Use of Maximal Sterile Barriers during Central Venous Catheter Insertion: Clinical and Economic Outcomes

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Background. We performed a cost-effectiveness analysis to determine the effect of maximal sterile barriers (MSBs) on reducing central venous catheter (CVC)—related infections. Use of MSBs when placing CVCs may reduce the risk of infections but is more cumbersome, time-consuming, and expensive than other techniques.

Methods. We developed a decision analytic model in which a patient could have a CVC placed with either an MSB or a less stringent technique. We calculated total direct medical costs and the incidences of catheter-related bloodstream infections, catheter colonization, and death.

Results. Use of MSBs lowered costs (from $621 to $369 per catheter insertion) and decreased the incidences of catheter-related bloodstream infections (from 5.3% to 2.8%), catheter colonization with local infection (from 5.5% to 2.9%) and death (from 0.8% to 0.4%). MSBs improved patient safety throughout all sensitivity analyses.

Conclusions. Use of MSBs during CVC insertion likely lowers medical costs and decreases the incidences of catheter colonization, catheter-related bloodstream infections, and death. Cost savings were found over a wide range of clinical and economic assumptions, suggesting that MSBs should be routinely used when CVCs are inserted.

Central venous catheters (CVCs) are crucial for intravenous therapy for patients in intensive care units and for ambulatory patients needing long-term intravenous access [1]. Unfortunately, CVCs are commonly associated with infectious complications, including bacterial colonization of the catheter, local infection at the insertion site, and catheter-related bloodstream infection (CR-BSI). These complications contribute to increased CVC-related morbidity, mortality, duration of hospitalization, and health care costs [2]. In the United States, there are ~15 million CVC-days per year, with 5.3 CR-BSI per 1000 catheter-days in patients in intensive care units. Annually, these infectious complications are estimated to lead to between 2400 and 20,000 deaths and to cost from $296 million to $2.3 billion [3–6].

Numerous interventions are recommended to reduce the risk of catheter-related infections [4, 5, 7], including improved sterile technique during insertion. The so-called “maximal sterile barriers” (MSBs) technique requires that the person inserting the CVC wear a head cap, face mask, sterile body gown, and sterile gloves and use a full-size sterile drape around the insertion site. Less-stringent measures usually require only sterile gloves and a small regional sterile drape. Many experts have recommended adopting MSBs [4, 5, 7–12]. On the basis of a systematic review of the literature on MSBs, we concluded that the evidence, although limited, suggests that this technique reduces infectious complications [13].

How often MSBs are actually used when inserting CVCs remains unclear; however, several articles report poor compliance in clinical practice [14–16]. Although the reasons for noncompliance have not been evaluated, it is possible that clinicians are not convinced that the available data support adopting this more cumbersome
and time-consuming technique [7, 14]. Accordingly, we conducted a cost-effectiveness analysis to estimate the clinical and economic consequences of using MSBs, compared with less-stringent sterile barrier techniques, when placing a CVC.

METHODS

Decision model. We created a decision analytic model to assess the outcomes of MSBs versus less-stringent sterile barrier techniques in a hypothetical cohort of hospitalized patients requiring a multilumen CVC. In either group, a patient could develop one of the following: no infectious complications, catheter colonization, or CR-BSI. Catheter colonization could lead to no infectious complications or to a local infection. The final outcome for each patient was life or death.

The hypothetical cohort was modeled to represent the types of hospitalized patients for whom short-term (2–10 days, on average) multilumen CVCs are most often used (specifically, those in intensive care units, with immunosuppression, or receiving total parenteral nutrition) [17–19]. The analysis followed-up each hypothetical patient for his or her entire hospitalization. The costs were determined from the perspective of the hospital.

Likelihood of events. The relative risk for catheter-related infections with use of MSBs was determined by pooling the data from available studies. We calculated the Mantel-Haenszel weighted relative risk of infection for MSBs to be 0.53 (range, 0.32–0.86) [8, 20]. This estimate for catheter-related infections was used for both catheter colonization and CR-BSI.

The probabilities of a patient developing CR-BSI or catheter colonization were derived from a recent National Nosocomial Infections Surveillance System report [6] and meta-analyses of CVC-related infection prevention techniques [4, 17, 18, 21]. For a standard, noncoated catheter placed with povidone iodine skin preparation and used for 8 days, the estimated probability of CR-BSI was 4.2% (range, 3.1%–5.2%), and the estimated probability of catheter colonization was 21.7% (range, 18.1%–24.7%). These estimates include CVCs placed with use of MSBs, as well as those placed with use of less-stringent sterile barrier techniques. By use of an estimate of compliance with MSB techniques of 44% [14] and a relative risk for use of MSBs at 0.53 [8, 20], we calculated the base probability of CR-BSI to be 5.3% (range, 3.9%–6.6%) and the base probability of catheter colonization to be 27.4% (range, 22.8%–31.1%) for CVCs placed with use of less-stringent sterile barrier techniques.

The probability of death from CR-BSI was approximated from previous studies [17, 19, 21]. Among hospitalized patients, the excess mortality rate attributable to CR-BSI has been estimated to range from 4% to 25% [2, 17, 21–25]. We selected a base-case probability of death associated with CR-BSI of 15% and used a range from 4% to 25% in the sensitivity analysis.

We estimated the likelihood of a local infection developing in a patient with catheter colonization to be 20% (range, 0%–40%) [17, 21, 26, 27]. We assumed that those without any infectious complications would have no increased mortality and that catheter colonization (with or without local infection) did not significantly increase mortality. Thus, the only increase in mortality was attributed to CR-BSI.

Costs. The additional material cost of MSBs (i.e., for a head cap, face mask, sterile body gown, and full-size sterile drape), compared with that of less-stringent sterile techniques, was estimated at $15 (adjusted to 2003 dollars) [20]. In addition to the material costs, clinicians must spend more time assembling MSB supplies and implementing their use. To estimate the additional time required, we informally queried physicians in 3 settings: a tertiary-care academic medical center, a Veteran Affairs medical center, and a community hospital. The estimated average additional time needed to use MSBs was 20 min but ranged from 2 to 30 min, depending largely on whether MSB supplies were available in the patient care unit. Assuming $75/h for a health care professional’s time, this additional time accounts for $25. In our model, the additional cost of MSBs (materials plus time costs) was thus estimated at $40 (range, $20–$60).

An episode of CR-BSI typically leads to additional intensive care unit days, general medicine ward days, professional fees, and procedural costs. The cost of each episode of CR-BSI has been estimated to be as much as $28,690 and as little as $6005 [2, 4, 17, 28]. A similar economic analysis of CR-BSI estimated the cost at $9738 [17] (or $11,469 in 2003 dollars). We used this conservative estimate and varied this cost in sensitivity analyses between $5734 and $22,939.

Local catheter-related infections would likely result in the need for cultures of blood and of the catheter tip and replacement of the CVC. The material costs for managing these local infections have been estimated at $210 ($24 for cultures and $186 for a replacement catheter) [17], or $247 (range, $124–$371) in 2003 dollars.

Outcome assessment and sensitivity analyses. For the hypothetical cohort of patients who had their CVC placed with use of MSBs or less-stringent sterile barrier techniques, we calculated the total direct medical cost and the incidences of CR-BSI, catheter colonization, and death attributable to CR-BSI. The incremental benefit of MSBs was calculated by subtracting the outcomes for MSBs from the results for less-stringent sterile barrier techniques. Finally, we computed 1-way sensitivity analyses, as well as best-case and worst-case scenarios.

RESULTS

Costs and outcomes. The expected clinical and economic outcomes are shown in table 1. In the base-case analysis, implementation of MSBs resulted in fewer infections and lower costs. Use of MSBs decreased the incidence of CR-BSI by 2.5% (from
Table 1. Results of cost-effectiveness analysis (base-case scenario) of use of maximal sterile barriers (MSBs) to prevent catheter-related bloodstream infection (CR-BSI).

<table>
<thead>
<tr>
<th>Sterile barrier method</th>
<th>Direct medical costs, 2003 dollars</th>
<th>With CR-BSI</th>
<th>With death due to CR-BSI</th>
<th>With catheter colonization and local infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSBs</td>
<td>369.34</td>
<td>2.81</td>
<td>0.42</td>
<td>2.90</td>
</tr>
<tr>
<td>Less-stringent sterile barrier techniques</td>
<td>621.39</td>
<td>5.30</td>
<td>0.80</td>
<td>5.48</td>
</tr>
<tr>
<td>Difference between methods</td>
<td>-252.05</td>
<td>-2.49</td>
<td>-0.38</td>
<td>-2.58</td>
</tr>
</tbody>
</table>

5.3% to 2.8%), decreased the incidence of catheter colonization with local infection by 2.6% (from 5.5% to 2.9%), decreased the incidence of death by 0.4% (from 0.8% to 0.4%), and decreased costs by $252 (from $621 to $369) per catheter.

**Sensitivity analyses.** MSBs remained a dominant strategy throughout 1-way sensitivity analyses. The effect of the most influential parameters on the incremental cost estimate in the 1-way sensitivity analyses is shown in figure 1. Varying the cost of CR-BSI between $5734 and $22,939 altered the incremental cost savings from $109 to $538. The threshold value for CR-BSI—the cost above which MSBs would save money—was $1351. Other influential parameters on the incremental cost estimate were the risk ratio of MSBs (threshold value of 0.94) and the incidence of CR-BSI (threshold value of 0.63%).

For the worst-case scenario analysis, we set each variable in the model at its lowest plausible level. Even in this unlikely situation, use of MSBs decreased the incidence of death by 0.02%. This clinical benefit was associated with a cost of $29 per catheter. In the best-case scenario, use of MSBs was clearly a dominant strategy, saving $1041 per catheter and decreasing the incidence of death by 1.1%.

**DISCUSSION**

This study provides the first formal analysis of both the clinical and economic consequences of using MSBs for preventing CR-BSI. Our decision analytic modeling indicates that use of MSBs leads to a reduction in the incidence of catheter colonization, CR-BSI, and death, all at decreased medical costs. Thus, implementing MSBs is a dominant strategy. These results held over a wide range of likelihood and cost estimates. In view of how commonly CVCs are used in hospitals, the potential reductions in morbidity, mortality, and cost could be substantial.

As is the case with other economic evaluations, this study is limited by the validity of the likelihood and cost estimates we used. We derived these estimates from published sources, but the literature has important gaps in supportive data [13]. Furthermore, some studies may have overestimated the effect of catheter-related infections on cost and mortality. In these situations, we made conservative (i.e., toward the null hypothesis of no difference between the 2 strategies) approximations. For instance, the reported cost of CR-BSI ranges from $6005 to $28,690 [2, 4, 17, 28]. On the basis of previously published cost studies of CVCs, we chose an estimate of $11,469 for our...
base-case analysis. Despite these conservative estimates, MSBs remained cost-saving throughout a wide range of plausible model parameters.

The additional cost of MSBs was driven primarily by the time required to gather MSB supplies. If sterile drapes and gowns need to be ordered from the hospital’s central supply, notable time delays can occur. However, in units in which use of MSBs has been established as the standard of care and these supplies are readily available in CVC insertion kits, additional time requirements can be minimized.

The results of this cost-effectiveness analysis are also limited by the model assumptions. As noted, the literature has important gaps in supportive data [13]. For instance, the difference in outcomes for preventable and nonpreventable infections is not clearly understood, and thus all CVC-related infections were modeled together. In addition, the particular circumstances in which CVCs are placed may vary from setting to setting. Generalizing these conclusions to individual hospitals should be done cautiously. For example, if a hospital with rates of catheter-related infection lower than our estimates were to adopt use of MSBs, their potential cost savings and infections avoided would be less than described in this analysis.

Infection control authorities advocate several measures to avoid CR-BSI [4]. Despite some disagreement [3], most studies have shown that use of antimicrobial-coated catheters and skin antisepsis with chlorhexidine gluconate solution each decrease the incidence of infectious complications and provide cost savings [17, 18, 21, 29]. The relative merits and potential additive value of MSBs compared with these techniques need to be further explored.

This formal economic evaluation suggests that for every 270 catheters placed with use of MSBs, $68,000 would be saved, and 7 episodes of CR-BSI and 1 death would be avoided. The results of this study strongly support use of MSBs during all nonemergent CVC placements in hospitalized patients. The next effort will be identifying and overcoming barriers to using MSBs during CVC placement. Convincing physicians and hospital administrators of the added safety and economic benefits of MSBs is crucial to increasing their use in clinical practice.

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Potential conflicts of interest. All authors: No conflict.

References

13. Hu KK, Lipsky BA, Veenstra DL, Saint S. Using maximal sterile barrier precautions during insertion reduce the risk of central venous catheter–related infection lower than our estimates were to adopt use of MSBs, their potential cost savings and infections avoided would be less than described in this analysis.


