Mobile Lung Screening: Should We All Get on the Bus?

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Background. Despite favorable recommendations, national lung screening adoption remains low (2% to 3%). Patients living in rural areas have additional challenges, including access to lung screening programs. We initiated a mobile lung screening program to serve the rural patients at risk. This is what we learned from this 12-month feasibility project.

Methods. Utilizing a multidisciplinary approach, we began an 8-month design and build schedule. This was the first build of this type. The operational team included a radiology technician, nurse practitioner, driver with a commercial driver's license, and program developer. Specialized software was used for data mining. Downstream revenue projections were based on previously published Medicare claims data. Generally accepted accounting principles were used.

Results. The prototype bus was delivered January 2018. During the 12-month feasibility period, we performed 548 low-dose lung screenings at 104 sites. Mean patient age was 62 years, mean pack-years of smoking was 41; 258 (47%) were male. Five lung cancers were found in addition to a type B thymoma. Financially, we exceeded the break-even analysis by 28%. The 5-year pro forma using 1 year of actual data and 4 additional years of projected data demonstrated a net present value of 1 million, internal rate of return of 34.6%, and profitability index of 2.2—all highly dependent on downstream revenue.

Conclusions. Although challenges exist, a commercially viable bus and a financially sound mobile program can be developed. However, without a centralized approach for incidental findings, the downstream revenue may be at risk as well as the financial viability of the project.

(Ann Thorac Surg 2020;110:1147-52)
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In 2013, the United States Preventative Services Task Force recommended annual lung screening for persons aged 55 to 80 years, who have smoked at least 30 pack-years, and currently smoke or have quit within the last 15 years.[1] Lung screening was further endorsed by the Centers for Medicare and Medicaid Services in 2015 when it announced its national coverage decision.[2] Despite this, adoption rates remain low with only 1% to 3% of eligible patients getting screened.[3] In 2016, the Lung Cancer Screening Registry reported more than 7.6 million eligible patients in the United States, with 3 million of those eligible located in the southern states. The southern states include Delaware, Florida, Georgia, Maryland, North Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, and Texas. Despite having the majority of accredited sites, screening implementation in the south was among the lowest in the nation at 1.6%.[4]

One explanation involves the poor distribution of imaging centers in the south favoring urban over rural regions. Only 22% of US rural residents aged 55 to 79 years have access to lung cancer screening centers in our state, and geospatial mapping of Tennessee highlights the geographic distance between rural counties at risk and hospitals with cancer centers (Figure 1). Closure of rural hospitals and a lack of primary care providers in these counties only compound the problem.[5-9]

To bridge the access gap, improve lung screening adoption rates, and serve the rural patients at risk, we developed a mobile lung screening program. This paper highlights the building challenges, first-year results, and financial analysis of our mobile lung screening initiative.

Patients and Methods

A quick search for a commercially available mobile lung screening vehicle that fit our geographic needs revealed none existed. Computed tomography (CT) scanners are a sensitive, complex electrical machine that require climate control and a level environment to operate. Historically, they have been placed in tractor trailers and parked on level concrete slabs connected to external power supplies. We needed mobility, self-leveling, independent power,

Accepted for publication Mar 23, 2020.

Presented at the Sixty-sixth Annual Meeting of the Southern Thoracic Surgical Association, Marco Island, FL, Nov 6-9, 2019.

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Published by Elsevier Inc.

0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2020.03.093

Ann Thorac Surg
2020;110:1147-52

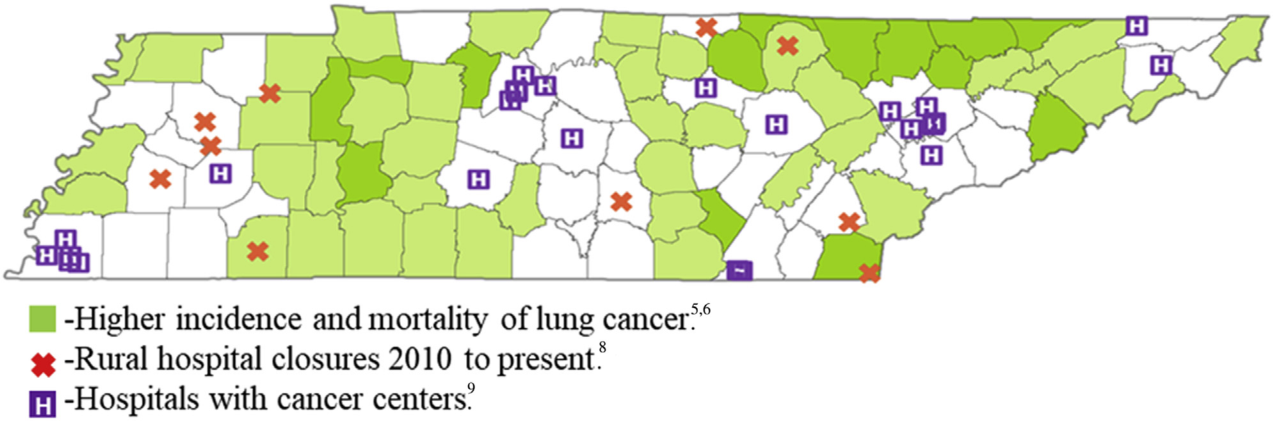

Figure 1. Geospatial mapping of Tennessee. Green indicates higher incidence and mortality of lung cancer;[5,6] red indicates rural hospital closures 2010 to present;[8] purple indicates hospitals with cancer centers.[9]

climate control, patient comfort, and drivability. Our hypothesis was that a mobile lung screening program could be developed (bus built), become financially viable, and reach patients at risk in rural areas.

A design team was assembled consisting of engineers from Siemens Healthineers (Malvern, PA), Winnebago Industries (Forest City, IA), and Medical Coaches (Oneonta, NY). Clinical input was obtained from a thoracic surgeon, pulmonologist, radiologist, CT technician, and driver with a commercial driver's license. We established an 8-month design and build process that utilized a Winnebago specialty vehicle commercial shell and a modified Siemens 16-slice Somatom Scope CT scanner. The specialty vehicle was built on a Freightliner (Gaffney, SC) MB front-engine, straight rail commercial bus chassis. It was powered by a Cummins diesel 6.7 L, 340 HP engine with a 500,000-mile engine life. An Allison 6-speed automatic transmission with overdrive completed the powertrain. The chassis had a 27,500 gross vehicle weight rating (GVWR) and was equipped with air brakes. The weight of the Winnebago specialty vehicle was 20,000 lbs. The Somatom Scope CT scanner weighed 4000 lbs, leaving 3500 lbs for lead shielding, cabinetry, finish work, and gantry supports.

Because the GVWR could not be kept below 26,000 lbs, the vehicle required a class B commercial driver's license. Final assembly, instillation of the CT scanner, interior construction, and exterior wrapping was completed at Medical Coaches in Oneonta, New York. The rear cap of the specialty vehicle was removed after production to allow placement of the Somatom Scope CT scanner in the forward section of the bus.

All funds to build the vehicle were donated through the CHI Memorial Foundation and came from two local nonprofit foundations. The prototype vehicle, including the Winnebago shell, Freightliner chassis, and CT scanner cost $650,000. Any additional funding for the project was done in-kind by CHI Memorial, Medical Coaches, and Siemens. This vehicle was not meant to be a commercially reproducible vehicle, but a test prototype. The commercially reproducible vehicle is estimated to cost $850,000.

All vendor partners along with CHI Memorial shared risk in this first build prototype. Final testing, certification, state inspection, and personnel training was done after delivery to CHI Memorial in Chattanooga, Tennessee. The final operational team included a driver with commercial driver's license who was cross trained in patient registration, CT technician, advanced nurse practitioner, and thoracic surgeon who was the program director. Marketing and public education for the project was done utilizing earned television and print media, public service announcements, and internet marketing.

The service area of the bus was restricted to a 2-hour drive to prevent any overnight trips. Priorities were given to rural screening opportunities. The established mobile mammography program at CHI Memorial helped with introducing the mobile lung program to existing partners and with scheduling of the screening sites. The National Comprehensive Cancer Network lung screening guidelines were used for screening criteria, including high-risk groups 1 and 2.[10]

All data collection, submission to the American College Radiology, and program oversight were done with the assistance of a lung screening software program from ThynkHealth (Lexington, KY). Monthly meetings were held to review the mobile lung screening data, significant pulmonary and incidental findings, quality metrics, and effectiveness of screening sites. All patients with Lung CT Screening Reporting and Data System (Lung-RADS) category 3 or 4 findings along with any significant incidental findings received a phone call from a provider. Lung-RADS category 1 or 2 patients received a results letter. All pulmonary findings were followed up in our nodule clinic.

Generally accepted accounting principles were used for all financial calculations. Downstream revenue contributions were set at a fixed amount ($587) per patient screened based on a published Cleveland Clinic study.[11] We subtracted our shared decision making and CT

Figure 2. Prototype bus (upper panel) and its interior (lower panel).

screening average reimbursement from the $817 dollar value they determined each screening patient produced in revenue.

The study was approved by the Institutional Review Board of the University of Tennessee College of Medicine. Informed consent was not required.

Results

The prototype bus was delivered to Chattanooga in January 2018 (Figure 2). It was taken to a certified automated truck scale for verification of its weight. Fully loaded, the bus weighed 27,900 lbs. That was 400 lbs over the GVWR. It was returned to Medical Coaches where the cabinets were replaced with a lighter material. Nonessential equipment like a rear ladder, trailer hitch, and handicap lift were removed. The final weight was reduced to 26,820 lbs. This modification along with training of the staff took 2 months before the bus was ready for operation.

During the remainder of the 10 months in 2018, the bus traveled to 104 sites and screened 548 patients. Demographics included mean age 62 years (range, 50 to 86), mean smoking pack-years 41 (range, 1 to 110), whites 91% (501), and female sex 53% (290). The Lung-RADS findings included one Lung-RADS category 0, 303 (55%) Lung-RADS 1, 193 (35%) Lung-RADS 2, 33 (6%) Lung-RADS 3, and 18 (3%) Lung-RADS 4. Lung nodules greater than 2 mm were found in 232 (42%) of screening patients, with few (54 of 232; 23%) requiring further testing. The majority (49 of 54; 91%) required simply a short interval CT scan or positron emission tomography scan. Few patients required invasive testing; 3 required a CT-guided biopsy, and 2 underwent endobronchial ultrasonography.

Five lung cancers were identified; 4 of 5 (80%) were early stage. Two were stage 1A, one was stage 1A2, one was stage 1B, and one was stage 3A. Two early stage patients underwent stereotactic body radiation therapy. Two patients underwent minimally invasive surgery: one, a segmentectomy and the other, a lobectomy. One patient with stage 3A disease underwent curative chemotherapy and radiation therapy. One type B1 thymoma was identified and that patient underwent robotic-assisted thoracoscopic resection with en bloc pericardial resection and reconstruction. Seventeen of 51 patients (33%) with a significant pulmonary finding (Lung-RADS 3 or 4) did not follow up for further testing as advised. The majority of these patients (15 of 17; 88%) were screened at a rural location or a homeless health clinic.

Nonpulmonary significant findings were found in 152 (28%) of the persons screened. The most common finding was moderate to severe coronary artery disease in 101 of 152 (66%), followed by abdominal findings in 15 of 152 (10%), thyroid in 14 of 152 (9%), other thoracic findings in 10 of 152 (7%), and ascending aortic dilatation in 9 of 152 (6%). Few patients (13 of 152; 9%) required further testing; tests included four abdominal CT scans, three thyroid ultrasounds, two abdominal magnetic resonance imaging scans, two mammograms, one stress test, and one swallowing study. No patient required treatment owing to their nonpulmonary findings.

The Somatom Scope CT scanner had no mechanical issues and only underwent routine service. The most common mechanical issue with the bus was related to the recreational air conditioners. Six air conditioner units required replacing during the study period. Electrical failures included the uninterruptible power supply for the CT scanner, line power unit, and surge protector, all of which required replacing. Frequently used door locks on the driver's side and the patient entry door were the only nonessential items requiring replacement on the bus.

A 5-year pro forma was created to assess the financial viability of initiating and sustaining a mobile screening program. One year of actual data and 4 additional years of projected data were used to construct the pro forma. All patients in year 1 received a shared decision-making consultation. For years 2 to 5, we assumed an annual retention rate of 40%, with the remaining scans being initial scans requiring a shared decision-making consultation. An annual break-even analysis on yearly patients screened was performed on our project assuming there was no capital outlay (bus donated) and again if we purchased the bus with capital funds. The income statement, including capital outlay, fixed expenses, salaries, and benefits, is shown in Table 1. A valuation of the project was then performed for both a purchased and donated bus. The weighted average cost of capital was 8% and inflation was set at 2%. Net present value (NPV), internal rate of return (IRR), and the profitability index (PI) were calculated. The final scenario removes the downstream revenue from the calculations and repeats the financial ratios. Results are shown in Table 2.

Comment

Mobile lung screening is not new, it dates back to 1996 in Japan when Sone and associates[12] utilized a CT scanner in a van. They were able to perform more than 13,000 scans for more than 5000 patients from 1996 to 1998. Ten-year survival was calculated to be 86.2% for deaths from lung cancer.[12] The Levine Cancer Center has also started a mobile lung cancer screening program centered around a very specific population at risk in North Carolina.

Late stage cancer treatment is known to be expensive with poor outcomes, but few consider the significant economic impact it also has on families and on our country's economic health. In 2015, it was estimated that cancer deaths cost $94.4 billion in lost earnings and 8.7 million years of life lost. That has an impact not only on a family's security but also on our country's workforce. When broken down by type of cancer, lung cancer had the largest economic impact on society with $21.3 billion in single-year family economic losses. The South owns the largest burden followed by the Midwest. That is why lung cancer screening has the greatest opportunity in decades to change the impact a disease has on individual families and on society as a whole.[5,6,13]

With 12-year data and many randomized trials supporting lung cancer screening, why has implementation been slow? There are many barriers. Cautious optimism and some skepticism are natural among the medical community when any new screening tool is introduced. The American Academy of Family Physicians came out with an early statement recommending against low-dose CT in 2013 and has yet to update their statement despite additional studies showing even greater mortality reduction, unfounded concern about false positive biopsies, and now 12-year follow-up data from the National Lung Screening Trial.[1,14,15] Patients with a smoking history also carry an existential nihilism or fatalistic view of life and are mostly unaware of the survival benefits of low-dose CT. Smokers, in general, shy away from all screening tests.[16]

Geography also presents a barrier for many in the South. Information about lung screening benefits and access to an imaging center is essentially nonexistent in many rural locations. In Tennessee, many rural hospitals have closed and health care providers are sparse. Yet geospatial mapping of states like Tennessee demonstrate that the population most at risk and least likely to be aware of lung screening benefits live in these rural counties (Figure 1).[5-7] We developed a prototype mobile platform to determine whether we could reach this vulnerable population, increase awareness, and save lives. Financial sustainability was important to this project.

Screening appropriate patients is challenging. Because of this, we chose to include National Comprehensive Cancer Network groups 1 and 2 for our screening criteria. Group 2 includes patients with fewer pack-years of smoking history.[10] Although smoking history is certainly linked to lung cancer, understanding the actual pack-years is complicated. First, in this formula, equal weight is given to duration and intensity, which is debated.[17,18] Second, many have never counted how much they smoked over their lifetime, and when asked, usually underestimate that number.[19,20] African Americans also have increased risk for lung cancer with shorter smoking history, at 76.1 per 100,000 compared with 69.7 per 100,000 of white persons.[21,22] Race is also not factored into screening determination.

We ran into additional barriers such as employers punishing smokers with higher health insurance premiums. Surprisingly, many employers in our region have a "don't ask, don't tell" policy. Employees were afraid to admit to their smoking status and amount. Some qualified for the examination but opted to pay cash for the study so they would not have to accurately report their tobacco use. That is how our data showed people screened with a less than 20 pack-year history. We also scanned 4 patients who were aged more than 80 years. They were all living independently, driving, and some were still working. They met the criteria other than age, were informed they were outside the current criteria, and elected to pay cash for the examination.

When the bus first arrived, we had many people requesting its presence. We restricted the bus to a 2-hour distance mainly for operational logistics. In the end, a distant screening event proved more difficult for the patients who had a significant finding: 33% of patients with a significant pulmonary finding did not follow up for additional testing as recommended; and 88% were screened at a rural site or a homeless clinic. It is also not realistic to expect someone to travel for as much as 4 hours round trip for additional testing. Ensuring accurate and reliable ways to contact a screening patient and creating partnerships with regional medical centers will help solve this issue. We have currently proposed a statewide network utilizing multiple partners operating additional buses traveling only 60 to 90 minutes from their medical center as a solution.

The costs to purchase and run a mobile screening program, as well as the long-term financial implications, were important for us to understand. Financial sustainability is a requirement for this being a viable component in any lung screening program. To help determine that we used 1 year of actual data and 4 years of conservative estimates to create the pro forma. Monthly screening numbers began at 46 year 1 and reached 166 in year 5. That is well below the capacity of the bus, projected at 200 patients a month. An income statement was generated and is displayed in Table 1. An income statement demonstrates the financial performance of the program taking into account how much money it made, how much money

Table 1. Income Statement Break-Even Analysis

Analysis	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue					
Net patient revenue	136,804	231,607	299,413	386,949	499,916
Expenses					
Salaries, wages, benefits	319,592	325,984	476,574	509,558	519,749
Marketing	10,000	10,100	10,201	10,303	10,406
Supplies	1500	1545	1591	1639	1688
Rentals/leases	4500	4545	4590	4636	4683
Maintenance/service contracts	...	55,000	55,550	56,106	56,667
Travel, including fuel	6250	6313	6376	6439	6504
Depreciation/amortization	170,000	170,000	170,000	170,000	170,000
Total operating expenses	511,842	573,486	724,882	758,681	769,697
Operations income/(loss)	(375,038)	(341,879)	(425,469)	(371,732)	(269,781)
Downstream impact	340,324	592,588	737,032	916,683	1,140,125
Net income/(loss)	(34,714)	250,709	311,563	544,951	870,344
Annual volume break-even visits					
Bus purchased	653	738	939	991	1013
Bus donated	428	511	711	760	781

Values are US dollars unless otherwise indicated.

it paid out, and the resulting profit or loss. It also includes the depreciation of the bus if it was purchased. Expenses year 1 were just over $500,000 and reached $770,000 by year 5. The largest component to this was salaries, wages, and benefits. When downstream revenue was included, the program reached profitability by year 2 and remained profitable the remaining 4 years. Our break-even analysis for year 1 with our donated bus was only 428 scans. We exceeded that number by 28% (548) despite only scanning patients 10 of the 12 months.

Reviewing the income statement, the revenue from the shared decision-making visit (G0296) and the actual screening CT (G0297) was inadequate to cover the expense of a mobile program even when the bus was donated. With dramatic cuts to lung screening imposed by the Centers for Medicare and Medicaid Services in 2017, its likely true for any type of screening program.[2] The downstream revenue from significant pulmonary and nonpulmonary findings is critical to a program's sustainability and is also difficult for most to quantitate. We used the Cleveland Clinic published

Table 2. Net Present Value, Internal Rate of Return, and Profitability Index

Variables	Year 1	Year 2	Year 3	Year 4	Year 5
WACC, 8%					
Cash flows					
Start-up costs	(850,000)	0	0	0	0
Working capital (57 days net A/R)	(20,047)				
Total operating margin	(61,795)	203,962	252,720	470,869	777,056
Add back: depreciation	170,000	170,000	170,000	170,000	170,000
Net cash flows	(761,842)	373,962	422,720	640,869	947,056
Discounted cash flows	(769,857)	320,612	335,569	471,058	644,550
Total: 1,001,932					

Bus purchased with DR		Bus donated with DR	
5-Year NPV	1,001,932	5-Year NPV	1,851,932
IRR, %	34.6	IRR, %	709.5
PI	2.20	PI	NA
Bus purchased with no DR		Bus donated with no DR	
5-Year NPV (1,699,451)		5-Year NPV (849,451)	

Values are in US dollars, unless otherwise indicated.

A/R, accounts receivable; DR, downstream revenue; IRR, internal rate of return; NA, not applicable; NPV, net present value; PI, profitability index; WACC, weighted-average cost of capital.

value of $817 generated from each screening patient (Medicare rates).[11] That included the shared decision making and CT reimbursement. We removed our reimbursement for these services to get the $587 average downstream contribution per patient. This number is likely higher given that 39% of our patients in our screening program have commercial insurance.

Financial ratios were then calculated to analyze the financial health and sustainability of a mobile lung screening program. We looked at two scenarios: one where the bus was purchased, and the other where the bus was gifted through a foundation. The NPV, IRR, and PI were used. The NPV is the value of all future cash flows (positive and negative) discounted back to the present. A positive NPV means the project is worthwhile. The IRR is the interest rate returned to the organization for its initial investment. If the IRR equals or exceeds a company's required rate of return, then it is a justifiable investment. The PI is the ratio of payoff to investment and allows quantification of the amount of value created per unit of investment. A PI greater than 1 means the project is profitable and can proceed. In both scenarios, all three ratios were positive even when capital dollars were used to purchase the bus. When the downstream revenue was removed from the project, all ratios turned negative even in the donated bus scenario. That only stresses the importance of having protocols and accountability measures in place to capture the necessary downstream revenue.

From this feasibility study, future design changes have been made to the bus. The chassis needed to be more robust and have a much larger GVWR, and it has been upgraded to a different Freightliner chassis with a GVWR of 52,000 lbs. This extra safety margin brings less stress to the chassis, brakes, tires, transmission, and engine than our fully loaded recreational-vehicle style bus. With additional time and input, Siemens has designed a 64-slice CT scanner made for the mobile platform that operates through an iPad and is capable of performing gated coronary calcium scores. Faster image acquisition with even further reductions in radiation dosage all favor lung screening. Commercial heating, ventilation, and air-conditioning systems, throughput design changes, more robust structural components, and streamlined construction should all improve reliability and capacity while keeping cost controlled.

In summary, a mobile lung screening program can offer great value to those most at risk. It also provides a great medium for educating the public on the benefits of lung screening that seem slow to disseminate. For those who are hesitant to be screened, it offers a convenient and easy way to be scanned. If a medical center sees the value in a mobile lung screening program, it can be done with limited financial risk.

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