Published in final edited form as:
J Bronchology Interv Pulmonol. 2012 October ; 19(4): 294–303. doi:10.1097/LBR.0b013e318272157d.

Navigational Bronchoscopy with Biopsy versus CT-guided Biopsy for the Diagnosis of a Solitary Pulmonary Nodule: A Cost-Consequences Analysis

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Abstract

Background—Solitary pulmonary nodules (SPN) are frequent and can be malignant. Both CT-guided biopsy and electromagnetic navigational bronchoscopy (ENB) with biopsy can be used to diagnose a SPN. A non-diagnostic CT-guided or ENB biopsy is often followed by VATS biopsy. The relative costs and consequences of these strategies are not known.

Methods—A decision tree was created with values from the literature to evaluate the clinical consequences and societal costs of a CT-guided biopsy strategy versus an ENB biopsy strategy for the diagnosis of a SPN. The serial use of ENB after non-diagnostic CT-guided biopsy and CT-guided biopsy after non-diagnostic ENB biopsy were tested as alternate strategies.

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The authors all attest that they do not have any potential or actual personal or financial involvement with any company or organization with financial interest in the subject matter.

Author contributions:
Dr. Dale: Served as primary author, conceived and designed the study protocol, collected and analyzed all the data and wrote the manuscript and its revisions and approved the final version of the manuscript.
Dr. Madtes: Assisted with design of the study protocol and analysis, reviewed the manuscript and approved the final version of the manuscript.
Dr. Fan: Assisted with design of the study protocol and analysis, reviewed the manuscript and approved the final version of the manuscript.
Dr. Gorden: Assisted with design of the study protocol, reviewed the manuscript and approved the final version of the manuscript.
Dr. Veenstra: Assisted with the design of the protocol and analysis, reviewed the manuscript and approved the final version of the manuscript.

Results—In a hypothetical cohort of 100 patients, use of the ENB biopsy strategy on average results in 13.4 fewer pneumothoraces, 5.9 fewer chest tubes, 0.9 fewer significant hemorrhage episodes and 0.6 fewer respiratory failure episodes than a CT-guided biopsy strategy. ENB biopsy increases average costs by $3719 per case and increases video assisted thorascopic surgery (VATS) rates by an absolute 20%. The sequential diagnostic strategy that combines CT-guided biopsy after non-diagnostic ENB biopsy and vice-versa decreases the rate of VATS procedures to 3%. A sequential approach starting with ENB decreases average per case cost relative to CT-guided biopsy followed by VATS, if needed, by $507; and a sequential approach starting with CT-guided biopsy decreases the cost relative to CT-guided biopsy followed by VATS, if needed, by $979.

Conclusions—An ENB with biopsy strategy is associated with decreased pneumothorax rate but increased costs and increased use of VATS. Combining CT-guided biopsy and ENB with biopsy serially can decrease costs and complications.

Introduction

Abnormal chest CT scans are a common finding in pulmonary practice. In a population of high-risk individuals screened for lung cancer, over 25% of patients had an abnormal chest CT scan.[1–3] The probability of malignancy in an abnormal chest CT depends upon the characteristics of the abnormality and the patient's clinical characteristics, such as age and smoking status, and range 0 to 80%.[4] Many solitary pulmonary nodules (SPN) contain non-small cell lung cancer (NSCLC), the most common type of lung cancer, and the larger the nodule, the more likely it is to contain cancer.[3] As the early detection and resection of NSCLC has been shown to improve survival, prompt diagnosis and treatment of the SPN is vitally important.[1]

The probability of malignancy of a SPN may be estimated using existing models.[2,5] If high, generally a probability of malignancy in excess of 60%, the American College of Chest Physicians clinical practice guidelines for the evaluation of patients with pulmonary nodules recommends going directly to surgical resection for both diagnostic and therapeutic reasons, either with video-assisted thorascopic surgery (VATS) or an open surgical procedure.[3,6] This approach is expensive and commits the patient to the morbidity associated with VATS procedure but does have a very high likelihood of securing the diagnosis of NSCLC if it is present.[7] Alternately, if the probability of malignancy is low, serial CT scans to monitor for increase in the size of the lesion over time is the preferred strategy.[5–7] The management strategy for the SPN with an intermediate probability of malignancy or for patients with a high surgical risk frequently involves biopsy of the lesion, although the optimal biopsy approach has not been determined.

One diagnostic strategy is CT-guided biopsy which, is 81–97% sensitive for the diagnosis of NSCLC.[5,10] CT-guided biopsies, however, are associated with a pneumothorax rate of approximately 15%, over 40% of which require a chest tube to manage.[11] This has led some to search for a better diagnostic technology.

Electromagnetic navigational bronchoscopy (ENB) with transbronchial biopsy is an increasingly common alternative technology for the diagnosis of the SPN. Navigational bronchoscopy has emerged as a technology that improves the sensitivity of conventional bronchoscopy.[12–14] The technology has been reviewed elsewhere and increases the sensitivity of transbronchial biopsy to approximately 70% and it is associated with a low risk of complications, including approximately a 1.6% pneumothorax rate.[14,15] It is, however, a new technology that is relatively expensive and its role in the multidisciplinary approach to the diagnosis of the SPN is not certain. Either CT-guided or ENB strategies may

result in a non-diagnostic biopsy results, and if a patient is a surgical candidate VATS resection of the SPN is often performed to obtain a definitive diagnosis.[16,17]

Both the NCCN and UK NICE guidelines for the evaluation and treatment of lung cancer recommend a team-oriented, multidisciplinary approach.[18,19] Multidisciplinary teams have been shown to improve guideline adherence and process measures of quality.[20–22] New and evolving diagnostic technologies might be best studied and implemented within a comprehensive, multidisciplinary thoracic oncology program where greater attention could be focused on how the technology is deployed in the nodule evaluation algorithm.[23]

We performed a cost-consequences analysis to understand the clinical consequences and cost differences of a CT-guided biopsy strategy versus an ENB biopsy strategy for the diagnosis of a SPN with an intermediate probability of NSCLC.

Methods

We created a decision model to evaluate the costs associated with both ENB with transbronchial biopsy versus CT-guided biopsy for the diagnosis of a SPN (Figure 1). A limited societal perspective was used, and indirect costs were thought to be negligible and similar between the two arms and were not included in the study. The inflation rate was estimated at 3%.[24]

Clinical Inputs

The base case was 65 year-old with a > 40 pack-year smoking history with a 2 cm SPN. Such SPN would have approximately a 60% chance of malignancy.[2,25] We assumed that there were no other features, radiographic or otherwise, to signal that there might be more advanced disease. Additionally, we assumed that if a positron emission tomography (PET) scan were obtained prior to the biopsy, it would only affect the pretest probability of malignancy and not the operating characteristics of either diagnostic technology. The decision tree did not address the possibility of watchful waiting or follow-up imaging at a future time point, as it was assumed that a tissue diagnosis was desired. Additionally, the location of the lesion within the chest or relative to an airway was not considered separately from the effects that those lesion features would have on the sensitivity of the two diagnostic technologies.

The first node on the decision tree represents the choice between ENB biopsy (upper path) and CT-guided biopsy (lower path).[5,6,26] In the base case scenario, it was assumed that all non-diagnostic ENB and CT-guided biopsy attempts were sent directly to VATS for a diagnostic excisional biopsy.[16,17] The decision tree shown in Figure 1 includes the possibility of performing the other technology if the first biopsy were non-diagnostic (ENB biopsy if CT-guided biopsy were performed first or CT-guided biopsy if ENB were performed first). However, in the base case the serial use of diagnostic testing was assumed to be zero and all patients with non-diagnostic biopsies went onto VATS.

In our secondary analysis, we increased the rate of serial testing in both arms to 100%, so that patients in the ENB arm who had a non-diagnostic ENB biopsy all went onto CT-guided biopsy. Similarly, patients in the CT-guided biopsy arm with a non-diagnostic CT-guided biopsy all went on ENB biopsy.

There are three main significant complications that can befall patients with either of these diagnostic technologies (Table 1).[11,15] The first is pneumothorax, which occurs in approximately 15% of CT-guided biopsies and 1.6% of ENB biopsies. Approximately 56% of the time the pneumothorax resolves without further intervention. Chest tube placement

and an observation stay in the hospital are required in approximate 44% of pneumothoraces, a number that is independent of the diagnostic technology that produced the pneumothorax.[11,15,27]

The second significant complication is clinically significant hemorrhage requiring hospitalization. This can either be in the airway (more common with navigational bronchoscopy with biopsy) or around the lung (more common with CT-guided biopsy) and occurs in approximately 1% of CT-guided biopsies and 0.1% of ENB biopsies.[11,15] The final significant common complication captured by our decision tree is respiratory failure requiring hospitalization, and possibly mechanical ventilation. This occurs in approximately 1% of CT-guided biopsies and 0.1% of ENB biopsies.[11,15]

Baseline and peri-procedural and complication utilities were all obtained from the literature.

Cost Inputs

The costs were obtained from the literature, the American Medical Association and private coding websites and are national Medicare reimbursement rates expressed in 2011 dollars. For patients with two or more complications requiring hospitalization, the most expensive of the conditions subsumed the hospitalization costs of the other complications. A range of +/− 50% of values was used in the sensitivity analysis unless the numbers were clinically implausible.

The model did not include the cost of treating the ultimate diagnosis, be it either cancer or an unspecified benign condition, nor did it include any of the costs of the imaging done to evaluate the SPN prior to the diagnostic procedure. We assumed that there were no ultimate false-positive or false-negative results. An initial positive biopsy for either cancer or a non-cancerous cause by either CT or navigational bronchoscopy was not confirmed with VATS in accordance with practice patterns and the literature.[28]

One-way and multivariable sensitivity analyses were performed and multiple one-way sensitivity analyses were plotted on a tornado diagram. Monte Carlo simulations with 10^4 iterations in the base case and in the secondary serial testing analysis were performed to allow multi-variable sensitivity analysis and to estimate the 95% central cost range. All analyses were carried out in TreeAge Pro 2011 (TreeAge Software, Inc., Williamstown, MA 01296).

Results

Results from the base case analysis and the alternate serial testing scenarios are both shown in Table 3. Both models had the same final probability of diagnosis in accordance with the assumption that there were no false positive or false negative diagnoses and that initial non-diagnostic biopsies went on to additional testing. In the base case scenario, the ENB with biopsy strategy was associated with a 20% increased rate of VATS surgery compared with the CT-guided biopsy strategy (30.0 per 100 patients versus 10.0 per 100 patients). The ENB biopsy strategy, however, was associated with fewer complications. For every 100 ENB procedures, 13.4 fewer pneumothoraces were produced and 5.9 fewer chest tubes were placed compared to CT-guided biopsy. Additionally, 0.9 fewer hemorrhages and 0.6 fewer cases of respiratory failure occurred.

The costs were greater in the ENB biopsy strategy. In the base case scenario, the ENB with biopsy strategy was on average $3719 per patient more expensive than the CT-guided biopsy strategy. Mean costs per biopsy were $6633 (95% CI $1518–18,511) vs. $2913 (95% CI $1248–18,241) in the ENB and CT-guided arms, respectively.

Figure 2 shows the tornado diagram of the univariate sensitivity analyses. Costs were most influenced by the sensitivity of the CT-guided biopsy. Given that a VATS procedure cost $16,993, a decrease in the sensitivity of the CT-guided biopsy led to an increase number of VATS procedures and greater costs. In fact, the cost of the VATS procedure itself is the second factor in the tornado diagram, highlighting its direct role in overall costs. The third factor in the tornado diagram is the probability of performing an ENB biopsy after a non-diagnostic CT-guided biopsy, assumed to be zero in the base case scenario.

The impact of the sequential use of diagnostic technologies is seen in the serial biopsy strategy shown in Table 3. If the use of CT-guided biopsy after non-diagnostic ENB biopsy (or conversely ENB biopsy after non-diagnostic CT-guided biopsy) were to increase from 0% in the base case scenario to 100%, use of VATS then falls to 3% in either arm. As expected, the rate of other complications increases in both arms with a sequential approach. For example, the rate of pneumothorax in the ENB-first arm increases by 4.5 per 100 patients to 6.1 from 1.6 per 100 patients.

Costs are decreased in both arms in the serial biopsy strategy. The average cost of the ENB biopsy strategy falls to $2406 (95% CI $1518–19,759) from $6633 (95% CI $1518–18,511), a savings of $4227 or 64%. Similarly, the average cost of the CT-guided biopsy strategy decreases by $978 or 34% to $1934 (95% CI $1248–19,759) from $2913 (95% $1248–18,241). In two-way sensitivity analysis, where two parameters are varied simultaneously, exploring the cost of the diagnostic strategies, we found an inverse linear relationship between the sensitivity of the CT-guided biopsy and the ENB biopsy (Figure 3). For example, if ENB biopsy were to have a sensitivity of 95% or greater, it would be the less-expensive strategy if the sensitivity of CT-guided biopsy were less than 93.4%.

Additional two-way sensitivity analysis revealed a curvilinear relationship between the sensitivity of either CT-guided or ENB biopsy and the probability of using the alternate diagnostic technology after an initial non-diagnostic biopsy and the overall cost. Figure 4 demonstrates the decreasing sensitivity of CT-guided biopsy needed to make it the less expensive technology as the probability of performing ENB after a non-diagnostic CT-guided biopsy increases from zero (the base case scenario) to 1 (the serial biopsy scenario). For example, if the sensitivity of the CT-guided biopsy were 85% and VATS procedures were to follow all non-diagnostic CT-guided biopsies, ENB biopsy would be the less expensive strategy. However, if all non-diagnostic CT-guided biopsies were followed by ENB biopsy and not by VATS, not only do overall costs decrease, but the same CT-guided biopsy with 85% sensitivity would be less expensive than ENB. This shows that the likelihood of following one diagnostic technology with the other, in series, has an effect on overall costs as well as the relative sensitivities at which one of the diagnostic technologies is preferred.

Calculation of cost per Quality-Adjusted Life Year (QALY) allows comparison of the relative value of various diagnostic or therapeutic interventions. In an attempt to construct a QALY analysis we evaluated the differences in utility (the numerator in QALY analyses, where, by definition, one year in perfect health has a utility of 1) based on published literature values. The baseline utility in our base case is approximately 0.84 to 0.88.[29,30] The utilities associated with VATS and the various complications are similar: VATS (0.73 to 0.88), mechanical ventilation (0.76), pneumothorax (0.63) and relatively short-lived.[30–35] Assuming two-week duration of disutility, an ENB-based strategy in the base case scenario would result in a loss of 0.002 QALY/person. Similarly, an ENB-based strategy in the serial biopsy scenario would experience a gain of 0.0009 QALY/person. Both of these values are significantly smaller than the precision of the QALY measurements themselves.

Discussion

Electromagnetic navigation bronchoscopy is a relatively new technology that is associated with a decreased risk of pneumothorax and other complications versus the competing diagnostic technology, CT-guided biopsy, for the diagnosis of the solitary pulmonary nodule. The decrease in number of pneumothoraces, chest tubes, cases of hemorrhage and respiratory failure seen with the ENB biopsy strategy, however, comes at a cost of an increased rate of VATS surgery and at an increased cost.

The average greater cost of ENB ($3719 additional cost/biopsy) vs. CT-guided biopsy is largely driven by the high sensitivity of CT-guided biopsy and the need to use an alternate diagnostic technology to secure a diagnosis after a non-diagnostic ENB biopsy. Several factors have been reported to impact the sensitivities of ENB and CT-guided biopsies, like the “bronchus sign,” size of the lesion and location of the lesion within the chest.[15,36–39] These factors exert their influence on the relative sensitivities of ENB and CT-guided biopsies and were not considered individually.

Many of the studies performed when a new diagnostic technology emerges on the market look to define its operating characteristics, particularly its sensitivity and specificity relative to a current technology or a gold standard.[15–17] In practice, diagnostic tests are often not used in isolation. Rather providers often seek to combine diagnostic tests to maximize certain parameters of their operating characteristics.

Combining two or more tests in series serves to increase the sensitivity of the combined tests over each of the tests individually. Given that ENB and CT-guided biopsy have similar sensitivities for both benign and malignant disease, the combined serial sensitivity is: 1 − (1 − Sensitivity[CT-guided])*(1 − Sensitivity[ENB]).[15,27] The 3% serial non-diagnosis rate, and therefore VATS rate, is predicted by this formula. Such a combination assumes that there are no false-positives for either malignant or benign diagnoses.

PET scans are often obtained to evaluate the SPN, and a lesion that is PET avid has a higher post-test probability of cancer. We chose not to include PET scan status in our model explicitly because we felt that the PET result exerted its effects via the pre-test probability of malignancy. As shown in Figure 2, the costs of both the CT-guided biopsy strategy and the ENB biopsy strategy were relatively insensitive to the pre-test probability of disease.

We did not include a watchful waiting arm in our decision tree. Because biopsies have similar sensitivities for both benign and malignant disease, the post-test probability of malignancy is not significantly decreased by a non-diagnostic biopsy.[15,27] Additionally, both the patient and the provider have a revealed preference to obtain a diagnosis by virtue of the fact that they chose to undergo a diagnostic procedure.[5,6,40] We did not evaluate equivocal biopsy results (e.g. “inflammation suggestive of a granuloma”), which would change the post-test probability of malignancy and could lead to a watchful waiting strategy.

Additional limitations include a lack of primary patient-level data and a reliance on literature values that might not be generalizable to all patient populations. Costs are given as Medicare costs and might not generalize to other countries, nor do they represent the cost to individual patients or health care systems.

We did not conduct a formal cost-utility analysis. The changes in QALY were small between the two arms. This was driven largely by the study design which considered only the peri-biopsy period and did allow for different long-term QALY states. Additionally, given the range of utility reported in the literature for the various health states considered,

we did not feel that without patient level utility data that we could adequately comment on differences that were small in comparison to the precision of the measurements.

The context within which a diagnostic technology is used is an area that merits future study. We have shown that the costs and consequences of CT-guided biopsy and ENB biopsy are quite different depending upon how these technologies are used in the evaluation of the SPN in ways that go beyond their simple cost and sensitivity. Future work should focus on understanding the multidisciplinary environment in which the evaluation of malignancy occurs, including organizational factors like a “multi-disciplinary nodule clinic” on resource utilization and patient-centered outcomes. Additionally, provider and patient preference should be incorporated in decision analysis to understand why and in what circumstances providers and patients choose one diagnostic technology over another.

Conclusion

The use of navigational bronchoscopy with biopsy in preference to CT-guided biopsy of the SPN results in fewer episodes of pneumothorax, hemorrhage and respiratory failure, but increases average costs by $3719 per case and is associated with a 20% absolute increase in VATS procedure rates. A diagnostic strategy that combines CT-guided biopsy and ENB biopsy in series decreases the rate of VATS procedures and decreases costs. An ENB-first sequential biopsy approach decreases average per case cost relative to CT-guided biopsy alone by $507. A CT-biopsy-first sequential biopsy approach decreases cost by $978 per case compared to CT-guided biopsy alone.

Acknowledgments

This work was supported by the National Institutes of Health [Grant T32 HL07287].

Abbreviation List

SPN	Solitary pulmonary nodule
NSCLC	Non-small cell lung cancer
VATS	Video-assisted thorascopic surgery
CT	Computed tomography
ENB	Electromagnetic navigational bronchoscopy
QALY	Quality-Adjusted Life Year

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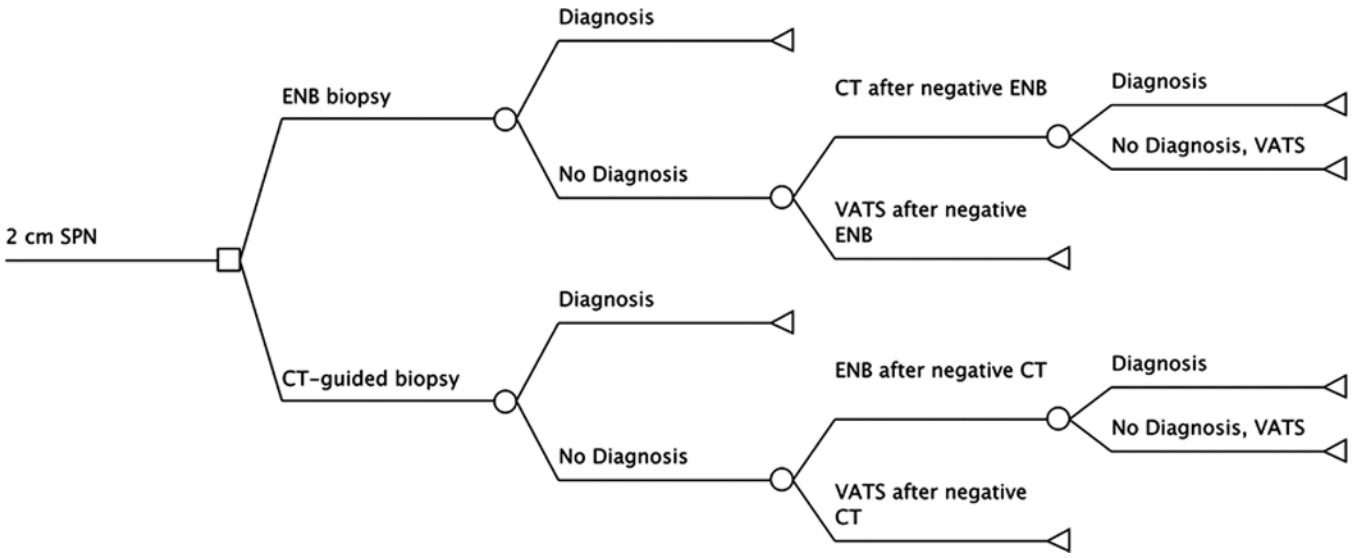

Figure 1.
Decision tree of navigational bronchoscopy with biopsy versus CT-guided biopsy of a 2 cm solitary pulmonary nodule. In the base case scenario, all initial non-diagnostic biopsies went directly to VATS.

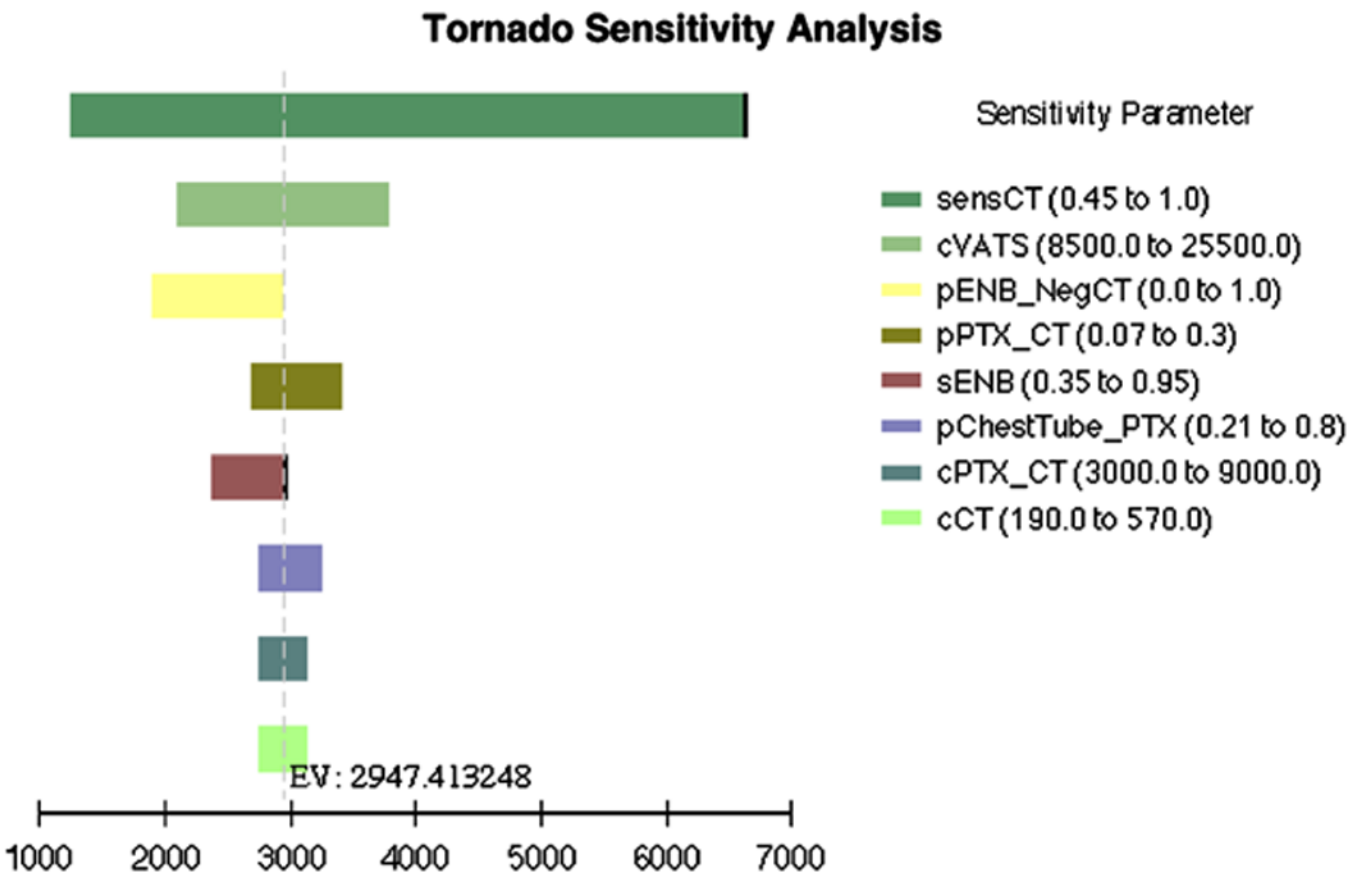

Figure 2.

Tornado diagram of the effects of model parameters on the cost of CT-guided and ENB biopsies in the base case scenario of a VATS resection after a non-diagnostic CT-guided or ENB biopsy. The parameters varied are, in order, Sensitivity of a CT-guided biopsy; Cost of a VATS procedure; Probability of ENB-biopsy after a non-diagnostic CT-guided biopsy; Probability of a pneumothorax with a CT-guided biopsy; Sensitivity of a ENB biopsy; probability of a chest tube insertion given a pneumothorax; Cost of a pneumothorax treated with a chest tube; cost of a CT-guided biopsy. The range tested is shown in parenthesis. The "EV" noted at the bottom of the figures shows the expected cost of a diagnosis in the base case scenario.

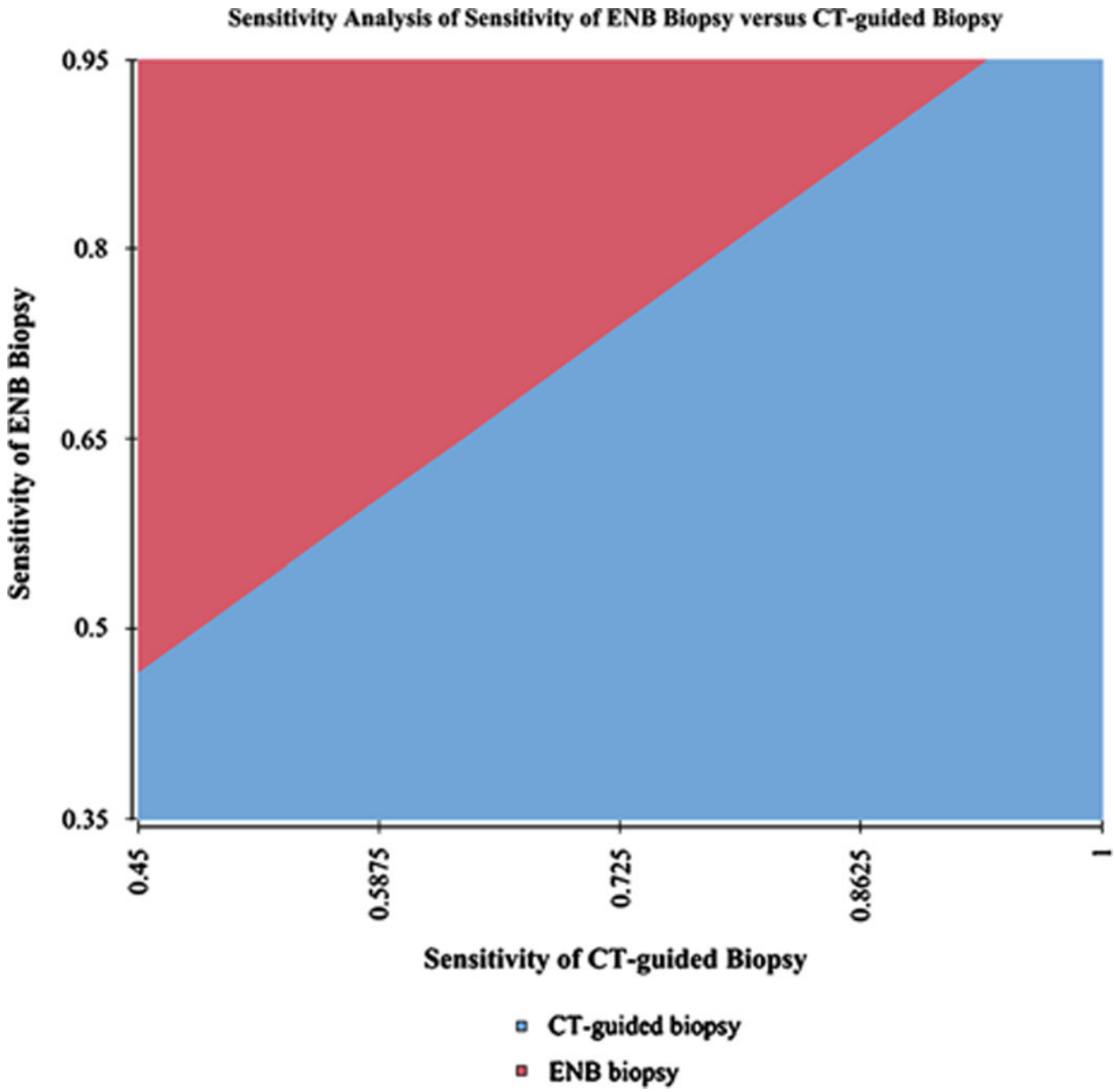

Figure 3.

Sensitivity analysis of CT-guided biopsy versus ENB biopsy (dark grey) for the diagnosis of SPN. The light grey region corresponds to sensitivities of CT-guided biopsy and ENB biopsy where CT-guided biopsy is the less expensive technology. The dark grey region corresponds to sensitivities of CT-guided biopsy and ENB biopsy where ENB biopsy is the less expensive technology.

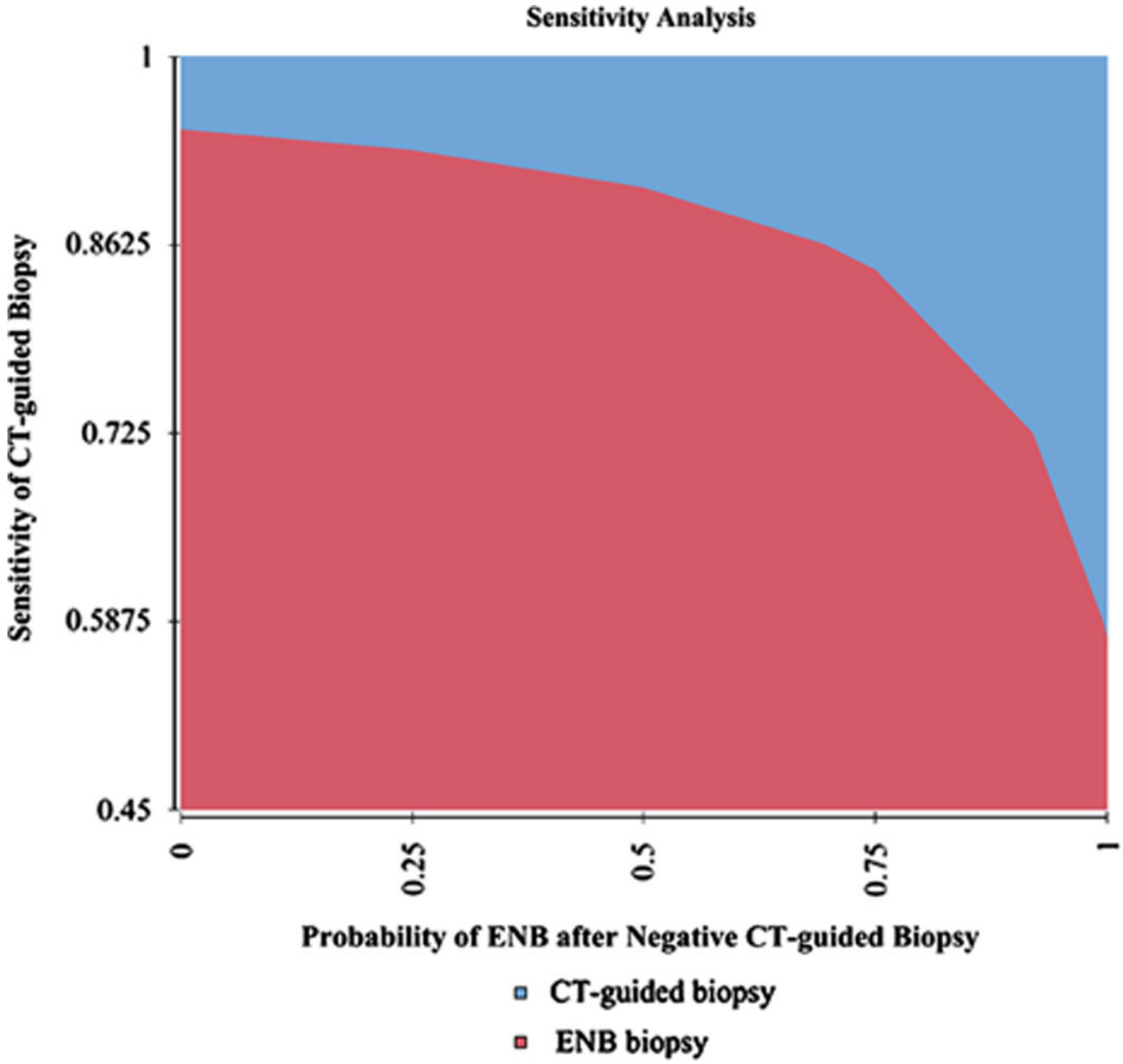

Figure 4.

Two-way sensitivity analysis showing the relationship between the sensitivity of a CT-guided biopsy of a SPN versus the probability of obtaining an ENB biopsy of the SPN if the initial CT-guided biopsy was negative. The light grey region shows the relative probabilities where the CT-guided biopsy is the less expensive technology. The dark grey region corresponds to where ENB biopsy is the less expensive technology.

Table 1

Probability estimates used in decision tree analysis.

Variable assumption	Base-case estimate	Range tested	Reference
Navigational bronchoscopy with biopsy, sensitivity	0.70	0.35 to 0.95	5, 15, 33, 41
Navigational bronchoscopy done with general anesthesia	1.0	0 to 1	41, 46, 47
CT-guided biopsy, sensitivity	0.90	0.45 to 0.99	5, 11, 30
CT-guided biopsy, pneumothorax	0.15	0.07 to 0.30	11, 15, 30, 41
CT-guided biopsy, fraction of pneumothoraces requiring chest tube placement	0.44	0.22 to 0.99	11, 15, 41
CT-guided biopsy, clinically significant bleed given pneumothorax with a chest tube	0.01	0.005 to 0.02	11
CT-guided biopsy, clinically significant bleed given pneumothorax without a chest tube	0.01	0.005 to 0.02	11
CT-guided biopsy, clinically significant bleed given no pneumothorax	0.01	0.005 to 0.02	11
CT-guided biopsy, respiratory failure, given any pneumothorax	0.008	0.004 to 0.02	11
CT-guided biopsy, respiratory failure, given pneumothorax with chest tube	0.014	0.001 to 0.029	11
CT-guided biopsy, respiratory failure, given hemorrhage	0.043	0.02 to 0.09	11
CT-guided biopsy, respiratory failure, given no complications	0.006	0.003 to 0.012	11
Navigational bronchoscopy with biopsy, pneumothorax	0.016	0.008 to 0.058	4, 15, 41, 46
Navigational bronchoscopy with biopsy, fraction of pneumothoraces requiring chest tube placement	0.44	0.21 to 0.80	4, 15, 41
Navigational bronchoscopy with biopsy, clinically significant bleed given pneumothorax with a chest tube	0.001	0.0005 to 0.002	15
Navigational bronchoscopy with biopsy, clinically significant bleed given pneumothorax without a chest tube	0.001	0.0005 to 0.002	15
Navigational bronchoscopy with biopsy, clinically significant bleed given no pneumothorax	0.001	0.0005 to 0.002	15
Navigational bronchoscopy with biopsy, respiratory failure, given any pneumothorax	0.001	0.0005 to 0.002	15
Navigational bronchoscopy with biopsy, respiratory failure, given pneumothorax with chest tube	0.002	0.001 to 0.004	15
Navigational bronchoscopy with biopsy, respiratory failure, given hemorrhage	0.006	0.003 to 0.012	15
Navigational bronchoscopy with biopsy, respiratory failure, given no complications	0.001	0.0005 to 0.002	15

Table 2

Costs used in decision tree analysis.

Variable	Definition	Total Cost (2011 Dollars)	Reference
CT-guided biopsy	CPT 77012, 32405, 88172, 88173	571	42, 44, 48
Navigational bronchoscopy with biopsy	CPT 31627, 31628, 88172, 88173, APC 076	1228	42–45, 48–50
Pneumothorax requiring observation	CPT 99220, 99217, APC 616	557	42, 44, 45
Pneumothorax requiring chest tube and hospitalization	CPT 99223, 99233, 99238, MS-DRG 200	5844	42, 44, 45
Significant hemorrhage requiring hospitalization	CPT 99223, 99233, 99238, MS-DRG 167	11,751	42, 44, 45
Respiratory failure	CPT 99223, 99233, 99238, MS-DRG 208	12,928	42, 44, 45
Video-assisted thorascopic surgery (VATS)	Includes professional fee cost	16,993	42, 46
Anesthesia professional services	Base code 00520 + 1 hour (4 units) of anesthesia time = 10 ASA units	216	42, 44, 47

Table 3

Estimates based on a Monte Carlo simulation of costs and consequences of navigational bronchoscopy with biopsy versus CT-guided biopsies of a solitary pulmonary nodule. In the base case all patients with a non-diagnostic ENB biopsy go on to VATS wedge resection. In the alternate scenario, all patients with a negative navigational bronchoscopy biopsy then go onto a CT-guided biopsy.

Base Case (VATS after non-diagnostic biopsy)		
Estimates per 100 cases	Navigational bronchoscopy strategy	CT-guided biopsy strategy
Total Cost ($), mean (SD)	663, 278 (779,457)	291,343 (505,227)
Pneumothorax/100 cases, n	1.6	15.0
Chest tube/100 cases	0.7	6.6
Significant hemorrhage/100 cases	0.1	1.0
Respiratory failure/100 cases	0.1	0.7
VATS cases/100 cases	30.0	10.0
Serial Biopsy Strategy (ENB biopsy after non-diagnostic CT-guided biopsy and CT-guided biopsy after negative ENB biopsy)		
Estimates per 100 cases	Navigational bronchoscopy strategy	CT-guided biopsy strategy
Total Cost ($), mean (SD)	240,621 (311,637)	193,494 (322,257)
Pneumothorax/100 cases, n	6.1	15.2
Chest tube/100 cases	2.7	6.7
Significant hemorrhage/100 cases	0.4	1.0
Respiratory failure/100 cases	0.3	0.7
VATS cases/100 cases	3.0	3.0