosocomial infection are adjustment for prior length of stay, severity of illness, and underlying comorbid conditions. Failure to consider and adjust for these factors can result in biased estimates of attributable cost. These concepts are discussed below.

Adjustment for length of hospitalization prior to onset of infection. When comparing costs and outcomes for patients who developed nosocomial infection with outcomes for those
who did not, it is important to control for length of stay prior to the onset of infection for the patients who developed infections and to control for total length of hospital stay for the comparator group who did not develop infection. Studies that make no adjustment for the time at risk of development of nosocomial infection have been shown to overestimate the length of hospitalization and the costs that are attributable to nosocomial infection by up to 2-fold because prolonged length of stay may itself be an important risk factor for nosocomial infection.

Several methods have been proposed for accurately estimating the extra days spent in the hospital as a result of nosocomial infections and the associated increased costs. At a minimum, the hospital stays of the patients in the reference group who did not develop infection should be at least as long as the time that the patients who developed infection were hospitalized before developing infection. This can be accomplished by matching case and reference patients on the basis of length of stay before infection or by performing more complicated statistical analyses.59

Adjustment for underlying severity of illness and comorbidities. Patients who develop nosocomial infection typically have greater severity of acute illness and more substantial histories of past chronic medical illnesses, compared with patients who do not develop infection. Because severity of illness and past medical illnesses are also independent predictors of resource use (eg, length of stay), it is important to control for illness severity and comorbidities present prior to infection because these variables may distort or confound the relationship between infection, costs, and outcomes.

Various methods have been proposed and employed to grade severity of illness, including subjective scores (eg, the McCabe and Jackson scores), ICU-data driven measures (eg, the Acute Physiology, Age, and Chronic Health Evaluation score60), and administrative severity scores (eg, the Medical Illness Severity Grouping System admission severity group score and the All Patient Refined Diagnosis Related Groups classification system). However, there is currently no well-validated aggregate illness severity score for infectious disease outcomes, and each of the tools mentioned above has important limitations as well as strengths, particularly with respect to its applicability to infectious disease outcomes.59

The timing of the assessment of underlying disease severity is important. Severity of illness may be a risk factor for infection, but severe illness can also be caused by the presence of infection, in which case it represents an intermediate variable in the chain of events between the exposure (ie, the infection) and the outcome of interest (eg, death or length of stay). Because adjustment for an intermediate variable usually causes an underestimation of the effect of the exposure of interest on the outcome, care must be taken to assess severity of illness prior to the first signs of infection (ie, more than 48 hours).59 Results of studies that assign the illness severity score at the time of the infection should be interpreted with caution as they may underestimate the magnitude of the effect that the nosocomial infection has on outcomes.59,60

Preexisting comorbidities may confound the association between infection and costs in a manner similar to that of the initial severity of illness. Aggregate comorbidity measures, such as the Charlson Comorbidity Index61 and the Chronic Disease Score,62 have been used to summarize patients’ underlying comorbidities for the purpose of adjustment in studies examining the risk factors and outcomes of patients with nosocomial infections.53,62

Defining costs. It is critically important to decide which costs to measure. Potential approaches to evaluating the economic burden of nosocomial infections in an institution include the following measurements: hospital costs, hospital charges, resources used, and/or actual reimbursed charges.64 Hospital costs include daily operating costs (sometimes called “fixed costs”), which do not vary based on patient volume, as well as the cost of drugs, tests, and other patient care-related activities (sometimes called “variable costs”), which are dependent on the number of patients admitted or their length of hospitalization.65 Under the US system of healthcare financing, a hospital must ensure that all of its costs are reimbursed by third-party payers; therefore, it assigns fees to hospital resources, which appear on a patient’s bill as charges. Insurance companies, Medicare, and Medicaid do not pay the amount stated on the bill because they receive discounts; therefore, for all patients the charge on the bill is greater than the actual hospital costs, to cover these losses.70 Hospital costs can be a useful outcome measure for an individual hospital because they best reflect the actual economic burden of the hospital. Although some institutions have implemented complex cost accounting systems that track resources used and assign costs, in most institutions, actual or true costs are difficult to retrieve.71 In contrast, hospital charges are less indicative of actual cost but are usually easy to retrieve from administrative databases and are consistent from patient to patient in most settings. Because hospital charges typically overestimate actual cost by 25%–67%, adjustment can be performed by use of cost-to-charge ratios.71,72 Both hospital and departmental cost-to-charge ratios are determined annually on the basis of data submitted to the Centers for Medicare and Medicaid Services. Hospital cost-to-charge ratios may be a more accurate measure of costs for a cohort of patients in multiple diagnosis related groups, while departmental cost-to-charge ratios may be more accurate for a cohort of patients in the same diagnosis related groups.71,73,74 It is important to note that physician professional fees and costs to the patient in the form of lost work are not captured when assessing only hospital costs or charges.

Direct measurement of resource use, through the use of microcosting, assesses specifically what services or procedures are used by a patient. Such methods may be preferred in countries where hospital operating costs are financed directly by the state rather than through reimbursement for patient care by third-party payers (eg, Canada). When microcosting is used, the resources consumed must be identified, measured,
and valued to translate resource use into monetary units. For example, one might identify gowns as an important source of variable costs in a program to control the rate of VRE infection. The number of gowns used in an ICU in a year could be measured by counting, and the value of the gowns used could be determined by multiplying the number of gowns used by the cost of an individual gown.

A comparison of the ratio of the total costs or charges for patients with nosocomial infections and those for comparable patients without nosocomial infections in one institution over a relatively short period provides the most generalizable estimate of the magnitude of the attributable economic impact of nosocomial infections. In contrast, the absolute values of cost or charge cited in studies should be interpreted with more caution because they may not be applicable beyond the institution in which they were collected. It is important to note that some administrators may view business-case analyses with skepticism if the cost data used are not from the local institution. Multicenter studies must report measures that are standardized across institutions.

Using cost estimates in the existing literature to supplement institutional estimates. If the costs of nosocomial infections cannot be measured within an institution, it may be necessary to use literature sources to estimate the economic impact of specific infections prior to completing a business-case analysis for an intervention. A synthesis of the published literature regarding the cost of representative healthcare-associated infections was created by the authors with literature published during 1995-2006 (Table 1). All cost estimates were inflation adjusted to 2005 US dollars, using the medical care services component of the nonseasonally adjusted Consumer Price Index.10,49 Length of stay data means the total hospital stay, including ICU stay, if available, that was attributable to the specific infection. All amounts not in US dollars were converted to US dollars with the Economic Research Federal Reserve Bank of St. Louis’s Federal Reserve Economic Database II.75 by use of the rate from January 1 of the year the study data were collected. Most cost estimates from the studies shown in Table 1 represent hospital costs, although a few estimates included the total societal costs of the infection.

Measuring the Economic Impact of Interventions to Reduce Nosocomial Infections

Optimal decisions concerning infection control programs must incorporate the economic impact of specific interventions. Most of the utility of economic analyses in the area of infection control lies in their ability to help convince hospital administration or public health authorities to fund and support a specific intervention. Unfortunately, the current literature is lacking in high-quality studies, such as randomized controlled trials, that could be used to support the efficacy and cost-effectiveness of specific interventions.

Decision making about infection control interventions requires the availability of proper cost-effectiveness analyses. Several important articles have outlined the optimal methodologies to use when measuring the economic impact of antimicrobial-resistant pathogens.68,72 However, a 2005 survey assessing all of the infection control intervention studies published found that 69% of the studies used a quasi-experimental design, and only 4% incorporated a cost analysis.76 From January 2001 through June 2004, of the 30 studies published that claimed to be economic analyses of infection control interventions, only 5 were proper cost-effectiveness analyses.13 Because so few studies have been published that assess the cost-effectiveness of interventions, there is a glaring need for proper economic evaluation of most infection control interventions. Importantly, even among the few studies completed, many have inherent methodological weaknesses that create bias against reporting an infection control intervention as cost-effective. Below, we describe the strengths and weaknesses of the basic study designs, which should be considered when assessing the efficacy and cost-effectiveness of infection control interventions.

Randomized controlled trials and cluster-randomized control trials. Infection control interventions can be broken down into 2 basic categories. In the first, the patient who undergoes the intervention is the same patient who directly benefits from the intervention. An example of this type of intervention is optimal timing of antibiotic prophylaxis to reduce the risk of a SSI.72 Here, the person who receives the antibiotics at the correct time would be at reduced risk of developing a SSI, and no other patients in the hospital would directly benefit from this intervention. Therefore, if we were trying to measure the benefit of appropriately timed antibiotic use, it can be said that for this type of intervention the unit of analysis is the individual patient. In this case, the “gold standard” study design to evaluate efficacy and safety is the randomized controlled trial. Even though observational trials, such as cohort studies, can yield results similar to those of randomized controlled trials, a randomized controlled trial is considered the “gold standard” for evaluating the efficacy of interventions.78-80

The second category of infection control interventions includes those interventions in which the specific infection control program is directed at either individual patients or a specific population of patients, and a different group of patients benefits from the program. An example of this type of intervention is the collection of surveillance culture samples to detect MRSA colonization on ICU admission and the isolation of colonized patients in a medical ICU. To study these types of programs, a cluster-randomized trial is necessary to adjust for the clustering effect that is inherent in control programs that involve transmissible infectious diseases.81,82 Patients who are impacted by these types of infection control programs represent a cluster (eg, an ICU) exposed to a common environment, common care practices, and other patients who are colonized with MRSA. Studies that fail to control for the nonindependence of patient outcomes may overestimate the effectiveness of the intervention. Thus, if we were...
trying to measure the benefit of active surveillance in reducing MRSA colonization and infection, the unit of analysis in this case is the entire ICU. Instead of randomizing individual patients, individual ICUs need to be randomized; this requires that multiple hospitals be involved, which requires a substantial investment of both money and time. These types of trials are called cluster-randomized trials or group randomized trials, and they are increasingly used by public health officials to study group interventions and also to study individual interventions that have group-level effects. Numerous articles have been written about the specific methodological and ethical issues involved in cluster-randomized trials. 

Quasi-experimental studies. Situations in which randomized trials cannot be completed ethically and/or economically are common in hospital epidemiology; consider, for example, a trial to evaluate the cost and effectiveness of an intervention to stop an active outbreak. Quasi-experimental studies, also known as pre-post intervention studies, can be used when it is not feasible to perform randomized controlled trials or cluster-randomized control trials. Quasi-experimental studies differ from randomized trials in that patients are put into the intervention group and the control group without randomization. As a result, these studies have a potentially lower internal validity because multiple confounders and biases can affect their quality. Even with these limitations, the quasi-experimental study design has been used with increased frequency in infection control research; a 2004 review of published studies that assessed interventions to reduce healthcare-associated infections found that 69% used a quasi-experimental design and 23% used a randomized trial design. A recent systematic review of infection control and antibiotic stewardship articles published during 2002 and 2003 found that 39 (53%) of 73 studies used the most basic quasi-experimental study design, which involved single measurements taken before and after the intervention and no control group. Importantly, studies that assess the cost-effectiveness of specific infection control interventions by use of the basic quasi-experimental design should be interpreted with caution, particularly when completed during an outbreak. Detailed options for improving and interpreting quasi-experimental studies can be found elsewhere.

Decision-analytic models and mathematical models. Mathematical models are useful tools for evaluating interventions prior to implementing them in human populations. Models allow researchers to use existing knowledge and data in a rigorous, efficient, and testable manner towards the goal of making medical decisions for the assessed population’s greatest benefit. Importantly, clinical trials are expensive, are labor intensive, and do not necessarily provide adequate data to make decisions for populations with all possible baseline characteristics. Therefore, models can be an ideal way to determine which interventions would be most cost effective and where an intervention would be most cost effective in preventing the spread of transmissible pathogens, including MRSA and VRE.

As an example, active surveillance and isolation of patients have been available for years as tools to control the spread of antimicrobial-resistant organisms in hospitals, but these strategies are only implemented in a minority of hospital ICUs because of their perceived costs and a lack of definitive clinical trial data. Many factors or variables that are related to the population (eg, ICU size and discharge rate), to individual patients (eg, comorbidities and age), or to the infectious organism being evaluated (eg, duration of colonization and likelihood of infection) can be individually evaluated with modeling strategies to assess their individual and combined importance in causing the observed outcome. This type of evaluation is called “sensitivity analysis,” and it is used in most mathematical and decision models. Thus, mathematical models can focus future clinical trials, greatly benefit patients, and optimize expenditures within the limited budgets of microbiology and infection control departments. Importantly, given the number and great variety of hospitals and other healthcare institutions that exist, it would be close to impossible to perform clinical trials to test the cost-effectiveness of all potential infection control interventions.

In conclusion, demonstrating the value of infection control programs is increasingly important in the context of limited budgets and no direct reimbursement for infection control activities. Hospital epidemiologists and infection control specialists must be able to complete accurate and timely business-case analyses to justify existing or planned quality improvement initiatives. Currently, the availability of accurate published estimates measuring the economic impact of healthcare-associated infections and related interventions is limited. In the future, accurate estimates of the attributable costs of hospital-acquired infections and the relative value of specific interventions will be required to inform clinical decisions, develop guidelines, and direct societal resource allocation optimally.

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