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Economics of Infection Control Surveillance Technology:

Cost-effective or Just Cost?

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Abstract

Background—Previous studies have suggested that informatics tools, such as automated alert and decision support systems, may increase the efficiency and quality of infection control surveillance. However, little is known about the cost effectiveness of these tools.

Methods—We focus on two types of economic analyses that have utility in assessing infection control interventions, cost-effectiveness analysis and business-case analysis, and review the available literature on the economics of computerized infection control surveillance systems.

Results—Previous studies on the effectiveness of computerized infection control surveillance have been limited to assessments of whether these tools increase the sensitivity and specify of surveillance over traditional methods. Furthermore, we identified only two studies, which assessed the costs associated with computerized infection control surveillance. Thus, it remains unknown whether computerized infection control surveillance systems are cost effective and whether use of these systems improves patient outcomes.

Conclusions—The existing data are insufficient to allow for a summary conclusion on the cost effectiveness of infection control surveillance technology. All future studies of computerized infection control surveillance systems should aim to collect outcomes and economic data to inform decision-making and assist hospitals with completing business-cases analyses.

Surveillance of nosocomial infections is an essential component in the assessment of the effectiveness of on-going infection control interventions.(1) However, infection control surveillance is labor-intensive, often requiring a large proportion of an infection control professional's time.(2) Medical informatics is a science that determines how best to use information to improve healthcare.(3). The use of medical informatics in infection control surveillance has fostered efforts to increase efficiency by computerizing surveillance activities, including the collection, analysis, and dissemination of data.(4) For example, a computerized infection control surveillance system could perform control-charting activities and notify the infection control professional when the incidence of infection rises above endemic levels or

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alert an admitting physician that a patient is known to have been previously colonized with an antimicrobial-resistant pathogen.(5)

Economic considerations are major determinants in the decisions to implement, maintain, or discontinue computerized infection control surveillance systems in healthcare settings. These systems often require considerable initial capital investment followed by continued financial commitments for maintenance and support. Even if the use of a computerized infection control surveillance system is effective in increasing the efficiency of infection control surveillance, the financial burden necessitates economic analyses to inform decision-makers on the utility of these systems. Yet, improved surveillance alone doesn't necessarily reduce infection rates or reduce associated costs. An important advantage of the computerized systems are that they can have decision support or notification features that may aid in other infection control activities related to surveillance, and those features could help to reduce the incidence of infections.

In this article, we focus on two types of economic analyses frequently used in assessing healthcare interventions (cost-effectiveness and business-case analyses) and review the existing literature in which economic analyses were used to evaluate computerized infection control surveillance systems. We then discuss the available evidence and make recommendations for future studies of the effectiveness and cost-effectiveness of computerized infection control surveillance.

Types of Economic Analyses

Cost-effectiveness analyses, cost-utility analyses and cost-benefit analysis are the three basic types of economic-analyses used in healthcare decision making.(6) While these methods are defined and recommended for use in publication and to inform societal decision making, they are not often used by individual institutions when determining which programs to target for implementation.(7,8) A business-case analysis is often required when planning a new infection-control initiative.

Cost-effectiveness Analysis

Cost-effectiveness analyses compare interventions or products that may vary in their ratio of cost to effectiveness, where effectiveness is defined as the degree to which the intervention/product accomplishes what it was designed to do in a given population. If a new intervention delivers more benefits at increased cost when compared to the standard, a scenario that occurs frequently in the setting of technology-based interventions, then the choice between the new intervention and standard practice is often difficult. In cost-effectiveness analysis, the benefits of an intervention are measured in the most natural unit of comparison, such as lives saved or infections prevented.(6) Interventions are then compared in terms of cost per life-year gained or cost per infection prevented. Just as the effectiveness of an intervention may vary when implemented in different populations, so too can the cost-effectiveness of the intervention. While it may be tempting to compare interventions by using the easier to measure cost per infection prevented, this only has utility when comparing interventions that prevent the same type of infection (e.g. urinary tract infection). However, it would not be recommended to compare cost per infection prevented if the infection prevented by one intervention is a surgical site infection and an infection prevented by another intervention is a urinary tract infection. This follows from the fact that surgical site infections and urinary tract infections have very different effects on patient morbidity and mortality.

The related, cost-utility analysis allows for benefits of a specific intervention to be adjusted by health preference scores or utility weights.(6) Thus interventions are compared in terms of quality-adjusted life years (QALY) gained. The rationale of this approach is that it allows the incorporation of disability or adverse events. It is recommended that both cost-utility and cost-effectiveness analyses use the societal perspective.(9) A societal-perspective economic analysis includes all costs and outcomes regardless of who incurs them. The societal perspective is important to use when aiming to inform broader public health decisions beyond a single institution, however, it is not used by hospital administrators when deciding what to implement at their institution. Texts are available that describe standard methods for completing cost-effectiveness or cost-utility analysis of healthcare interventions.(6,9)

Business-case Analysis

Given the current reimbursement structure in the United States that does not directly reimburse for infection control interventions, quality-improvement initiatives are often considered cost centers and not revenue generating, so they are often identified as potential areas for budget cuts.(10) Demonstrating the value of a new initiative to administrators is increasingly important as health executives are faced with many initiatives and decreased budgets.(11) In order to initiate new interventions or introduce new surveillance technologies, hospitals infection control programs are often asked to complete a business-case economic analysis to be included in budget negotiations.

A business-case analysis, although not typically listed in the taxonomy of economic evaluations used in healthcare, is a hospital-perspective (i.e. it only includes costs and benefits that impact the hospital budget) cost analysis and is therefore not directly based upon patient outcomes. If we consider a healthcare improvement intervention, a business case for the intervention "exists if the entity that invests in the intervention realizes a financial return on its investment in a reasonable time frame, using a reasonable rate of discounting."(12) The reasonable return can be through increased revenue in addition to existing fixed costs, reduction in losses or cost avoidance. In this case, the rationale for performing a business-case analysis is to compare costs and financial benefits of a new or existing surveillance technology from the prospective of the hospital in order to justify its implementation to hospital administrators. The Society for Healthcare Epidemiology of America has recently published guidelines to assist in the completion of business-case analyses of infection control interventions.(7)

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 method for economic evaluation in healthcare.(9,13) Importantly, it is recommended to compare new interventions to a reference case or current practice using a societal perspective (i.e. include costs and benefits of hospital, clinics, patient, patient's family, etc.) and, whenever possible to use standard units such as cost per lives-saved or QALYs-saved.(9) If a healthcare system, such as the Veterans Affairs, wanted to choose between funding a new system-wide infection control surveillance system 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-years saved with each program, then an informed decision could be reached. Thus, for economic analyses intended for publication, it is preferred that the cost-effectiveness methodology be used. A program is typically considered cost-effective in the literature if it costs less than $50,000/QALY saved; however, some suggest the threshold has increased to $100,000/QALY saved.(14) If infection control interventions are shown to be cost effective using standard methodology, it is likely that more resources, in terms of increased reimbursement and investment, will be made available to infection control programs.

Cost-effectiveness studies in the infection control literature

As was discussed above, we cannot assess cost-effectiveness without data on both costs and effectiveness. Thus, we discuss below the issues relevant to assessing the effectiveness of computerized infection control surveillance systems. We then briefly discuss the use of computerized surveillance systems to assess nosocomial infections, surgical site infections, and adverse events, including medical device-related events, which are often associated with nosocomial acquisition of pathogenic microorganisms. Lastly, we present the results of a systematic review to identify studies that assessed the cost effectiveness of these tools.

Issues relevant to assessing effectiveness

Numerous previous studies have demonstrated the potential effectiveness of computerized systems for infection control surveillance. Again, these studies have primarily compared computerized surveillance methods to traditional infection control surveillance (i.e. surveillance that is conducted through the review of electronic and paper medical records). The primary measures of comparison have been sensitivity, specificity, and positive and negative predictive values for the ability to identify outbreaks, patients with infections or patients at high risk of developing an infection using traditional surveillance as the gold standard.

Optimally, effectiveness would be assessed using cluster randomized controlled trials in which one or more wards would be randomly assigned to utilize either the experimental, computerized infection control surveillance system or the standard method of surveillance. The sensitivity, specificity, and efficiency of each method to estimate infection control parameters (e.g. infections, adverse events) would be compared. Ideally, effectiveness studies would also assess differences in patient outcomes such as infections prevented or lives saved between the two methods. However, it is often impractical and potentially unethical to randomize patients or patient groups to a specific method if there is already strong evidence to suggest that one method is superior to the other.(15) Thus, despite the potential for bias and increased threats to the validity of the findings, quasi-experimental, often termed before-after, studies or observational (e.g. cohort, case-control) studies are often used. The quality of evidence must be viewed in light of inherent strengths and weakness of the chosen study design.

An overview of functional goals of computerized infection control surveillance systems

Evidence supporting the effectiveness of computerized surveillance systems for identifying patients with various types of nosocomial infections in different hospital settings has been previously reported.(16-23) These studies include evaluations of systems designed to track bloodstream infections, pneumonias, and urinary tract infections among patients admitted to select medical and surgical wards, adult and neonatal intensive care units, as well as studies conducted in whole hospitals. However, although computerized systems were generally observed to improve surveillance efforts by increasing the sensitivity of previous efforts, none of these studies included an assessment of whether the computerized systems translated into improved patient outcomes. Furthermore, one previous study reported that computerized administrative data alone had lower sensitivity compared with targeted active surveillance to identify nosocomial infections.(24)

Computerized surveillance also has been used to identify patients with or at high risk of developing surgical site infections.(25-30) These studies used automated laboratory data, antibiotic exposure data, claims data, discharge diagnoses, and other administrative data and included a broad range of patients including outpatients who received breast or obstetric procedures or inpatients who received coronary artery bypass grafts or gastrointestinal surgeries to evaluate these systems. Consistent with many of the studies of computerized surveillance for nosocomial infections that were described above, these studies also demonstrated that computerized systems could be used to identify surgical site infections among patients while in the hospital or post-discharge. However, also consistent with the studies of surveillance for nosocomial infections, none of the studies of computerized surgical site infection surveillance systems assessed whether the use of the technology improved patient outcomes.

Finally, electronic administrative data has been shown to increase the sensitivity of identifying adverse events, including medical device-associated events, which could result in nosocomial infections.(31,32) Bates et al. published a comprehensive review of the different methods of using information technology to identify adverse events.(31) This review concluded that several information technology tools could be used to identify adverse events and that these methods will soon be commonly utilized given the considerable labor associated with previous methods of detection. However, similar to previously described effectiveness studies, this review did not discuss whether or not patients' outcomes were improved. In addition, a previous study by Wright et al., suggested that electronic review of administrative data was neither as sensitive nor correlated well with a review of medical records with respect to identification of central venous catheters procedures, which are often associated with infections.(23)

A systematic review of studies that assessing the cost-effectiveness of automated infection control surveillance systems

In light of the evidence for the effectiveness of computerized infection control surveillance systems, we systematically reviewed the literature to identify studies that used these tools to assess excess costs, hospital length of stay, and mortality. We searched the National Library of Medicine electronic database using the key words: "surveillance" "cost" and "infection" for manuscripts published between January 1, 2000 through March 1, 2007. We did not identify a single study, which assessed the costs or cost-effectiveness of an automated infection control surveillance system. We did, however, identify two studies that used economic analyses to assess infection control interventions that utilized an informatics component (e.g. use of hand-held computers or a relational database for identification of patients at high risk of active colonization or infection with an antibiotic-resistant organism). We discuss these studies below.

Farley et al. assessed the cost-effectiveness of using hand-held computers and computer-based surveillance compared with traditional surveillance (review of paper and electronic medical records) to identify urinary tract infections among patients with urinary catheters in a medical intensive care unit.(33) There was considerable initial capital investment in the automated surveillance system, mostly attributable to database creation and programming of the hand-held computers. Estimated costs were slightly higher for computer surveillance if surveillance was only conducted on one unit, however if surveillance was conducted on five units, the savings by the automated surveillance system was estimated at $147,815 compared with traditional surveillance over a four-year period.

Wernitz et al. utilized computerized admission surveillance to identify patients with a previous positive anterior nares surveillance culture for methicillin-resistant *Staphylococcus aureus* (MRSA) and facilitate subsequent contact isolation of these patients as part of a study to evaluate the effect of targeted admission screening on nosocomial MRSA transmission and acquisition.(34,35) Although other patient groups (e.g. nursing home residents, patients transferred from foreign hospitals or from hospitals where MRSA was endemic) were also targeted for surveillance culturing, investigators did note that 46% (51/111) of patients colonized with MRSA upon hospital admission were identified for screening by the computerized surveillance indicator. Of these, 39 patients (75%) had no other risk factor (e.g. residency in a nursing home) that would have identified them for screening. Using data from a 19-month period when no screening program was in place, investigators estimated that they likely prevented 48% of predicted nosocomial MRSA infections at a cost saving of €110,237. Investigators further reported that sensitivity analyses suggested that this program would be cost-effective even when MRSA incidence was low (2.9 infections prevented per year).

Discussion

The implications surrounding the need to recognize and reduce the incidence of nosocomial infections have never been greater. There is increasing pressure from legislature on hospitals for public reporting of nosocomial infections including mandating collection of active surveillance cultures.(36) For large, tertiary care hospitals, use of some type of computerized surveillance to effectively monitor incoming patients, culture collection, microbiology laboratory results, and contact isolation efforts would greatly reduce the burden of person-time. At smaller institutions with limited infection control resources, surveillance may not be feasible without some computerized assistance.

We identified only two studies that reported the costs and cost savings of computerized infection control surveillance systems. Thus, at present there are insufficient data to determine whether or not infection control surveillance technology can be cost-effective. It is important to recognize that not all computerized systems are equivalent in terms of effectiveness or efficiency. The effectiveness of the system is dependent on many factors, including the design of the system, the training of the users, and the willingness of the users to fully utilize the new technology. There have been many studies that have suggested technology-assisted surveillance was more effective in earlier or increased identification of infections or adverse events compared with traditional surveillance. However, although these studies have reported increased sensitivity or specificity, they have not assessed whether increased accuracy or earlier identification was associated with improved patient outcomes. It is logical that the increased speed and efficiency often provided by automated surveillance systems would facilitate earlier interventions. However, the impact of improved efficiency still needs to be quantified epidemiologically, since earlier intervention may not alter patient outcomes. In any case, cost-effectiveness ratios cannot be estimated without proper outcome studies that measure improvements in infection rates or lives saved. Of note, diagnostic systems, such as computerized surveillance software are not required by the U.S. Food and Drug Administration to show improved patient outcomes in randomized trials unlike new pharmaceuticals.

This scarcity of data on costs may be due to several factors. First, costs of proprietary software programs, often utilized for these studies, may either not be publicly available or it may be desirable not to disclose these costs if an institution has negotiated a reduced price. Cost-effectiveness analyses of informatics systems should incorporate the costs of the software, installation, and maintenance, which can often be considerable and constitute a large proportion of the initial investment. Second, although certainly not limited to this area of biomedical research, potential effects of publication bias must be considered when viewing the results of all literature reviews. Often studies, which have negative results or fail to show effectiveness, will not be submitted or accepted for publication in the peer-reviewed medical literature. Again there is far too little data on these economic analyses to determine the extent to which publication bias has occurred. It is important to publish or otherwise communicate the results of cost-effectiveness or business-case analyses of surveillance technologies, even if they are negative studies. If only positive studies, i.e. ones where the surveillance system is estimated to be cost-effective, are published, then systematic reviews of cost-effectiveness of these interventions would lead to biased estimates and potentially jeopardize patient safety.

Considerably more data are necessary to evaluate whether automated infection control surveillance is both effective and cost-effective. All future studies of these tools should attempt to assess whether increased accuracy or efficiency of surveillance methods actually impacts patient outcomes. In addition, studies should also include the collection of economic data. Again, these data should include costs and time associated with equipment (e.g. computer hardware), software, installation, staffing and education of staff, validation, maintenance, and upkeep. Previous estimates of costs of infections can be used, but this will vary between hospitals. Sensitivity analyses can beuseful in providing ranges of costs and effectiveness, and insights into cost-effectiveness under a variety of circumstances and thus, their use is encouraged.

In conclusion, hospitals with available resources may implement computerized infection control surveillance technology in the near future. At present, a business case for implementation cannot be based on evidence that enhanced surveillance is cost-saving from a hospital or societal perspective. However, even if sufficient evidence supporting the cost effectiveness of computerized surveillance becomes available in the future, continued evaluation is necessary because of inherent differences between systems, differences in populations, and differences in implementation. Thus, hospitals will still be required to complete individual business-case analyses to justify adoption of specific systems at their institution.

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