Background: Aspiration can occur in patients of any age group, but it can be prevented. The primary population at risk is made up of survivors of cancer because of their increased risk of mucositis, mucosal atrophy, and dysphagia associated with chemotherapy, radiotherapy, and the disease process itself. The rate of incidence of aspiration cannot be quantified, because minor cases of aspiration often go unreported. Sequelae ensuing from aspirations can include pneumonia, end-stage kidney disease, dialysis, and death.

Methods: Analyses of cost, decision-tree modeling, and cost effectiveness were performed to compare a hypothetical, interventional model based on best practices with usual (standard) care. A societal perspective was used as the economic viewpoint. Direct costs, caregiver time, and market values for wages were estimated for the 2 interventions. Effectiveness values for the cost-effectiveness and decision-tree analyses were obtained from the literature. The incremental–cost-effectiveness ratio was calculated and used to compare the intervention with usual care.

Results: The interventional method was more costly but more effective than usual care. A sensitivity analysis considered the uncertainty of event probability (aspiration vs no aspiration). The interventional protocol for aspiration reduction continued to be more cost effective than usual care.

Conclusions: Aspiration takes a financial toll on all facets of health care, including on nurses, skilled nursing facilities, patients, their families, and insurers, among others. Implementing guidelines that describe best practices for aspiration appears to be a cost-effective strategy for reducing aspirations among cancer survivors — especially elderly patients — who live in skilled nursing facilities.

Introduction
Aspiration can affect every age group, so all patients are at risk; although aspiration can be prevented, because of the toxic effects of chemotherapy and radiotherapy, the cancer disease process, mucositis, dysphagia, aging, and mucosal atrophy, elderly cancer survivors are especially at risk.1,2 Aspiration occurs when a patient chokes and the resulting food, medication, liquid, emesis, or low pH gastric fluid escapes into the lung.1,3 Aspiration can also occur during anesthesia, while patients are being treated in intensive care units, and in the trauma setting.1 Of greater public health significance is the unidentified or unnoticed, minor aspiration cases that occur and can lead to pneumonia. Thus, the incidence rate of new cases of aspiration is difficult to quantify.1

A wide range of outcomes is possible with aspiration. The severity of complications of aspiration depends on the patient’s health status and follow-up care, such as hospitalization and ventilator intubation, that may be necessary. Aspiration can result in aspiration-associated pneumonia (bacterial colonization of the lung), acute lung injury, or acute respiratory distress syndrome.2 Furthermore, aspiration can result in respiratory failure, organ failure, dialysis, need for transfusions, and unnecessary hospitalization stays and procedural expenditures for health care organizations.3 Aspiration can be avoided by using guidelines to prevent choking, especially in cancer survivors already at risk.4

Aspiration has a major influence on the expenditures of health care organizations, whose staff may care for elderly cancer survivors.5 Medicare does not reimburse health care organizations for hospital-associated infections and preventable hospitalizations.5 In 2012, the national mean inpatient costs for aspiration totaled $13,542, with an average hospital stay of 7 days.6 This cost of care included treating aspiration, but it did not include costs related to the treatment of complications (eg, hospital-acquired pneumonia).6 Patients insured by Medicare have the highest incidence of aspiration and inpatient hospitalizations.6 Some of these cases may be preventable while patients reside in skilled nursing facilities. It is worth noting that aspiration is the second leading cause of hospital transfer, mortality, and infection in long-term care facilities.7
In this study, guidelines and best practices for nursing recommended by the American Association for Critical-Care Nurses (AACN) to reduce aspiration risk, hospital-associated infections, and unnecessary expenditures from aspiration was compared with usual (standard) care. This was performed via cost analysis and then by using cost-effectiveness and decision-tree analyses to compare the 2 methods, known hereafter as the intervention and usual care models. Using the interventional protocol, registered nurses are trained to identify and remedy risks of aspiration-associated pneumonia using the decision model. However, administrators of skilled nursing facilities may prefer to allocate their nurses’ time toward patient care, rather than implementing an optional, interventional protocol to help reduce aspiration risk. Thus, usual care was used as an alternative. In the usual care model, nurses rely on their experience, with no special training, to prevent aspirations.

Methodology

This study did not require Institutional Review Board approval because only published literature and publicly available data were used.

Study Design

Cost-effectiveness analysis was used in this study as a form of economic evaluation, which values costs and outcomes. Thus, cost-effectiveness analysis compares costs in relation to a natural unit, such as years of lives saved or number of cases prevented; by contrast, cost-utility analysis uses concerns, such as quality of life or classic utility values, as the outcome. In this study, cost-effectiveness analysis performed uses the natural unit of the number of aspirations averted. In addition, using aspiration — rather than using a utility — as an end point becomes relevant with recent trends toward bundled payments, because payers are beginning to reimburse only for a single disease, outcome, or condition regardless of procedures performed for additional complications.

A decision-analytic model was used to evaluate the costs per aspiration averted in a prospective cohort of skilled nursing facility residents. Several forms of decision analysis exist, including Markov models and decision trees. Markov modeling evaluates long-term effects and uses “health states.” In Markov models, the disease process of the patient is modeled, and a patient is expected to be in a health state at a given time. However, the Markov model has disadvantages and, in this case, may not be ideal due the Markovian assumption involved (memory-less model).

Decision trees linearize the decision process and provide an overview of the logical flow of each pathway. Decision trees are easy-to-follow pathways and use relevant probabilities for each decision and are more appropriate for a state of short-term analyses. Because the time period evaluated in this study is 1 year, a decision tree was used for the cost-effectiveness analysis, which did not require the creation of health states. In addition, a decision tree structured and represented the decision at hand for skilled nursing facilities, ie, which treatment pathway was more cost effective at preventing the episode of aspiration in elderly cancer survivors.

Fig 1 is a diagrammatic representation of the deci-

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**Fig 1.** — Decision tree. This decision tree illustrates the decision node, noted by a blue square, between the interventional (aspiration risk-reduction protocol) and usual care models. The first-chance node, noted by green circles, shows the uncertain occurrence of having an aspiration during the 1-year follow-up period for the 2 models. The red triangles represent the payoffs for an individual traversing each branch of the decision tree.

a Probability.
sion tree used for the cost-effectiveness analysis. The payoffs included costs incurred by health care professionals, patients, and caregivers for the skilled nursing facilities, as well as effectiveness and outcomes, and were the number of aspirations averted over the time period of 1 year. Using the decision tree, the incremental–cost-effectiveness ratio was calculated for the intervention (the aspiration risk-reduction protocol training program) compared with the usual care models. A sensitivity analysis of the cost effectiveness of these interventions was performed based on a range of estimates for the effectiveness of the training program and the direct and indirect costs of aspirations.

Data from the literature were used for this study, as per common practice in decision-analysis studies. The alternatives were modeled with a decision tree that incorporated parameters from the literature, allowing decision makers to understand the impact of each direct and indirect cost. Specifically, effectiveness data (rates of aspirations/gastroesophageal reflux) were garnered from systematic reviews and practical trials. Effectiveness data were gathered from a systematic review that included a randomized controlled trial, a quasiexperimental study, and an observational study. Each article used a different time period for evaluating aspiration rates, and these values were converted to 1-year probabilities. In addition, effectiveness data were obtained from a published article that implemented an aspiration risk-reduction program concerning head of bed elevation, feeding tube insertion and placement, and gastric volume.

This cost-effectiveness modeling study utilized microcosting from the societal perspective to measure direct and indirect medical costs, patient productivity, informal caregiver time, and family time for visits. Direct and indirect costs were estimated for both the intervention (best care) and control arm (usual care) of the study. Training costs were estimated for supplies, training materials, facility use, and implementation. Recruitment costs were not included because these interventions were modeled to take place within the skilled nursing facilities.

The cost of an aspiration was estimated as the average provider cost of an aspiration case in 2012. There is no interventional cost for usual care, whereas training costs are included for the interventional program. Patient productivity costs were excluded from the model, because the residents of skilled nursing facilities were assumed to have no productivity or work output. Time spent by family caregivers was estimated to be 20 minutes of travel time each way (job salary lost) to visit the patient affected by the adverse effects of aspirations. Most caregivers (74%) lived approximately 20 minutes away from their care recipient, and 76% of caregivers visited their care recipient at least once a week.

### Interventions and Alternative Strategies

#### Interventional Protocol:
Material was adapted from the AACN guidelines for head of bed elevation and aspiration risk. The impact of positioning the head of bed elevation to a 45-degree angle, even during wound care and the changing of bed linens, was modeled in this study. The interventional protocol was modeled to last for 1 year, with 100 nursing staff members from all departments. Skilled nursing facilities often are understaffed, so a conservative number of nursing staff was considered.

#### Usual Care Protocol:
In this alternative strategy, nurses focused on the actual delivery of care and care processes, rather than spending work hours in training programs for the interventional protocol (based on AACN guidelines regarding aspiration risk reduction).

Table 1 shows the base case estimate and range of the probability of no aspiration with the hypothetical interventional and usual care programs. A rate to probability function was used to convert the respective rates into 1-year probabilities. Table 2 indicates the direct costs of preventing aspiration; direct costs of medical care (costs of aspiration) were $13,542. Training and material costs were only applicable for the interventional protocol.

The indirect costs per patient, which are comprised of wages lost during informal caregiver time spent with the patient following aspiration, were es-

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Base Case</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention (Aspiration Risk-Reduction)</td>
<td>0.46</td>
<td>0.28</td>
<td>0.52</td>
</tr>
<tr>
<td>Probability of no aspiration</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Aspiration averted</td>
<td>68.4</td>
<td>56.6</td>
<td>1460.0</td>
</tr>
<tr>
<td>Cases of aspiration</td>
<td>30.10</td>
<td>22.80</td>
<td>34.80</td>
</tr>
<tr>
<td>Usual Care</td>
<td>0.20</td>
<td>0.11</td>
<td>0.48</td>
</tr>
<tr>
<td>Probability of no aspiration</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Aspiration averted</td>
<td>59.30</td>
<td>10.95</td>
<td>842.31</td>
</tr>
<tr>
<td>Cases of aspiration</td>
<td>35.30</td>
<td>31.90</td>
<td>73.90</td>
</tr>
</tbody>
</table>

Data from references 12, 13, and 15.

### Table 2. — Direct Costs Per Patient

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate, $ (range)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training and materials</td>
<td>62 (50–186)</td>
<td>Assumption</td>
</tr>
<tr>
<td>Aspiration</td>
<td>13,542 (7,014–24,334)</td>
<td>Inpatient aspiration costs</td>
</tr>
</tbody>
</table>

*Ranges include costs of aspiration by payer, age, sex, location, and facility size subgroups. Data from reference 6.*
Integrating the direct and indirect costs indicates that the average costs of an aspiration are $11,425.75 while receiving usual care in a skilled nursing facility setting compared with the average costs of $7,774.35 using the interventional model. Overall, this cost analysis indicates that the interventional program was less expensive than usual care.

Results
Table 3 lists the results of the cost-effectiveness analysis. The interventional protocol is more cost effective. It dominated usual care because it was more effective, had lower costs, and incurred savings.

The sensitivity analysis considered the uncertainty of event probability (aspiration/no aspiration). The 1- and 2-way deterministic sensitivity analyses indicate similar results. The interventional training program was more effective and less costly at all levels of the parameters. The results of the 2-way deterministic sensitivity analysis are presented in Fig 2. When all of the parameters (effectiveness) were simultaneously varied, the interventional protocol continued to dominate the usual care at most probabilities of effectiveness.

A Tornado diagram indicates the variables with the greatest impact on the incremental–cost-effectiveness ratio (Fig 3). The number of aspirations averted using the interventional program resulted in the greatest impact on the incremental–cost-effectiveness ratio; this indicates a need for information. The probability of no aspirations with the interventional program has a significant impact of the cost effectiveness of the intervention.

Discussion
Aspiration takes a financial toll on skilled nursing facilities, patients and their families, and insurers. Need exists to reduce the rate of aspirations as well as to assess the cost effectiveness of current interventions. In this study, the interventional model, which was based on the aspiration risk-reduction protocol recommended by the AACN, was compared with usual care in elderly cancer survivor. The incremental–cost-effectiveness ratio for usual care was
$11,425.70 per aspiration averted. The interventional training for front-line nurses regarding head of bed elevation and aspiration was less expensive and was effective at preventing aspirations. The average person resides in a skilled nursing facility for 3 years, and it is likely that a cancer survivor will accrue more comorbidities that will extend that stay another year. Thus, in the long term, skilled nursing facilities with residents who have survived cancer are likely to have reduced costs if their staff implements a best practice program now. The interventional protocol dominated the usual care protocol, confirming that the usual care regimen used in many skilled nursing facilities is expensive and less effective at preventing aspirations.4,13 When all parameters were simultaneously varied, sensitivity analyses indicated that the interventional program was the most cost effective at nearly all probabilities of effectiveness. The magnitude of the probability of no aspirations (ie, effectiveness) of such a best practice program was the most significant factor impacting the results of the cost-effectiveness analysis.

In the medical literature, patients with cancer and survivors of cancer alike are at higher risk for dysphagia, aspiration, and related consequences than their counterparts.18,19 Chemotherapy and radiotherapy are major risk factors for increasing dysphagia, which can lead to aspiration, and patients with head and neck cancers are at a higher risk for dysphagia.20 For example, in a cohort of 3,513 elderly patients with head and neck cancers who were treated with chemoradiotherapy, 801 (24%) had an aspiration and related pneumonia.18 In the setting of head and neck cancers, aspiration-related pneumonia also results in increased mortality by 42%.18

Head of bed elevation has been shown to have a major impact on the prevention of aspiration, health care–associated infections, and ventilator-associated pneumonia.4,12-15 Evidence-based, clinical practice guidelines indicate that keeping head of bed elevation at a 30- to 45-degree angle reduces the probability of aspiration, especially in patients receiving enteral tube feeding.4,12-15 Similar findings have been reported by the Institute for Clinical Systems Improvement.21 The Institute of Healthcare Improvement has recommended a series of aspiration risk-reduction interventions, known as the ventilator bundle, that include head of bed elevation greater than 45 degrees, sedation to reduce extubation, and prophylaxes for peptic ulcer and deep venous thrombosis.22

Although other studies have evaluated the effectiveness and viability of head of bed evaluation interventions in nursing homes, a dearth of evidence exists regarding the cost effectiveness of aspiration-reduction interventions, nor have rigorous cost analyses been performed.12,13 I am not aware of any published cost analyses of aspiration reduction interventions prior to this study.

This study has several limitations. Because it was not feasible to obtain large sample sizes in skilled nursing facilities, many of the values used are from published studies with smaller sample sizes.12,13 In addition, skilled nursing facilities have relatively high dropout rates. Due to the 1-year time frame, follow-up costs were not included in the cost analysis. The variability in the number of aspirations parameter may partially be accounted for in the differences in measurements previously published elsewhere.12,13

Future research should include total parental nutrition and other nutrition methods in cancer care, as well as alternative methods for reducing aspiration in elderly cancer survivors residing in skilled nursing facilities as comparison for cost-effectiveness analyses. In addition, more empirical work on the feasibility and costs of aspiration-related interventions would be useful, as would research to help standardize the use of aspiration intervention-related outcome measures such as aspirations.
per 100 bed days, gastric residual volume, pepsin positive reactions, and probability of aspiration. In addition, aspiration-reduction interventions should be evaluated along with other conditions (eg, bedsores, oral health interventions) and guidelines for cancer survivors, as this should increase the value of training.19

Conclusions
These results demonstrate the cost effectiveness of the intervention protocol relative to usual care.4 Hopefully, these results will encourage administrators at skilled nursing facilities to consider implementing aspiration risk-reduction protocols for their elderly residents who have survived cancer.

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References