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Implementing Endobronchial Ultrasound-Guided (EBUS) for Staging and Diagnosis of Lung Cancer: A Cost Analysis

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

BCDEF 1 Catalina Lizama
ABDEF 1 Neli S. Slavova-Azmanova
AD 2 Martin Phillips
C 3 Michelle L. Trevenen
AD 4 Ian W. Li
ACDE 1 Claire E. Johnson

1 Cancer and Palliative Care Research and Evaluation Unit, School of Surgery, University of Western Australia (UWA), Crawley, WA, Australia
2 Department of Respiratory, Sir Charles Gairdner Hospital, Nedlands WA, Australia
3 Centre for Applied Statistics, University of Western Australia (UWA), Crawley, WA, Australia
4 School of Population and Public Health, University of Western Australia (UWA), Crawley, WA, Australia

Corresponding Author: Catalina Lizama, e-mail: Catalina.lizama@telethonkids.org.au
Source of support: Departmental sources

Background: Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) and guide sheath (EBUS-GS) are gaining popularity for diagnosis and staging of lung cancer compared to CT-guided transthoracic needle aspiration (CT-TTNA), blind fiber-optic bronchoscopy, and mediastinoscopy. This paper aimed to examine predictors of higher costs for diagnosing and staging lung cancer, and to assess the effect of EBUS techniques on hospital cost.

Material/Methods: Hospital costs for diagnosis and staging of new primary lung cancer patients presenting in 2007–2008 and 2010–2011 were reviewed retrospectively. Multiple linear regression was used to determine relationships with hospital cost.

Results: We reviewed 560 lung cancer patient records; 100 EBUS procedures were performed on 90 patients. Higher hospital costs were associated with: EBUS-TBNA performed ($p<0.0001$); increasing inpatient length of stay ($p<0.0001$); increasing number of other surgical/diagnostic procedures ($p<0.0001$); whether the date of management decision fell within an inpatient visit ($p<0.0001$); and if the patient did not have a CT-TTNA, then costs increased as the number of imaging events increased (interaction $p<0.0001$). Cohort was not significantly related to cost. Location of the procedure (outside *vs.* inside theater) was a predictor of lower one-day EBUS costs ($p<0.0001$). Cost modelling revealed potential cost saving of $1506 per EBUS patient if all EBUS procedures were performed outside rather than in the theater ($66,259 per annum).

Conclusions: EBUS-TBNA only was an independent predictor of higher cost for diagnosis and staging of lung cancer. Performing EBUS outside compared to in the theater may lower costs for one-day procedures; potential future savings are considerable if more EBUS procedures could be performed outside the operating theater.

MeSH Keywords: Costs and Cost Analysis • Diagnostic Techniques, Respiratory System • Endoscopic Ultrasound-Guided Fine Needle Aspiration • Lung Neoplasms • Neoplasm Staging

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Background

Endobronchial ultrasound-guided (EBUS) procedures are a relatively new technique used for the staging and diagnosis of lung cancer. EBUS performed under guide sheath (GS) potentially replaces CT-guided transthoracic needle aspiration (CT-TTNA) due to its ability to sample peripheral pulmonary lesions, while transbronchial needle aspiration (TBNA) EBUS may be performed for both diagnosis of centrally located intrapulmonary lesions and/or hilar and mediastinal lymph node staging of lung cancer. Where multiple procedures were previously required – including fiber-optic bronchoscopies (FBs) and CT-TTNA for diagnosis, and mediastinoscopy for staging – EBUS-TBNA has the potential to replace and/or combine multiple diagnostic and staging procedures into a single procedure.

From a clinical perspective, EBUS-TBNA has many advantages for patients with suspected mediastinal and hilar lymph node involvement: it has a low complication rate [1], is well-tolerated by patients [2], produces higher yields than conventional TBNA [3], avoids 93% of the more invasive criterion standard mediastinoscopy, [4] yet performs as well as mediastinoscopy [3,5]. From a cost perspective, some evidence highlights EBUS-TBNA's advantages: a projected cost analysis estimates significant cost savings following the introduction of an EBUS-TBNA service [6], and further research has demonstrated EBUS-TBNA to be cost-beneficial compared to both FB [7] and mediastinoscopy in decision-tree analysis [8,9]. In theory, EBUS-TBNA would be expected to be the most economical option if it is able to combine both diagnosis and staging into a single procedure and replace what previously required 2 procedures.

EBUS-GS primarily replaces CT-TTNAs for diagnosis of peripheral lung lesions, and is comparable when considering the cost of each as 1-day cases [10]. However, decision-tree modelling yields somewhat less definitive results, with Ang et al. finding EBUS-GS to be more expensive than either CT-TTNA or FB for diagnosis of lung cancer [9]. Further decision-tree modelling by Steinfort et al. notes that, given the high rate of complications associated with CT-TTNA, the costs of complication at different institutions will likely affect the threshold at which CT-TTNAs become more or less economical than EBUS-GS [10]. Little other research has been conducted on cost benefits of EBUS-GS.

Given the advantages and disadvantages of the range of procedures for diagnosis and staging of lung cancer, as well as the variability and complexity of diagnostic pathways for different patients, the introduction of EBUS procedures at an institution may lead to a shift in various aspects of clinical and cost outcomes [11]. Furthermore, there is limited research examining costing of EBUS procedures when implemented into practice. Our study sought to determine if the introduction of both EBUS-TBNA and EBUS-GS as routine practice at a tertiary hospital impacted the cost of diagnosis and staging of lung cancer from a hospital perspective, and to determine potential cost savings associated with the location in which the procedures were performed.

Material and Methods

This was a retrospective pre-post study of all new cases of primary lung cancer presenting at a tertiary hospital in Western Australia (N=560) between 1 January 2007 and 31 December 2008 (Pre-EBUS cohort) and between 1 January 2010 and 31 December 2011 (Post-EBUS cohort) as recently described [11]. EBUS was introduced at the hospital at the end of 2008. The typical care pathway in our institution involved initial imaging with x-ray/CT, followed by invasive investigations for pathological sampling; staging was conducted via review of PET images. In the majority of cases, results of a PET scan guided recommendations for an EBUS-TBNA investigation.

Diagnostic procedures

Data on diagnostic procedures were collected via internal hospital databases, and are explained elsewhere [11]. Both EBUS-TBNA and -GS were performed under general anaesthesia or moderate sedation. A pathologist provided rapid on-site evaluation (ROSE) on EBUS-TBNA samples. The site and number of lymph node stations sampled and the number of passes per lymph node were determined by the operator. At least 3 needle passes were made per lymph node unless the diagnostic material was reported adequate on ROSE. EBUS procedures were conducted by 2 experienced operators. FB was recorded if a pathology report from bronchoscopy with any of the following samples was reported: washing, brushing, tissue biopsy from the lung or airways, or TBNA from a lymph node or a hilar/mediastinal mass.

Costs

Costs for all items were obtained from the hospital Finance Department and reflect internal evaluation of costs; these costs were adjusted to 2015 Australian dollars based on health index prices published by the Australian Bureau of Statistics [12]. Costs were divided into imaging costs, outpatient costs, inpatient costs at our hospital, and costs for invasive investigations occurring at other hospitals (Table 1). Date of management decision was defined as the date of the lung cancer Multidisciplinary Team meeting when diagnosis was established and/or the initial treatment decision was made; only patients' costs from the date of first presentation at the hospital until the date of management decision were included and any costs not directly related to the lung cancer diagnosis were excluded.

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Table 1. Cost types, sources, and limitations.

Cost type	Cost subgroup	Cost calculation means*	Comments	Limitations
Imaging costs	1. Radiology (X-ray, CT scans, MRI) 2. Nuclear medicine (PET, SPEC)	Total imaging costs for each department, weighted by Commonwealth Medicare Benefits scheme	All lung cancer-related imaging events	Calculated specifically at our hospital but applied to imaging costs at any site
Inpatient costs	1. Day case visits 2. Inpatient visits	Cost provided by hospital finance department	Excluded imaging costs – calculated separately and added on	Included costs for unrelated events occurring within same admission, as could not be separated from lung cancer-related events
Invasive investigations	1. Investigations performed in theatre (mediastinoscopy; some EBUS cases)	Per minute rate, based on rates for all procedures conducted in theatre at our hospital	Procedures conducted externally costed at mean cost of that procedure at our site when performed as 1-day procedure Pathology costs were included in the cost of the related investigations	Investigations costed via different means (per minute/ per hour/per procedure) – direct comparison of costs is problematic
	2. Investigations performed outside theatre 2.1 (radiological/putative interventional/ bronchoscopy/gastro suite), some EBUS cases and all FBs	Per hour rate, based on rates for all procedures conducted on these premises at our hospital		
	2.2 Radiology department (CT-TTNAs)	Mean hospital cost of all CT-TTNAs performed across the four study years		
Outpatient visits	Lung-cancer related outpatient visits to Respiratory department and other outpatient clinics	Based on Independent Hospital Pricing Authority (IHPA) National Efficient Price	Number and type of outpatient visits from initial symptoms until date of management decision. Outpatient visits on day of management decision excluded	

* All costs indexed to 2015 prices. Pathology costs were included in the cost of the related invasive investigations and hospitalisation costs.

Modelling

Mean costs for EBUS-TBNA and -GS performed either in theater (operating theaters, or Procedure Room) or outside theater (Day Procedure Unit/radiological/putative interventional/ bronchoscopy/gastro suite) were calculated; modelling costs were determined by calculating the difference in costs of procedures done outside the theater or in theater, and applying this cost difference to each patient who underwent the more expensive procedure but was eligible for the other, thus calculating potential savings if all patients underwent the procedure in the less expensive setting.

Analyses

Means and standard deviations (SD) are presented for normally distributed continuous variables (medians and inter-quartile ranges (IQR) where non-normal distribution), while counts (n) and percentages are presented for categorical variables. Statistical analyses for patient demographics were undertaken using IBM SPSS Statistics 19. Pearson's chi-squared analyses, and Fisher's exact tests where appropriate, were undertaken for between-group comparisons for categorical variables and Mann-Whitney U tests for continuous variables between Pre-EBUS and Post-EBUS cohorts and, within the Post-EBUS cohort, the EBUS and non-EBUS groups. All other analyses were performed using the R environment for statistical computing [13].

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Table 2. Patient characteristics of both cohorts, and of EBUS and Non-EBUS patients within the Post-EBUS cohort.

Patient characteristics		Both cohorts		Post-EBUS cohort (n=326)	
		Pre-EBUS cohort (n=234)	Post-EBUS cohort (n=326)	EBUS group (n=90)	Non-EBUS group (n=236)
		Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Age at diagnosis# (years)		69 (15)	69 (17)	67 (15)	70 (18)
Charlson score#		1 (1)	1 (2)	1 (2)	1 (2)
		n (%)	n (%)	n (%)	n (%)
Male		139 (59.4)	200 (61.3)	58 (64.4)	142 (60.2)
Remoteness					
Major city		184 (79.3)	244 (74.8)	65 (72.2)	179 (75.8)
Inner regional		17 (7.3)	29 (8.9)	10 (11.1)	19 (8.1)
Outer regional		22 (9.5)	34 (10.4)	11 (12.2)	23 (9.7)
Remote		9 (3.9)	19 (5.8)	4 (4.4)	15 (6.4)
ECOG-PS##,**					
0		87 (37.2)	91 (27.9)	25 (28.0)	66 (27.8)
1		78 (33.3)	143 (43.9)	50 (55.6)	93 (39.5)
2		43 (18.4)	58 (17.8)	13 (14.4)	45 (19.1)
3		20 (8.5)	28 (8.6)	2 (2.2)	26 (11.0)
4		6 (2.6)	6 (1.8)	0 (0.0)	6 (2.0)
Tumour type##,**					
NSCLC	Stage I	27 (11.5)	55 (16.9)	14 (15.6)	41 (17.4)
	Stage II	12 (5.1)	23 (7.1)	6 (6.7)	17 (7.2)
	Stage III	58 (24.8)	75 (23.0)	29 (32.2)	46 (19.5)
	Stage IV	107 (45.7)	135 (41.4)	31 (34.4)	104 (44.1)
	Total	*204 (87.2)*	*288 (88.3)*	*80 (88.9)*	*208 (88.1)*
SCLC	Limited	8 (3.4)	18 (5.5)	8 (8.9)	10 (4.2)
	Extensive	22 (9.4)	20 (6.1)	2 (2.2)	18 (7.6)
	Total	*30 (12.8)*	*38 (11.7)*	*10 (11.0)*	*28 (11.9)*

Mann-Whitney U test, all others are Pearson's chi squared except ## (Fisher's exact test); ** $p<0.05$ for EBUS group compared with Non-EBUS group.

Multiple linear regression was used to determine whether the following variables were associated with (log-transformed) hospital cost: cohort (pre-EBUS *vs.* post-EBUS), whether the date of diagnosis fell within the inpatient visit, patient had other surgical/diagnostic procedures, EBUS-GS performed, EBUS-TBNA performed, pleural effusion drainage, thoracentesis or pleural biopsy performed, cohort, sex, referral source, stage, remoteness, ECOG-PS, Charlson Index, total length of stay as an inpatient (days; log-transformed), number of imaging events, number of FBs, number of other diagnostic procedures, age at diagnosis, number of complications, number of CT-lung biopsies, number of thoracentesis, number of outpatient visits, and number of inpatient visits. All two-way interactions with cohort, EBUS linear, EBUS radial, and number of imaging events were investigated.

Additionally, a sub-analysis was performed only on patients who underwent an EBUS-TBNA or -GS to identify which of the following variables were associated with hospital cost (this was

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Table 3. Linear regression analysis for (log-transformed) total cost of diagnosing and staging lung cancer.

Parameter	Anti-logged estimate	Anti-logged 95% CI	p-value
Intercept	2524.50	2297.32–2773.87	<0.0001
EBUS-TBNA performed	1.33	1.20–1.48	<0.0001
Length of stay (log-transformed)	1.98	1.90–2.08	<0.0001
Number of imaging events	1.10	1.08–1.13	Not Included[#]
Date of diagnosis fell within inpatient visit	1.46	1.31–1.62	<0.0001
Other surgical/diagnostic procedures performed	1.73	1.45–2.07	<0.0001
CT-lung biopsy performed	1.81	1.55–2.10	Not Included[#]
CT-lung biopsy performed * number of imaging events interaction	0.92	0.89–0.94	<0.0001

[#] When an interaction is significant, the main effects are not considered.

normally distributed, with no log transformation required): patient age and gender, type of EBUS procedure performed, whether the procedure was performed in theater, type of anaesthetic, ECOG-PS, Charlson Index, and duration of surgery. Variables that were significant at the 5% level were retained for the final model.

Results

For patient characteristics, there was no difference between cohorts or between EBUS and non-EBUS patients except for ECOG-PS (EBUS group compared with non-EBUS group, Fisher's exact test, p=0.009) and Stage (EBUS compared with non-EBUS, Fisher's exact test, p=0.038) (Table 2).

Predictors of total cost for diagnosis and staging of lung cancer

The median cost for diagnosis and staging of lung cancer for all 560 patients was $10,875 (IQR $10,656). The following variables were associated with higher hospital costs: EBUS-TBNA performed (p<0.0001); increasing length of inpatient stay (p<0.0001); increasing number of other surgical/diagnostic procedures (p<0.0001); whether the date of management decision fell within an inpatient visit (p<0.0001); and if the patient did not have a CT-TTNA, then costs increased as the number of imaging events increased (interaction p<0.0001) (Table 2). The results indicate that patients undergoing EBUS-TBNA had total costs approximately 33% higher than patients who did not undergo EBUS-TBNA (Table 3).

Costs for one-day invasive procedures

The most commonly utilized procedure among patients in the whole cohort for the diagnosis of lung cancer was FB (n=278), followed by CT-TTNA (n=196), EBUS-TBNA (n=63), and EBUS-GS (n=37). Mediastinoscopies were only performed on 3 patients in the second cohort, and 1 in the first cohort. Other less common diagnostic procedures included US-FNA (n=29) and EUS-FNA (n=6). Of one-day inpatient stays within the second cohort only, mediastinoscopy was the most expensive invasive investigation of the 4 main diagnostic procedures (median cost $11,438), followed by EBUS-TBNA in theater ($4,198), EBUS-GS in theater ($4,194), CT-TTNA ($3,367), EBUS-TBNA outside theater ($2,471), FB ($1,698), and EBUS-GS outside theater ($1,688) (Table 4).

Predictors of cost for one-day EBUS cases

To further consider the total cost of diagnosis and staging of lung cancer, we sought to determine what factors were associated with costs of individual EBUS-TBNA and EBUS-GS procedures at our hospital. Of 90 patients who had an EBUS procedure performed, 48 occurred during one-day inpatient stays (excluding 6 cases where both EBUS-GS and EBUS-TBNA occurred on the same day). Location of the EBUS procedure (in theater *vs.* outside theater) was the only factor associated with the cost of the one-day procedure, with EBUS performed in theater being a predictor of greater cost (mean difference=$1,974, SE=$442, p<0.0001).

Modelling results

The majority of EBUS procedures were performed in the operating theater (n=75, 75.0%), with the remainder – 25 (25.0%) – performed outside of theater (in a bronchoscopy suite). Mean one-day stay costs for EBUS-TBNA patients undergoing EBUS in theater were $4,347 compared to $2,471 for EBUS-TBNA outside of theater – a difference of $1,876; similarly, mean one-day costs for EBUS-GS patients who had the procedure

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Table 4. Hospital costs (AUD) associated with each procedure for one-day inpatient stays#,**.

	n	Cost Median (IQR)
Fibre-optic bronchoscopy	146	1698 (1105)
CT-transthoracic needle aspiration (CT-TTNA)	85	3367 (1298)
EBUS-GS outside theatre	7	1688 (1668)
EBUS-GS in theatre	12	4194 (1405)
EBUS-TBNA outside theatre	2	2471 (–)
EBUS-TBNA in theatre	27	4198 (1411)
Mediastinoscopy**	3	11438 (–)
US-FNA	3	1285 (–)
EUS-FNA	1	–

For CT-TTNA cases, imaging costs associated with the procedure itself are included ($910) plus costs for two chest x-rays ($110 each, standard component of the procedure); for EBUS-GS cases, the imaging costs of a fluoroscopy have been added ($141). Costing for all other procedures *excludes* imaging costs, as additional/unrelated imaging procedure costs could not be reliably determined from the costing data available. ** All costs here are for one-day stays (admitted same day as discharged), except for mediastinoscopies, which were all performed as overnight stays.

outside theater ($2,378) were $2,052 less than those in theater ($4,430). A model was developed to determine theoretical cost savings if all patients received EBUS outside theater rather than in theater; 6 patients who underwent both EBUS-GS and EBUS-TBNA on the same day (3 in theater; 3 outside theater) were excluded from the model. The modelled shift from all EBUS performed inside theater to all EBUS performed outside theater would represent a total cost saving of $66,259 per year ($132,518 over the two-year period), equating to approximate cost savings of $1,506 per EBUS patient (n=88) after excluding patients who had both EBUS-GS and EBUS-TBNA concurrently.

Discussion

Contrary to previous research projecting cost savings following the introduction of EBUS [6], our research found several predictors of increased overall cost for diagnosis and staging of lung cancer, including having undergone an EBUS-TBNA. Analysis of one-day procedures found that mediastinoscopy was the most expensive procedure, with EBUS-TBNA was the second most expensive procedure when performed in theater, but cheaper than CT-TTNA when performed outside theater. Similarly, EBUS-GS was comparatively expensive when performed in theater, but was the cheapest of all the 4 main procedures when performed outside theater. Cost modelling with all patients undergoing EBUS outside theater rather than in theater generated considerable cost saving.

Total diagnosis and staging costs: For 17% of patients (n=95), diagnosis occurred while hospitalized during an inpatient stay; this factor was a predictor of total cost of diagnosis. Many of these patients remained in hospital for extended periods following their diagnosis, but as a daily breakdown of costs was unavailable for analysis, the entire inpatient stay was included in their costing. This group of patients were costlier to diagnose; however, their costs may have included treatment or hospital costs unrelated to their lung cancer diagnosis. Other predictors of higher costs included number of imaging events and length of stay (days), both of which are predictably associated with additional costs. Unsurprisingly, having undergone other surgical/diagnostic procedures was also associated with greater overall costs; these events (including surgery for brain metastases, and bone and spinal lesions) are costly procedures, often requiring extensive inpatient stays or significant time spent in theater. The interaction effect between the number of imaging events and CT-TTNA may be explained by the need for an x-ray before and after CT-TTNA to check for complications from the procedure. Furthermore, patients with complications following the procedure (36%) (11) required further imaging until the complication resolved. In these CT-TTNA patients, a greater number of imaging events may relate directly to the procedure itself, resulting in only the relatively minimal cost of additional x-rays. However, for those patients who did not undergo CT-TTNAs, a greater number of imaging events may be indicative of a more complex case.

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Having undergone an EBUS-TBNA procedure (but not EBUS-GS) was also an independent predictor of overall greater cost of diagnosis and staging. We were unable to determine why EBUS-TBNA, but not EBUS-GS, was associated with greater cost. While staging was significantly different between the EBUS and non-EBUS patients in the second cohort, it was not a significant predictor of cost within the regression modelling, confirming that stage was not associated with greater costs for the EBUS-TBNA patients. It may be that those patients undergoing an EBUS-TBNA underwent a more extensive work-up to ensure accurate staging for the purpose of appropriate curative intervention, including surgical resection and radical chemo- or radiotherapy; further investigations may have been required to confirm their suitability for these treatments.

One-day EBUS case costs: There is some variation in previous research findings regarding optimal sedation type for conducting EBUS procedures; however, a recent systematic review indicates diagnostic yield and safety profile to be comparable between the 2 forms of sedation [14]. While internationally, EBUS is performed variably under moderate and deep sedation, dependent on institution and practitioner [14], recent guidelines indicate either moderate or deep sedation is appropriate [15]. While our study did not find sedation type to be associated with cost of one-day procedures, we noted that having undergone an EBUS procedure outside of theater as opposed to in theater was a predictor of lower costs for both EBUS-TBNA and EBUS-GS, irrespective of sedation type. Given the difference in methods of costing for these locations (calculated at a per-minute rate in theater, compared to a per-hour rate outside theater), such a difference is not surprising. While not necessarily unexpected, these findings prompt consideration of the resources required when introducing a new procedure at an institution. To ensure maximum potential cost savings from more efficient or effective procedures, it is important to consider the environment in which they are conducted, with low-cost environments targeted where appropriate. In line with this, Operating Efficiency Guidelines, which recommend considering other locations for non-surgical procedures, such as EBUS, have been implemented in some settings in order to maximize operating theater flow [16]. Institutions considering introducing EBUS should consult with theater management, respiratory physicians, and costing departments to develop the lowest-cost model available.

Although our study found that EBUS-TBNA was a predictor of greater overall cost of diagnosis and staging, it is impossible to conclude that the EBUS procedure itself resulted in increased costs; EBUS-TBNA patients may represent a cohort of patients differing from other patients in some respect not considered in our study. Given the complex nature of each case, we were unable to establish a subset of patients from the first cohort who may have been eligible for EBUS-TBNA. Such an evaluation would allow a more powerful comparison of EBUS-TBNA patients in the second cohort with potentially eligible EBUS-TBNA patients in the first cohort. Further research in the form of a randomized controlled trial would overcome this limitation.

Strengths and limitations

Our study used authentic hospital costing data, allowing for a realistic representation of the costs involved in the diagnosis and staging of lung cancer. While there are benefits to using such data, it provides certain limitations, such as discrepancies between costing methods for procedures performed in different departments. For example, CT-TTNAs were assigned a mean cost ($761 per CT-TTNA) from our dataset and, due to system errors, is most likely an underestimate of the true value, while EBUS procedure costs were calculated on a per-minute basis when performed in theater; FBs and EBUS procedures performed outside of theater were costed by the hour.

Conclusions

Our study revealed several predictors of greater cost for diagnosing and staging lung cancer: having undergone an EBUS-TBNA; length of inpatient stays; date of management decision having fallen within an inpatient stay; and having undergone other surgical/diagnostic procedures; and there was a significant interaction between having undergone a CT-TTNA and number of imaging events performed. Of particular interest was the finding that while EBUS-TBNA was a predictor of greater cost, EBUS-GS was not. Furthermore, we noted considerable potential savings if EBUS procedures were performed outside rather than in theater; given comparable suitability of either moderate or deep sedation, EBUS procedures performed outside theater represent a more cost-efficient means of diagnosing and staging lung cancer when compared to other conventional techniques. Subsequently, institutions introducing EBUS procedures should take these findings into consideration to ensure maximum cost saving.

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