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Technical Note

Evaluating single-institution resource costs of consolidative radiotherapy for oligometastatic non-small cell lung cancer using time-driven activity-based costing

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ABSTRACT

Background: Consolidative radiotherapy (RT) has been shown to improve overall survival in oligometastatic non-small cell lung cancer (NSCLC), as demonstrated by a growing number of prospective trials.
Objective: We quantified the costs of delivery of consolidative RT for common clinical pathways associated with treating oligometastatic NSCLC, by applying time-driven activity-based costing (TDABC) methodology.
Methods: Full cycle costs were evaluated for 4 consolidative treatment regimens: (Regimen #1) 10-fraction 3D conformal radiation therapy (3D-CRT) as palliation of a distant site; (#2) 15-fraction intensity-modulated RT (IMRT) to the primary thoracic disease; (#3) 15-fraction IMRT to the primary plus 4-fraction stereotactic ablative radiotherapy (SABR) to a single oligometastatic site; and (#4) 15-fraction IMRT to the primary plus two courses of 4-fraction SABR for two oligometastatic sites.
Results: For each of the four treatment regimens, personnel represented a greater proportion of total cost when compared with equipment, totaling 61.0%, 65.9%, 66.2%, and 66.4% of the total cost of each care cycle, respectively. In total, a 10-fraction regimen of 3D-CRT to a distant site represented just 37.2% of the total cost of the most expensive course. Compared to total costs for 15-fraction IMRT alone, each additional sequential course of 4-fraction SABR imparted a cost increase of 43%.
Conclusion: This analysis uses TDABC to estimate the relative internal costs of various RT strategies associated with treating oligometastatic NSCLC. This methodology will become increasingly relevant to each organization in context of the anticipated mandate of alternative/bundled payment models for radiation oncology by the Centers for Medicare and Medicaid Services.

1. Introduction:

Practice-changing, prospective randomized trials have recently demonstrated a progression-free and now an overall survival benefit to aggressive consolidation of oligometastatic sites in non-small cell lung cancer (NSCLC) and other histologies [1–3]. There are now over 100 registered clinical trials studying oligometastatic disease, with wide implications regarding the paradigm of how this patient population could be managed in the future [4].

In 2010, health care leaders called attention to the issue that more emphasis needs to be made on maximizing outcomes per dollar spent and facilitating reform of the reimbursement system to incentivize a value-based framework [5]. However, US healthcare spending as a percentage of gross domestic product remains disproportionately high as compared to other nations and is projected to continue increasing [6]. In addition, there is tremendous variation in price of similar services and poor transparency in price [7]. Furthermore, there is a lack of understanding of the true cost of

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delivering care both within an institution and across institutions. Reimbursements or charges are therefore used as proxies for cost, but often have limited bearing on the actual cost of resources, in the form of personnel, equipment, and facilities, that are require to deliver care.

Time-driven activity-based costing (TDABC) is a validated, bottom-up cost accounting tool to help improve transparency in treatment cost by quantifying and aggregating resource utilization [5]. Approaches such as TDABC generate comparative internal economic analysis and can inform the cost portion of the value equation from the provider perspective. Having an understanding of one's internal costs will increase in importance as radiation oncology is expected to be one of the first healthcare specialties to employ a mandated alternative/bundled payment model by the Centers for Medicare and Medicaid Services (CMS) [8]. This study uses TDABC to estimate the internal resource utilization expenses of variably complex and costly yet common strategies for using radiation therapy (RT) to treat oligometastatic NSCLC within a large academic cancer center.

2. Methods

2.1. Treatment pathways

Full cycle costs were evaluated for 4 treatment regimens: (1) 10-fraction 3D conformal RT (3D-CRT) to a single distant site; (2) 15-fraction intensity-modulated RT (IMRT) to the primary thoracic disease alone; (3) 15-fraction IMRT to the primary thoracic disease, plus a sequential 4-fraction stereotactic ablative radiotherapy (SABR) to a single site of oligometastatic disease; and (4) 15-fraction IMRT to the primary thoracic disease, plus two courses of sequential 4-fraction SABR for both sites of distant, oligometastatic disease.

2.2. TDABC analysis

TDABC analysis requires several steps, including: (1) outlining step-by-step process maps from the beginning of the care cycle (i.e. consultation) through the end of the care cycle (i.e. 12-month post-treatment follow-up); (2) determining all resources that are utilized at each step of the process map; (3) measuring the absolute time allocated from each resource at each step; (4) calculating the capacity cost rate (CCR), or cost per minute, of each resource based on its available capacity for productive work; and (5) accumulating the cost of care throughout the care delivery cycles by multiplying the time for each resource at each step by the respective CCR(s). The overall cost of an episode of care was defined as the sum cost of all resources utilized in care delivery. Costs were normalized to the most expensive regimen (treatment regimen #4) and reported in relative percentages rather than raw dollar amounts, as consistent with institutional policy [9]. Three rounds of detailed multidisciplinary panel interviews with radiation oncology faculty and staff (including physicians, physicists, nurses, dosimetrists, radiation therapists, administration, and others) were completed to estimate the processes, personnel, and equipment involved. A dedicated staff observed clinic workflow to estimate the time required at each process within the full cycle of care.

2.3. Process maps

The cumulative process maps regarding RT for a patient with oligo-metastatic NSCLC encompassed 11 major processes including: consultation, computed tomography (CT) simulation, treatment-planning preparation, treatment planning, physician quality assurance (QA), treatment plan corrections (assuming a 10% probability of occurrence), treatment delivery, weekly see visits, clinic drop-in visits, end-of-treatment evaluation, and follow-up. Each of these 11 major processes had between 7 and 21 minor steps involved, summating to 189 minor steps in total. The various personnel required to accomplish each step was determined, and all major and minor steps were weighted according to a probability multiplier based on likelihood of occurrence. Separate parallel processes were created for 3D-CRT, IMRT, and SABR, given the intrinsic procedural differences associated with each technique.

2.4. Personnel

The personnel costs included patient service coordinators, nurses, advanced practice practitioners (APPs, i.e. nurse practitioners and physician assistants), receptionists, radiation therapists, dosimetrists, medical assistants, physicists, and attending physicians. For each personnel member, cost data were pulled from the PeopleSoft (Oracle Inc., Redwood Shores, CA) payroll application and included salary, bonuses, fringe benefits, support, training, travel, and insurance expenses specific to our institution.

2.5. Facility, equipment & overhead costs

Equipment and software costs were initially built by starting with the upfront purchase price for each piece of equipment. Costs then accounted for equipment lifespan, depreciation schedule, and maintenance expense contracts when relevant, based on institutional and manufacturer recommendations. Facility costs were embedded within these equipment costs. An estimated overhead multiplier was modeled into the equipment costs and was provided with the assistance of our financial team to approximate indirect costs. Disposable supply costs were excluded from analysis due to their relatively minimal cost contribution. Each treatment regimen was assumed to have five follow-up visits included (each associated with CT surveillance imaging), through an entire year of follow-up, defining a full cycle of care delivery.

2.6. Capacity cost rates

Capacity cost rates (CCRs) represent the cost in dollars per minute of use. This was back calculated from annual expenditures after considering the annual availability of each resource. Personnel capacity considered time unavailable due to vacations, holidays, breaks, and weekends. For equipment, the available capacity for each resource was also estimated and measured in hours, based upon practical capacity. For example, CT simulators were expected to simulate no more than eight patients each workday, with at least 1 hour allocated per simulation slot, for 230 workdays per year.

3. Results

For each of the four treatment regimens, personnel represented a greater proportion of total cost when compared with equipment, totaling 61.0%, 65.9%, 66.2%, and 66.4% of the total cost of each care cycle, respectively. Absolute personnel costs increased proportionally with the total expense for each of the four treatment regimens. This was driven primarily by consultation, follow-up visits, QA, and treatment delivery. When examining the provider roles which contribute to personnel cost for each treatment regimen, physician cost contributed to 64.3%, 62.6%, 58.6%, and 56.5% of the total personnel cost of the four treatment regimens, respectively. The costs associated with the dosimetrist, radiation therapists, and physicists were the next largest contributors to personnel costs,

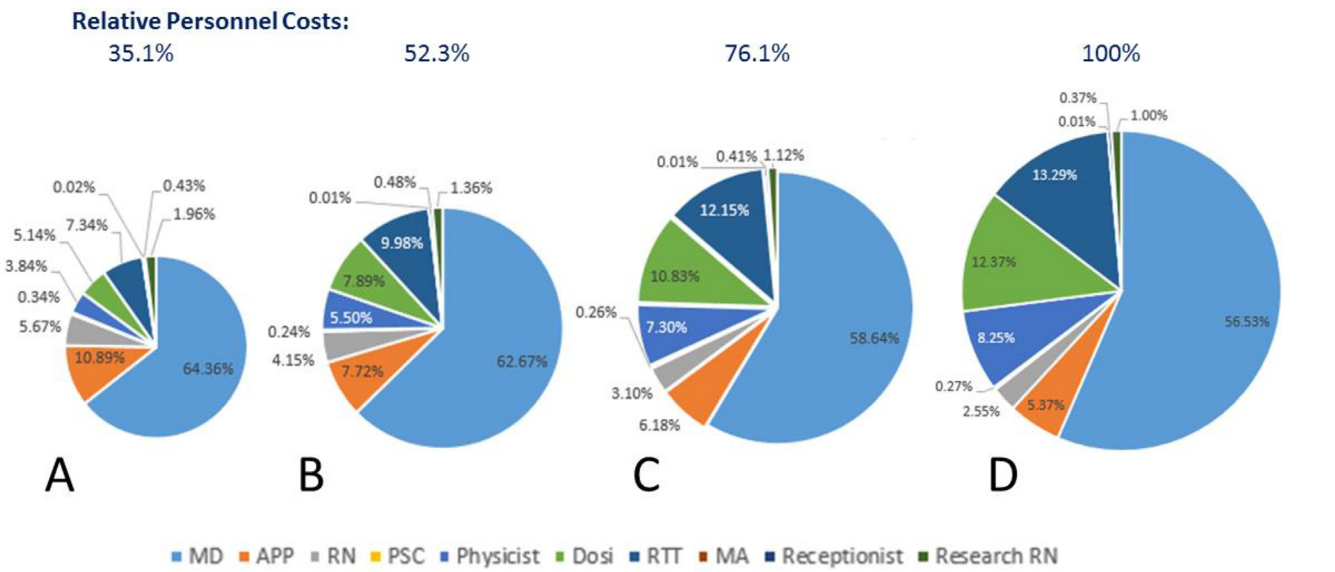

Fig. 1. Pie charts displaying the relative personnel costs involved for each treatment regimen. Note: Area of each pie chart is proportional to the total personnel cost of each treatment regimen. A = 10fx 3DCRT, B = 15fx IMRT, C = 15fx IMRT & 4fx SABR, D = 15fx IMRT & 4fx SABR (x2). *Abbreviations*: MD = Physician, APP = Mid-Level Provider, RN = Registered Nurse, PSC = Patient scheduling coordinator, Dosi = Dosimetrist, RTT = Radiation Therapist, MA = Medical Assistant, IMRT = intensity modulated radiation therapy, SABR = Stereotactic ablative body radiotherapy, fx = fraction.

Table 1
Table displaying the breakdown of the relative costs of each of the major and minor steps involved in each treatment regimen.

Major Step in Process	(#1) 10fx 3DCRT	(#2) 15fx IMRT	(#3) 15fx IMRT & 4fx SABR	(#4) 15fx IMRT & 4fx SABR (x2)
Consult (P)	4.44%	4.44%	4.44%	4.44%
CT Simulation (P)	1.68%	2.21%	4.85%	7.49%
Treatment Plan Prep (P)	0.77%	2.38%	3.44%	4.49%
Treatment Planning (P)	1.49%	3.01%	5.90%	8.78%
Plan Quality Assurance (P)	2.44%	2.88%	5.77%	8.65%
Treatment Plan Correction (P)	0.12%	0.27%	0.52%	0.78%
Treatment Delivery (P)	1.94%	8.59%	13.60%	18.60%
Weekly See (P)	1.79%	2.69%	3.59%	4.49%
Drop In Clinic Visit (P)	0.08%	0.04%	0.05%	0.07%
End of Treatment Work-up (P)	0.34%	0.81%	0.68%	1.03%
Follow Up Visit (P)	7.63%	7.63%	7.63%	7.63%
CT Sim (Equ)	1.81%	1.81%	3.62%	5.44%
Linac (Equ)	7.11%	10.66%	16.35%	22.03%
Treatment Planning Software (Equ)	0.25%	0.25%	0.51%	0.76%
Follow up Imaging (Equ)	5.33%	5.33%	5.33%	5.33%
Total	37.23%	53.00%	76.27%	100.00%

Abbreviations: P = Personnel cost, Equ = Equipment cost, IMRT = intensity modulated radiation therapy, SABR = Stereotactic ablative body radiotherapy, fx = fraction, CT = Computed tomography, Linac = Linear Accelerator.
**Percentages in each cell are in relative to the total cost of treatment #4.

with a breakdown for each of the four treatment regimens shown in Fig. 1.

Equipment costs were primarily associated with use of the linear accelerator and vault for all treatment regimens. A breakdown of the various equipment costs is outlined in Table 1 and Fig. 2.

In total, a 10-fraction regimen of 3D-CRT represented just 37.2% of the total cost of the most expensive regimen, consisting of 15-fraction IMRT to thoracic disease plus two SBRT courses to oligometastatic sites. Similarly, 15-fraction IMRT (regimen #2), and 15-fraction IMRT plus a 4-fraction SABR course to a single distant site (regimen #3), represented 53.0% and 76.2% of the most expensive course (regimen #4), respectively.

Compared to total costs for 15-fraction IMRT alone (regimen #2), each additional sequential course of 4-fraction SABR imparted a total cost increase of approximately 43%.

4. Discussion

Our TDABC analysis was performed at a highly relevant period in oncologic medicine given the large number of open clinical trials currently exploring local consolidation of oligometastatic disease. As patients continue to live longer with metastatic disease due to increasingly effective immunotherapeutic and targeted agents, it is reasonable to assume the role of RT for oligometastatic and primary disease will continue to increase.

However, as the healthcare industry transitions closer to value-based care, the increasing costs of medical advancements should be evaluated within the context of healthcare value (defined as outcome per cost). Our study addresses the denominator of this equation through the use of TDABC to quantify the incremental cost of resource utilization in delivering various pathways of

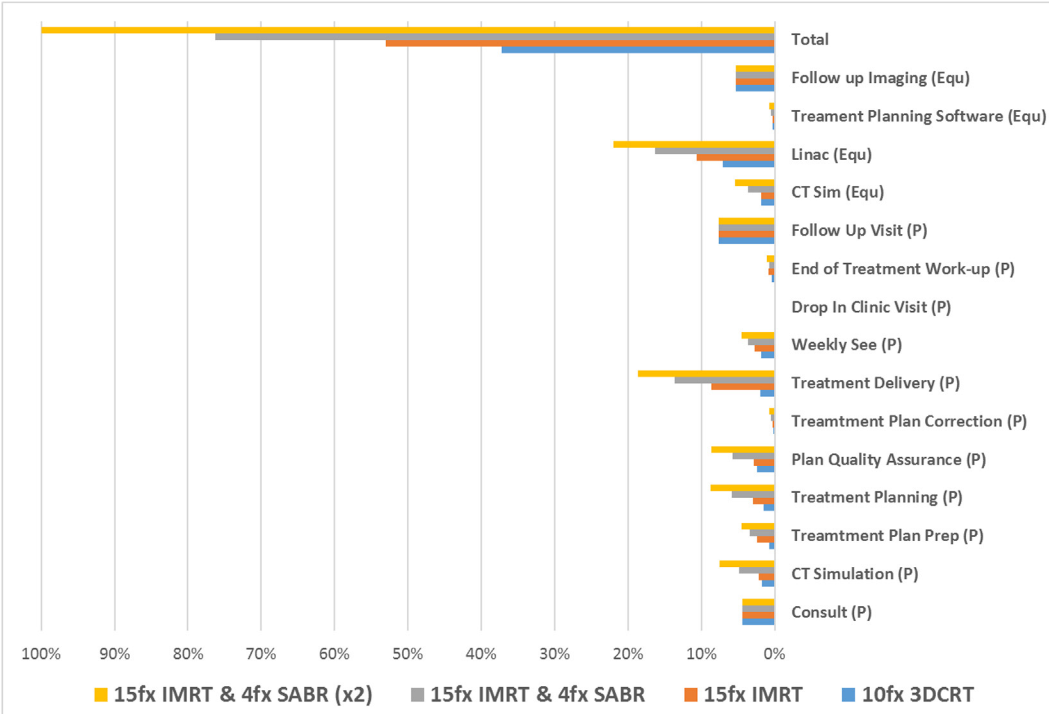

Fig. 2. Bar chart displaying the breakdown of the relative costs of each of the major and minor steps involved in each treatment regimen. Note: Percentages in each cell are relative to the total cost of Regimen #4. *Abbreviations*: P = Personnel cost, EQU = Equipment cost, IMRT = intensity modulated radiation therapy, SABR = Stereotactic ablative body radiotherapy, fx = fraction, CT = Computed tomography, Linac = Linear Accelerator.

consolidative RT for oligometastatic NSCLC at our single large academic institution.

Supplementing these findings, Panje et al published Swiss data regarding the cost effectiveness of consolidation for oligometastatic NSCLC using a Markov model, concluding that consolidation is generally economical in this setting [10]. While there are significant differences in baseline cost metrics between Switzerland and the United States, which may limit applicability [11], macroeconomic analyses such as theirs are quite valuable in providing insight from the payer and societal perspectives. Such analyses can complement the bottom-up granularity associated with the TDABC model, which seeks to define delivery costs from the perspective of the healthcare provider.

As alternative episode-based reimbursement models come to fruition, incentives will shift and transparent data regarding internal costs of delivering a variety of cost-effective treatment regimens will be critically important. In a speech made in Washington DC in November 2018, the Secretary of Health and Human Services, Alex Azar, specifically named radiation oncology as a discipline where these new reformed payment models will be implemented, with expected savings to CMS of 260 million dollars over 5 years [8]. Despite prior delays, the American Society for Radiation Oncology (ASTRO) has confirmed expectations for this mandate to be implemented prior to 2022 [12,13].

Our analysis explored four variable treatment strategies that could be used for consolidative RT for the management of oligometastatic disease. The heterogeneity in these individual and combination treatment modalities highlight the variability of associated expenses, and can serve as the building blocks to better understand the true cost of care delivery from the provider standpoint. These four pathways serve as common examples in our institution for consolidative RT for oligometastatic NSCLC, but pathways will likely vary between institutions. Despite that variation, this TDABC analysis shows that clinical pathway costs are modular and can be applied to many pathway variations. Such measurement can inform not only bundled payment calculations at a more global level within the institution, but can also be used to track patient specific costs over the full care cycle.

While these data can be time-intensive to collect on the front end, once collected, TDABC can be applied effectively in many cost-saving and quality improvement applications from the provider perspective. For example, in our particular analysis, consolidation to the distant site was considered sequential, rather than concurrent, with consolidation of the lung primary. However, if treatment to multiple sites may be safely and technically delivered concurrently, many of the duplicate or redundant steps in the care pathway would be consolidated, thus decreasing total costs. Note that this analysis assumed distant consolidation would be completed with SABR, a widely accepted but resource intensive technique perpetuated by multiple oligometastatic clinical trials [3]. While SABR is resource-intensive on the front-end as compared with conventional radiation therapy, SABR does have potential to improve local control as compared with conventional radiation therapy. Improved local control may translate to improved progression free survival, and thus decrease the need for subsequent courses of systemic or radiation therapy which can also have a detriment on patient quality of life and increase the cost of care. Further research needs to be done to quantify the total impact in the context of multidisciplinary care.

A notable limitation of this study is the single-institution design. As this was conducted at a large academic cancer center, the specific absolute costs may not be generalizable to all health systems and oncology practices, due to heterogeneity in resource utilization and process workflows among different practice settings. However, while this analysis reflects a single-institution experience, the underlying methodology remains consistent and can be implemented at other facilities to assist in decision-making, internal cost analysis, and utilization metrics.

5. Conclusion

This analysis uses TDABC to estimate the internal costs of various RT strategies associated with treating oligometastatic NSCLC. This methodology will become increasingly relevant in the context of the anticipated mandate of alternative/bundled payment models for radiation oncology by CMS.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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No direct acknowledgements. See below for full disclosures. Running Head: TDABC Analysis in Oligometastatic NSCLC.

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