CHEST Pulmonary

The Value of a High-Volume Bronchoscopic Lung Volume Reduction Program for Patients With Severe Emphysema

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BACKGROUND: Bronchoscopic lung volume reduction (BLVR) has emerged as a promising therapeutic option for patients with COPD. The development of a dedicated BLVR program requires significant resources, both from an interventional pulmonology (IP) team and from the medical center. The financial value of this program is important to assess to develop a feasible and sustainable plan for providing this service in the future.

RESEARCH QUESTION: Can a BLVR program bring value to a medical center in terms of patient referrals, revenue, and contribution margin?

STUDY DESIGN AND METHODS: We retrospectively reviewed the charts of patients who were referred for BLVR to the interventional pulmonology clinic at Beth Israel Deaconess Medical Center (BIDMC). Patient demographics were obtained. Outpatient services used to determine candidacy for endobronchial valve placement were analyzed and revenue was estimated. For patients who had valve placement, revenue from the bronchoscopic procedure and subsequent inpatient hospitalization was calculated and the contribution margin of the procedure was estimated.

RESULTS: An estimated total of $1 to 1.4 million in revenue was generated in the workup and placement of endobronchial valves for 37 patients. The total revenue for the care of 52 patients deemed not to be candidates for the valve procedure was $144,000 to $170,000. The contribution margin for the procedure was estimated to be 25%. The median length of stay was 3 days. Among all 89 patients referred for BLVR, 26 referrals were made to other specialties at BIDMC during workup. Of these patients, 69.6% were new patients referred to BIDMC for BLVR.

INTERPRETATION: In addition to the established therapeutic benefit of BLVR for patients with COPD, a BLVR program in a dedicated, specialized center is economically valuable and sustainable, attracts referrals from other medical centers and health care systems, and generates internal referrals within the medical center. CHEST Pulmonary 2025; 3(1):100095

KEY WORDS: bronchoscopic lung volume reduction; COPD; emphysema; endobronchial valves; interventional pulmonology

ABBREVIATIONS: BIDMC = Beth Israel Deaconess Medical Center; BLVR = bronchoscopic lung volume reduction; CCR = cost-to-charge ratio; EBV = endobronchial valve; IP = interventional pulmonology; SVS = Spiration Valve System

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Take-home Points

Study Question: Is a bronchoscopic lung volume reduction (BLVR) program economically valuable regarding upstream and downstream revenue, referrals, and contribution margin?

Results: Our organized and comprehensive BLVR program was able to generate > $1.4 million in upstream and downstream revenue with 89 patient referrals, two-thirds of which were from other medical centers, and achieve a contribution margin of 25% for the procedure.

Interpretation: A BLVR program can lead to substantial revenue and referrals for a medical center and is economically sustainable.

The development of a comprehensive and organized bronchoscopic lung volume reduction (BLVR) program can generate significant revenue for a medical center. Like other advanced bronchoscopic procedures such as endobronchial ultrasound, the full economic impact of interventional pulmonology (IP) procedures may be underestimated by considering the revenue from the procedure alone.[1] Other aspects of the care of patients referred for a procedure need to be included. Additionally, the contribution margin for the care episode including the procedure plus subsequent inpatient hospitalization can be a metric for the sustainability of this program.[2]

The availability of a highly specialized procedure such as BLVR through endobronchial valve (EBV) placement has the potential to bring new patient referrals into the medical center. Additionally, for all patients referred for BLVR, a comprehensive workup, including outpatient clinic visits, testing, and procedures, is undertaken to determine candidacy for the procedure. Finally, referrals to other specialties (eg, cardiology, thoracic surgery) within the medical center may be warranted based on findings of the workup. Therefore, all services used by patients who are referred for EBV must be accounted for when determining the actual value of such a program to a medical center. This study analyzes the value, including revenue prior to (upstream) the BLVR procedure and revenue after (downstream) the procedure, resulting from the implementation of a BLVR program at an expert IP center. We also determine the contribution margin of the BLVR procedure at the medical center.

Study Design and Methods

Study Patients

We analyzed records of 119 consecutive patients referred to the IP clinic at Beth Israel Deaconess Medical Center (BIDMC) for evaluation of BLVR candidacy from January 1, 2016, to May 15, 2022. Within this period, patients who had EBVs placed prior to June 2018 were excluded from the analysis. Follow-up of patients was conducted up to 1 year after the placement of the EBVs or until May 15, 2022, whichever date was earlier. This study was approved by the BIDMC institutional review board under exempt status (2019P000457 Version:3).

EBV Placement Procedure

The EBV placement procedures were conducted in the operating room, with a planned admission to the medical ward for at least 3 nights or 4 days postprocedure, per standard practice of close monitoring after valve placement due to the risk of pneumothorax (around 34%).[3] An attending interventional pulmonologist at BIDMC performed the procedure under general anesthesia, with assistance from the IP fellow. Zephyr valves (Pulmonx) or Spiration Valve System (SVS) (Olympus) were deployed in target segments per protocol. Prior to Zephyr valve placement, CHARTIS (Pulmonx) assessment was conducted to verify absence of collateral ventilation. For SVS placement, if the fissure integrity was ≥ 90% by quantitative CT scan, we proceeded to place the SVS valves in the target lobe. The Olympus BF-1TH190 bronchoscope was used for the procedure.

Chart Abstraction

Patients were classified as new patients or established patients. New patients had not been seen by another provider at BIDMC within the prior 3 years of the initial IP clinic visit, whereas established patients had been seen by a provider at our center within 3 years of the initial visit. Patient demographics were obtained. Age was recorded at the time of initial IP clinic visit.

Revenue Analysis

The outpatient services used by patients at BIDMC for valve candidacy evaluation (eg, clinic visits, radiographic studies, echocardiograms, pulmonary function tests,

lung perfusion studies, outpatient bronchoscopies) other than EBV placement were recorded. Negotiated charges with payers published by BIDMC were used to estimate revenue from these services.[4] Due to the inherent variability of reimbursement, these were estimates of revenue and not exact calculations. For this analysis, the Medicare negotiated rate was used for all patients to provide a conservative estimate of the reimbursement. Clinic charges and professional fees for IP clinic at our center were used. After valve placement, services used by patients were analyzed up to 1 year after the procedure, or until May 15, 2022, as previously mentioned. For the EBV procedure and hospitalization, exact revenue was obtained. Additional outpatient bronchoscopies and EBV placement procedures during the 1-year follow-up were also included in the analysis.

Only outpatient workup done to determine EBV candidacy and outcomes postprocedure was used in revenue calculations. Some established patients had numerous pulmonary function tests and radiographic studies. Because our aim was to identify revenue generated due to a BLVR referral specifically, we only considered outpatient workup done for EBV candidacy.

Total revenue was calculated using the estimates previously described. Minimum and maximum revenue estimates were generated based on assumed variations in clinic billing practices.

Projected revenue was calculated as a theoretical estimate of revenue for patients who had EBV placement. This calculation assumed that every patient who received EBVs had the following workup: pulmonary function test, arterial blood gas, 6-min walk test, CT chest scan, single-photon emission CT scan (for patients with homogenous disease or those with heterogeneous disease and 2 potential target lobes), transthoracic echocardiogram, and initial clinic visit prior to EBV placement; the EBV placement procedure and hospitalization; and afterward a pulmonary function test, 6-minute walk test, CT chest scan, and follow-up clinic visit. Our projected revenue for patients who did not receive valves assumed that every patient had the following workup: pulmonary function test, 6-min walk test, CT chest scan, transthoracic echocardiogram, and initial clinic visit.

Referrals made to other specialists in our center during workup for BLVR were recorded, but not included in the revenue analysis.

Contribution Margin Estimate

The exact reimbursement or payment for each EBV procedure and hospitalization was obtained, both from the hospital and physician side. Payments for IP and anesthesia physicians were included, which comprised most or all the physician services used. Payments made to other physicians who may have provided consultation services were not included.

There was no cost accounting of specific services during the operating room procedure and inpatient stay by the medical center. Therefore, cost of the EBV procedure and inpatient hospitalization was estimated using the average historical cost-to-charge ratios (CCRs) for our center from 2019 to 2022. The CCR is calculated by medical centers typically at an aggregate level, and it is defined as the total amount of money required for operation (cost) divided by the total charges. To estimate costs, the average CCR for BIDMC was multiplied by the total charges for each of the BLVR procedures plus hospitalization to estimate the direct cost of each procedure plus hospitalization.

The contribution margin was defined as the revenue generated minus the direct cost divided by the revenue. Direct cost was estimated as previously described. The contribution margin was an estimate of the percentage of revenue that was due to profit.

Statistical Analysis

A *t* test of unequal variances with independent samples was used for assessing differences between ages of the two cohorts. A χ^2 test was used to assess differences in sex, location, patient category, and insurance. R studio (version 1.1.383, Posit PBC) was used for analysis.

Results

There were 119 consecutive patient referrals for BLVR within this study period. Of these, 21 patients were excluded because they were still undergoing workup for valve candidacy, were never seen in clinic, or had initial EBV placement at another institution. Of 98 patients who were evaluated in clinic for BLVR, nine were excluded from the economic analysis due to enrollment in another clinical trial for fissure completion and BLVR. Among the 89 remaining patients, 37 (42%) received valves and 52 (58%) were deemed not candidates. Figure 1 depicts patient inclusion and analysis.

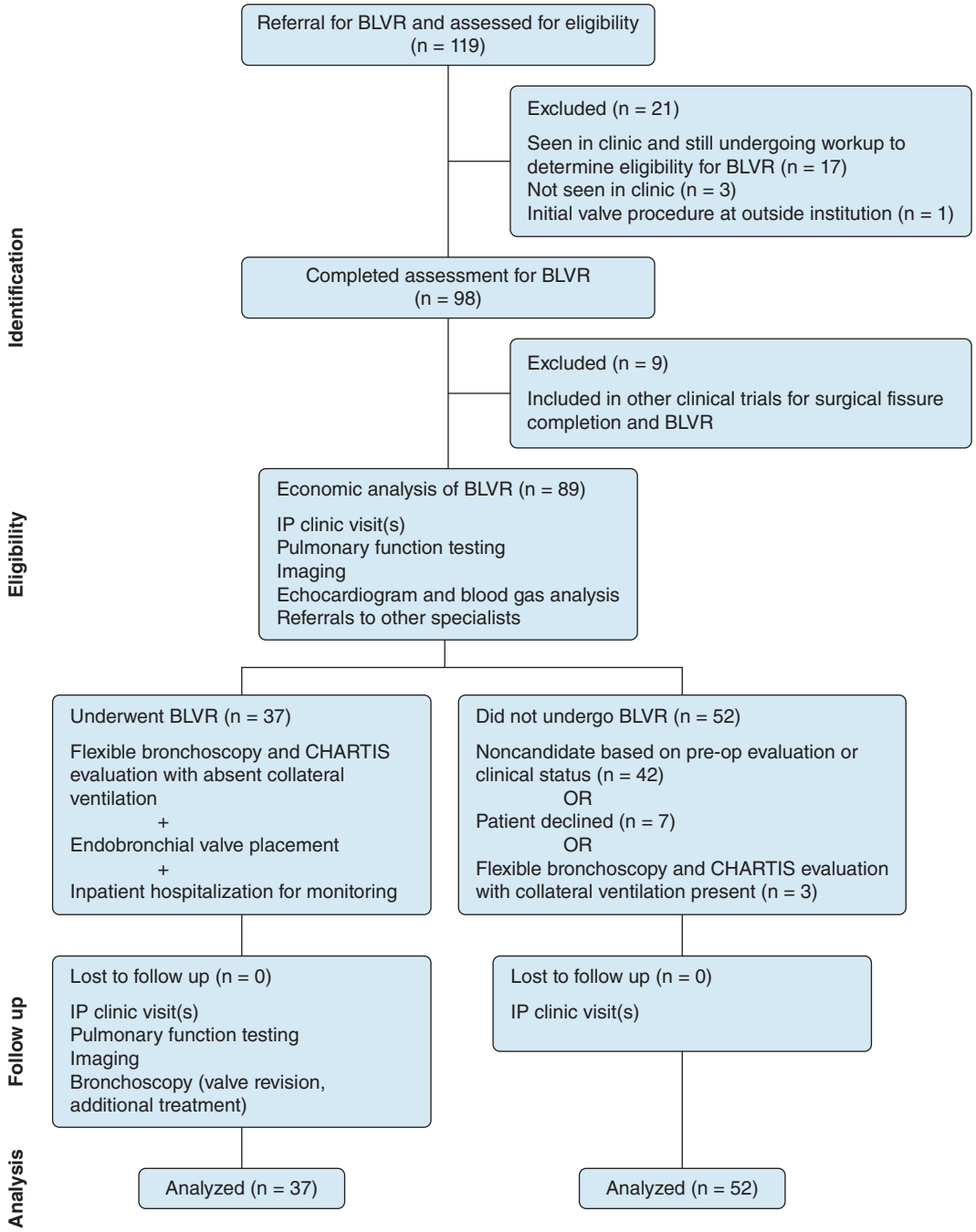

Figure 1 – *Flowchart depicting identification, exclusion, and analysis of patients referred for BLVR, including clinical evaluation, endobronchial valve placement procedure and hospitalization for applicable patients, and follow-up. BLVR = bronchoscopic lung volume reduction; IP = interventional pulmonology; pre-op = preoperative.*

Among patients who received valves (n = 37), SVS valves were placed in three patients (8%) and Zephyr valves were placed in 34 patients (92%). Our center was a quaternary academic teaching hospital in Boston, Massachusetts. In this cohort, 25 (68%) were from in-state and 12 (32%) were from other states. There were 28 new patients (76%) and nine established patients (24%). Twenty-seven percent had non-Medicare health insurance.

Among patients who did not receive valves (n = 52), 40 (77%) were from Massachusetts (in-state) and 12 (23%) were from other states (out-of-state). There were 34 new patients (65%) and 18 established patients (35%). Fifty

TABLE 1] Characteristics of Patients Who Were Evaluated for Endobronchial Valve

Characteristic	Received Valves (n = 37)	Did Not Receive Valves (n = 52)	*P* Value
Age, y	65 (58-71)	67 (62-74)	.0653
Sex, male	22 (59)	23 (44)	.2297
Location			.4606
In-state	25 (68)	40 (77)	
Out-of-state	12 (32)	12 (23)	
Patient category			.4197
New patients	28 (76)	34 (65)	
Established patients	9 (24)	18 (35)	
Type of valve			
Zephyr	34 (92)	NA	NA
Spiration	3 (8)		
Non-Medicare health insurance	10 (27)	26 (50)	.0503

Values are No. (%), median (interquartile range), or as otherwise indicated. NA = not applicable.

percent of patients in this cohort had non-Medicare health insurance. Among all patients, 40% had non-Medicare health insurance. Demographics are summarized in Table 1.

The hospital length of stay was calculated for patients who had valve placement. Mean length of stay was 5.3 days (range, 3-24 days), and median length of stay was 3 days (interquartile range, 3-5 days). For the hospital stay after initial valve placement, 27 patients (73%) had ≤ 4 days' length of stay and 10 patients (27%) had > 4 days' length of stay. Eight patients (22%) underwent ≥ 1 bronchoscopy for additional valve placements followed by inpatient hospitalization during the 1-year follow-up period. There were 10 additional valve placement procedures followed by inpatient stays. The reasons for repeat procedures were as follows: no atelectasis achieved (n = 5), valve migration (n = 2), and persistent air leak (n = 1); reexpansion of lobe after initial atelectasis (n = 1); and treatment of a contralateral lobe (n = 1). There were 47 total hospital stays for 37 patients. Of all hospital stays, 37 stays (79%) were ≤ 4 days and 10 stays (21%) were > 4 days. The reasons for hospitalization > 4 days include persistent air leak (80%), hypoxemia (10%), and pain requiring IV opiate administration and volume overload (10%). These results are depicted in Figure 2. There were no deaths from the procedure.

The average number of procedures and tests that patients had prior to EBV placement are depicted in Table 2. In total, 22 referrals were made to other specialties at BIDMC during workup of these patients. Among patients who did not have EBVs placed, five referrals were made to other specialties at our center, including thoracic surgery and pulmonary hypertension clinics.

Figure 3 shows the revenue from the BLVR program. An estimated total $1.40 to 1.44 million in revenue was generated in the care of 37 patients who received valves. The projected revenue for the group was $1.3 million. The revenue per patient was $38,000 to $39,000 (projected revenue of $34,000 per patient).

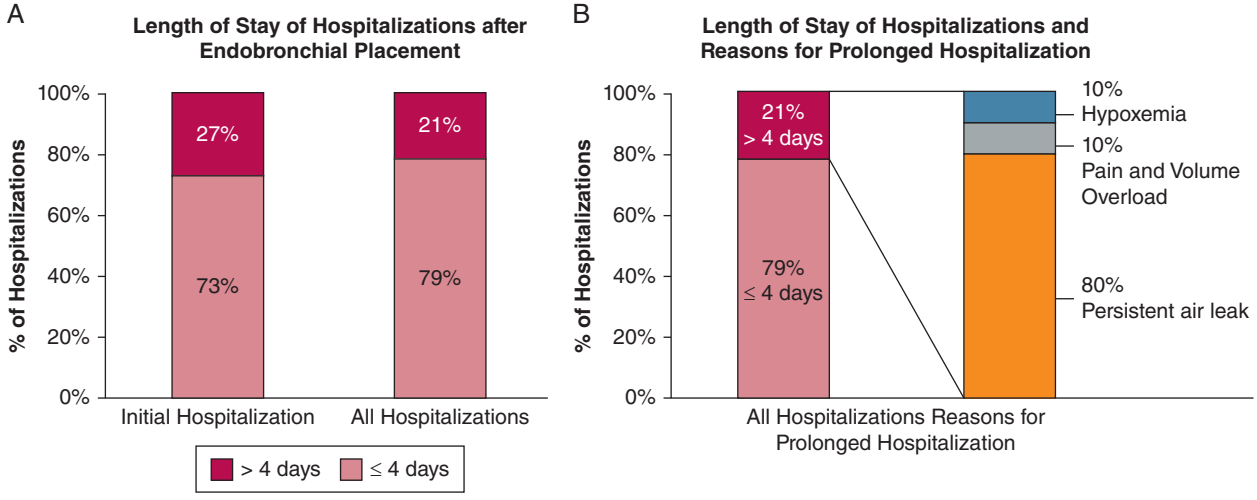

Figure 2 – *A, Length of stay for hospitalizations after endobronchial valve placement. B, Hospitalization length and postprocedural complications prolonging hospital stay (defined as > 4 d).*

TABLE 2] Median Number of Tests and Procedures Per Patient

	Test					
	PFT	6MWT	Chest Radiograph	CT Chest Scan	TTE	Single-Photon Emission CT Scan
Median No. of tests (interquartile range)	3 (1-4)	2 (1-3)	1 (0-2)	2 (1-2)	1 (0-1)	1 (0-1)

Values for those who had endobronchial valve placement throughout the initial outpatient evaluation and 1-y follow-up period. 6MWT = 6-min walk test; PFT = pulmonary function test; TTE = transthoracic echocardiogram.

An estimated total $144,000 to $170,000 of revenue was generated during the workup of patients who were deemed not candidates for EBVs (projected revenue of $101,000). Per patient, this amounted to $3,000 in revenue (projected $2,000 in revenue).

Most of the revenue from the care of patients who had EBV placement was from the EBV procedure and subsequent inpatient hospitalization. Figure 4 depicts the revenue breakdown from the BLVR procedure plus hospitalization vs outpatient services. The total revenue from EBV procedures and inpatient hospitalizations was about $1.2 million. Cost was estimated to be $900,000 for this care episode. The contribution margin of the procedure with hospitalization was 25%, which amounted to $8,100 per patient.

Discussion

Our results highlight the financial impact of a BLVR program in generating substantial revenue for the hospital. In addition to the established clinical benefits of BLVR for patients with COPD, which include improvements in lung function, quality of life, exercise capacity, and survival,[5-13] the procedure and clinical workup of these patients is economically beneficial and sustainable for the medical center.

The highest revenue was generated from placement of EBVs, amounting to about $1.4 million total or $38,000 per patient. One of the primary drivers of the revenue for this procedure was reimbursement based on the diagnosis-related group that is determined by the Centers for Medicare and Medicaid Services. The diagnosis-related group for BLVR is that of major chest procedures, which is also used for surgical procedures such as lobectomy. In addition to the procedure and inpatient stay, a comprehensive workup was needed for all patients referred for BLVR to determine candidacy. This workup included clinic visits, pulmonary function tests, and imaging. Outpatient bronchoscopies were sometimes performed as part of the initial workup when necessary to exclude infections and diagnose suspicious nodules. In our analysis, we found that the estimated revenue exceeded the projected revenue. It is important to note that the revenue was a conservative estimate based on negotiated Medicare reimbursement rates. Furthermore, some patients had imaging studies and pulmonary function tests done at outside institutions. These tests were not included in our revenue calculation because they did not generate revenue within our medical center. In institutions where all workup is performed in one medical center, this would generate more revenue.

In practice, a medical center that serves as a BLVR center of excellence operates within a larger health care system from which referrals are generated. For example, general pulmonologists at affiliate centers may refer

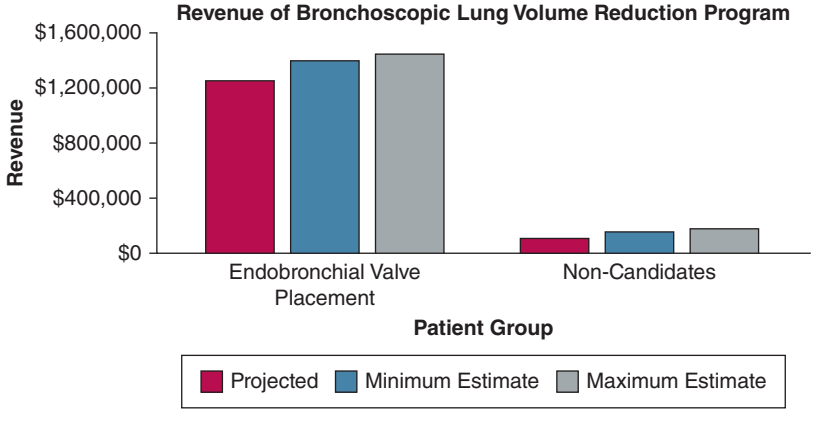

Figure 3 – *Total revenue of bronchoscopic lung volume reduction program from January 1, 2016, to May 15, 2022.*

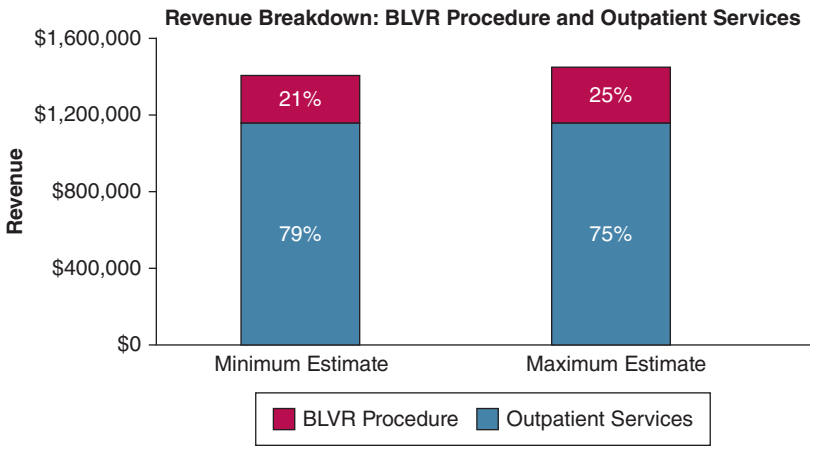

Figure 4 – *Revenue attained from the BLVR procedure plus hospitalization and from outpatient services before and after the procedure. BLVR = bronchoscopic lung volume reduction.*

patients with COPD to IP colleagues at a main medical center. It is possible that good-quality testing (eg, updated pulmonary function testing within a year, transmission of thin-slice CT scan images) may decrease repeat testing for some patients. However, CT scans, echocardiograms, and blood gas analysis are not necessarily performed for all patients with COPD as routine practice. Because these tests are required for assessment of BLVR candidacy, such testing would need to be performed. Therefore, regardless of effective integration within the health care system, it is likely that new testing is undertaken for BLVR, providing revenue.

Additional revenue, not included in this analysis, is also generated from referrals to other specialties within our center in the workup of patients undergoing BLVR. For 37 patients, 22 referrals were made to other specialties, particularly pulmonary hypertension and thoracic surgery. These referrals resulted in additional clinic visits, procedures, and surgeries (eg, right heart catheterization), or enrollment in another clinical trial. Referral to other specialties resulted in optimization of care (eg, diagnosis of pulmonary hypertension with further management, thoracoscopic resection of pulmonary nodules). These additional revenue sources from other subspecialty referrals were not included in our primary economic analysis but are important to note. A subset of patients referred for EBV candidacy workup were found to have incomplete fissures. These patients were enrolled in a clinical trial in which video-assisted thoracoscopic surgery with intraoperative fissure completion was performed with EBV placement. Patients who were enrolled in this clinical trial were excluded from our analysis because the economic impact of this procedure is not generalizable to other centers. Finally, although BIDMC does not have its own pulmonary rehabilitation program, in a medical center that has this program, it can be another source of revenue. In summary, the establishment of a BLVR program was key to the referral of patients to our medical center and optimization of their care resulted in additional revenue.

The BLVR procedure and hospitalization were estimated to have a favorable contribution margin of 25%. Mahajan et al[2] proposed that the financial justification of IP procedures hinges on the contribution margin and thus the sustainability of a procedure. Correlating this metric to EBV placement is not straightforward because the revenue and cost is from the procedure plus the subsequent hospitalization, and both hospital and physician reimbursement are analyzed. Additionally, cost accounting is typically not performed at the procedure and hospitalization level but rather at the aggregate level, as is the case at our center. We therefore used the CCR to estimate costs, a method used previously in health care cost analysis.[14-17] This method may even overestimate costs slightly, which would make our margin estimate even stronger.[18] We acknowledge that cost accounting at the procedure and hospitalization level may provide a more direct measure of cost. However, CCR is a reasonable and reliable method by which to estimate costs because we are analyzing historical data. The CCR for our institution was stable over the 4 years of our data analysis, adding to its reliability. Our favorable margin is sustainable and promotes further growth for the medical center and the IP program to continue care for the patients.

One of the ways in which contribution margin was maximized and cost minimized was by shorter inpatient hospital stays and admission to the medical ward rather than the ICU. As per standard practice, patients were observed for at least 3 nights after valve placement due

to high risk of pneumothorax. Thus, ≤ 4 days' length of stay of hospitalization was chosen to evaluate how many patients required an extended length of stay. In our analysis, patients spent a mean of 5.3 days and a median of 3 days in the hospital after the procedure. Of all hospital stays, most (79%) were ≤ 4 days in length. As expected, most extended stays were due to persistent air leak. Because the reimbursement based on diagnosis-related group was independent of length of stay, shorter stays helped minimize cost.

A potential way to reduce costs of the procedure is utilization of a bronchoscopy suite where minimally invasive procedures can be performed. This setting may reduce cost of the procedure compared with the operating room. Dedicated cost accounting at the procedure level can be implemented to quantify the difference in cost between the operating room and bronchoscopy suite, and the contribution margin can therefore be optimized for a setting that works best at the institutional level. A study by Desai et al[19] shows that an IP suite can be projected to provide consistent profit for a range of IP procedures. EBV placement in the bronchoscopy suite may reduce cost and increase the contribution margin.

BLVR programs benefit greatly from a dedicated nurse manager or advanced practice provider who can screen patients and coordinate care with a referring physician. For example, records (eg, recent chest CT scan, pulmonary function testing, 6-min walk testing, blood gas analysis, echocardiogram) can be obtained from the pulmonologist or performed at a local medical center prior to referral to IP. The patient can also enroll in pulmonary rehabilitation prior to evaluation. Alternately, a nurse manager or advanced practice provider can review testing that is already done and ensure completion of the workup that is needed. In addition, an advanced practice provider could see some of the patients for follow-up and allow IP faculty to see more new patients which would facilitate the growth of the practice. This effective coordination of care would minimize redundancy and maximize referrals to the IP clinic for BLVR.

Our study has limitations. First, it is a single-center retrospective study at an academic center in a large city. These data may not be generalizable to other types of centers. Second, we are unable to calculate exact costs at the patient level. Despite using a previously used methodology and reliable estimates of cost, ultimately these are estimates and not exact numbers. Although revenue generated is known, contribution margin is estimated.

Interpretation

We have shown that the BLVR program generates revenue for the hospital regardless of the ultimate candidacy of patients for EBV placement. New referrals to the medical center take place because of the program. Additionally, patients referred to our center also require services from other specialties. Our procedure has an estimated positive contribution margin, underlining the sustainability of the BLVR program. Higher margins could be achieved if a dedicated procedural suite is used.

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None declared.

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Author contributions: A. D. K. served as the principal author and performed data collection and analysis, developed the methodology, had full access to the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis, including and especially any adverse effects. J. P. U. performed data collection and analysis. A. P. performed data collection. A. M. conceived the study design, developed the methodology, had full access to the data in the study, and formulated the goals and aims of the study. A. D. K., J. P. U., A. P., M. S. P., J. A. B., C. Z., and A. M. contributed to data interpretation, drafting the manuscript, and critically reviewing the manuscript before submission.

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