



Comparative costs of advanced proton and photon radiation therapies: lessons from time-driven activity-based costing in head and neck cancer

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“Understanding provider costs will become even more important as healthcare reform transitions to value-based purchasing.”

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Advanced technology in the USA is, in part, responsible for driving improvements in cancer care outcomes but also steep increases in the cost of cancer care delivery [1–3]. Whether or not the US healthcare system delivers high-value care, which is defined as the quality of health outcomes divided by the cost of achieving those outcomes, is controversial. Despite much emphasis on comparative effectiveness analyses, cost–effectiveness analyses of costly therapies, such as advanced technologies, have been under emphasized. Although the Patient Protection and Affordable Care Act has limited the role of cost analysis in the federally funded Patient-Centered Outcomes Research Institute, given the controversy and fear of rationing of healthcare services [4], successful transformation from volume to value will require patients, providers and payors to understand the comparative effectiveness and cost–effectiveness of competing technological treatment modalities.

Radiation oncology in cancer care

Radiation therapy (RT), in particular, has relied on innovations in technology to improve cancer care outcomes but has also faced significant controversy regarding rising costs [5]. Each successive generation of new technology, from 2D to 3D and, more recently, to intensity-modulated radiation therapy (IMRT), has potentially improved outcomes and toxicity by more effectively delivering dose to tumor cells and sparing normal healthy tissues [6]. Extraneous irradiation can have long-term detrimental

effects, such as secondary cancers and toxicity. For example, outcomes for head and neck cancers have improved with technology that can spare high doses of radiation to normal tissues, given the proximity of critical structures in a limited anatomical area. However, the progressively complex machinery and skilled personnel required to deliver RT has become increasingly expensive with each generation of technology.

Proton beam therapy (PBT) is an evolution in RT delivery technology that has superior ability to spare RT dose to surrounding normal healthy tissues due to its unique physical properties. In anatomically challenging head and neck cancers, treatment with PBT in select cases may further reduce dose to normal portions of the mucosa of the oral cavity, oropharynx, larynx and brainstem, which could result in fewer side effects and reduced need for downstream healthcare interventions [7]. However, PBT equipment is significantly more expensive than IMRT equipment, which has driven higher reimbursement for PBT.

Although the theoretic advantage of PBT over IMRT is strong, prospective comparative effectiveness data on the clinical utility of PBT continue to develop by disease site. Comparative studies, in the form of clinical trials or population-based analyses, however, are often incomplete in their assessment of the full spectrum of short-term, patient-reported and long-term outcomes. Clinical trials tend to have stringent inclusion and exclusion criteria, which limit their external

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validity in real-world settings with truly representative patient populations. Most clinical trials are also powered for a specific primary end point, with collection of few secondary end points and limited, if any, patient-reported outcomes. Furthermore, population-based analyses are derived from large databases, such as Surveillance, Epidemiology, and End Results, which have a limited number of available data elements for analysis and risk stratification. Patient-Centered Outcomes Research Institute holds promise of comprehensively measuring relevant outcome dimensions, which may enhance the availability of robust health outcome data across many medical conditions.

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However, accurate cost comparisons, which is a fundamental input into the value equation, is notably missing in most clinical trials or population-based analyses that compare PBT with IMRT. Although the Affordable Care Act does not allow certain federally funded programs to assess cost-effectiveness, patients, providers and payors are not bound by this limitation. Implementing a robust cost accounting methodology would significantly strengthen comparative analyses, would aid in patient-centered medical decision-making and would provide direct insight into opportunities to maximize outcomes while minimizing costs.

Measuring time-driven activity-based costing

Costs in healthcare have traditionally been measured using top-down, charge-based accounting systems. Unfortunately, this approach has been inaccurate due to the tremendous cost shifting that has occurred in healthcare over the past several decades. Current fee-for-service reimbursements are not tied to the consumption of the underlying resources required to deliver a clinical service, which has caused over and underutilization of services and cost shifting from higher-margin service lines, such as radiation oncology, to subsidize the expense of under-reimbursed, but high-value, services such as endocrinology. Although, healthcare providers are unaware of the true costs of delivering a specific process of care, successful transition from volume to value will require a much more granular understanding of true costs.

The provider's cost of delivering PBT is not its reimbursement or billed charges but, rather, the cost of the various healthcare activities required to treat the patient's specific medical condition. If reimbursement rates are to be set in a financially neutral way, in

an effort to reduce financial incentives when choosing therapies, then reimbursement needs to be aligned with the actual cost to the provider for delivering care with that therapy. Several industries have successfully applied the concepts of activity-based costing to measure underlying resource consumption. Time-driven activity-based costing (TDABC) is a variation of activity-based costing where process costs are analyzed from bottom-up based on time consumption of resources, including personnel, equipment and facilities, required to render each patient-level activity over the full cycle of care [8]. The first step in measuring TDABC cost is to bring together clinical and administrative teams to create and update patient-level process maps of the full care cycle workflow and associate a specific resource and time (in minutes) for each activity. Financial teams then coordinate with clinical and administrative teams to calculate a cost per minute for each resource utilized in the workflow. Costs at each activity step are then integrated over the full care cycle to measure costs at the medical condition level [9].

TDABC costs reflect both direct and indirect costs. Direct costs include actual resources involved in a patient's care, such as personnel, equipment, facilities, supplies and support services. These calculations take into account the depreciation, interest, amortization and service costs of equipment and technology. Indirect, or 'overhead', costs are also associated with patient-facing resources that support these direct services, such as information technology, billing, human resources, and other space or facilities. This methodology uniquely integrates hospital inpatient, outpatient and physician costs, and requires the coordinated and undivided inputs of clinicians, financial analysts and administrators. While most applications of TDABC have pertained to industry personnel and process improvements, this concept can be readily applied to measure and communicate the value of technological care delivery systems.

Implementing TDABC in head & neck radiation oncology

Our institution has recently piloted TDABC in the Head and Neck Center to directly compare the cost, and ultimately the value, of PBT versus IMRT for oropharyngeal head and neck cancer patients. Costs are embedded as an end point within this trial, and comprehensive clinical outcome measures and TDABC costs are being collected in both retrospective cohorts and prospective clinical trial settings from initial registration through 1 year after completion of RT, rather than over a single intervention.

Not surprisingly, the TDABC cost of a single fraction of PBT is 2.8-times that of a single fraction of IMRT,

driven mostly by the substantial equipment cost associated with PBT. Modeling analyses for PBT versus IMRT, without actual patient-level clinical data, therefore predict a higher cumulative TDABC cost for PBT than IMRT. However, modeling does not take into account clinical heterogeneity and the true outcomes of patient care. Interestingly, when TDABC was applied to case-matched retrospective data from actual patient cohorts treated with PBT and IMRT, a subset of patients treated with PBT actually cost less than IMRT over the full care cycle. For this subset, reductions in dose to the oral cavity, oropharynx and emetic structures with PBT translated into less weight loss, less feeding tubes, better quality of life end points and lower cost. These preliminary full cycle cost results from these pilot studies have been surprising but ultimately suggest that careful patient selection of head and neck cancer patients for PBT may actually deliver higher-value care than IMRT. Such conclusions would be difficult to make if comparative analyses only focused on outcomes or reimbursements alone. Future efforts will need to focus on prospectively defining the clinical criteria relevant to this subset of patients whose gain from PBT may be substantial.

While most previous applications of TDABC have pertained to personnel costs, which can account for 70% or more of costs in most processes, TDABC can also be applied to measuring and communicating the value of technologically oriented delivery systems, such as PBT, where technology costs instead account for 65–70% of the full cycle cost. Interestingly, we have learned that TDABC can measure the cost of outcome variation, such as the cost of patient-specific toxicities or hospitalizations. In some ways, cost can even be viewed as an outcome itself. Prospective implementation of TDABC within this full care cycle context has allowed us to create an infrastructure for tracking resource utilization in near real time and has provided insight into the areas of excess cost, opportunities for improving the efficiency of PBT and IMRT clinical trial workflows and optimization of utilization capacity of RT resources. As we continue to evaluate the flow of resources within both retrospective cohorts and randomized controlled trial settings, we are creating quality benchmarks that will further improve clinical efficiency, optimize outcomes and lower costs.

Value-added opportunities for TDABC

This analysis highlights several value-added opportunities for TDABC that will enhance comparative effectiveness analyses.

Reducing waste & optimizing care cycle time

Although TDABC facilitates cost comparison between treatment modalities, this analysis compares costs of

relatively nonoptimized workflows. Thirty to even 40% of cost in the US healthcare system may be due to waste or inefficiency [10]. The better mechanism for value comparison of competing treatments, then, is to improve the efficiency and quality of current, baseline workflows and then compare the costs and outcomes of final state workflows [9]. Such efforts would streamline resource utilization by identifying and eliminating low or non-value-added services, shortening the care cycle time to improve volume throughput and focusing on optimizing process steps that improve total care cycle cost rather than simply lowering costs of individual interventions.

Conducting quality improvement initiatives

TDABC can be integrated into lean and quality improvement initiatives to focus improvement efforts on the most costly portions of the treatment cycle, thereby eliminating administrative and clinical processes that do not improve outcomes. TDABC can also capture process variations that lower efficiency and increase waste without improving outcomes. Such efforts have already started to reduce full care cycle costs of PBT at our institution by eliminating non-value-added services, increasing cost awareness in clinical teams and identifying processes for which initially higher costs may ultimately reduce costs and improve outcomes over the long term. Clinical and administrative teams can also utilize TDABC to predict the effects of future quality improvement initiatives to determine true savings (or expenditures).

Reorganizing & optimizing resource utilization

By understanding the cost drivers of PBT and IMRT, we may be able to reorganize and optimize resource utilization to ensure that each clinical provider is able to provide the quality of care at their maximum core competency. Similarly, TDABC can provide insight into how the right services can be provided at the right locations with the right resources. A pilot program is underway to facilitate community-based physician assessment of patients with certain types of common malignancies for PBT without requiring a patient referral to a disease site-specific radiation oncologist that specializes in PBT. This reorganization may free up more time for disease site-specific physicians to evaluate and treat complex cancers with PBT, while improving efficiency, decreasing cost and enhancing access of PBT to patients with more common cancers in the community setting. TDABC may be able to help minimize redundant clinical, administrative and financial units by reducing duplication and service fragmentation across the institution.

Developing novel reimbursement models

As reimbursement mechanisms move toward value-based payment, such as a bundled payment for an entire episode of head and neck cancer care, providers will increasingly need to understand which treatments optimize the full dimension of outcomes while minimizing costs. In a bundled payment environment, providers would negotiate the upfront reimbursement of all cancer care services provided over the entire care cycle, including RT (PBT or IMRT), chemotherapy and surgery. Bundling of services will encourage process mapping, cost analysis, reporting of performance metrics and financial integration between provider groups. Successful negotiations with payors, however, will rely on providers' accurate estimation of their true costs in order to maintain a viable margin, especially for costly yet potentially effective technologies. TDABC could therefore become a common costing language for local, national and international cross-healthcare system cost comparisons, which will ensure that competitive pricing reflects higher margins for care that is comparatively more effective.

Barriers to implementation

Despite these significant advantages, movement away from current legacy costing systems and toward TDABC will be met with several major challenges. Financial teams will need to fundamentally redesign their healthcare costing system from a top-down to a bottom-up approach, although crosstalk and comparisons between both systems will be necessary. Small-scale TDABC analyses are achievable through manual calculation methods, but larger scale efforts, such as prospective measurement of patient costs on clinical trials or throughout an institution, will require dedicated staff and software solutions that can connect TDABC costs with institutional data warehouses, budgeting and financial planning processes. Accurate analyses will also depend on comprehensive process mapping of each clinical pathway, requiring unprecedented integration and coordination of financial, administrative and clinical teams. Physician

champions will need to be identified across many specialties and provided with administrative support to keep the process maps modern and relevant. However, these resource-intensive efforts are well worth the investment, as these collaborations will identify unique and innovative opportunities to improve patient-centered clinical care and decrease institutional costs.

Conclusion

TDABC is an innovative costing tool in healthcare that can be used to directly compare the true cost of competing technologies over the full care cycle. Rather than only comparing therapeutic effectiveness over a limited number of outcome measures, healthcare stakeholders will need to move toward comparing the value of care delivery and therefore the cost of therapies. Measuring the value of advanced technologies like PBT versus IMRT is especially crucial, given the high upfront cost of developing, building and delivering care with these modalities. An incomplete understanding of the value of costly, yet effective, technologies could impede medical innovation and decrease the quality of cancer care through a reduction of patient access by third-party payors. With TDABC, providers may begin to uncover clinical situations in which higher-cost, advanced therapies are actually justified over the full episodic care cycle. Understanding provider costs will become even more important as healthcare reform transitions to value-based purchasing.

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