ABSTRACT

Emphasis on value-based healthcare has led to increasing use of time-driven activity-based costing (TDABC) across medical departments. When applied to brachytherapy, TDABC provides insight into differences in costs across various modes of therapy, the nuances that drive cost including institutional factors and involved personnel, and discrepancies in reimbursement which influence clinical practice. This is especially important with the new alternative payment model (APM) in radiation oncology which offers fixed reimbursement per 90-day episode of care. The TDABC model can thus be utilized to improve efficiency, optimize the role of ancillary staff in treatment planning and care delivery, and implement shorter fraction schedules when clinically appropriate to promote value-based care. Ultimately, application of this methodology could potentiate changes to practice and incentives to improve patient care. In this review, we discuss the utility and limitations of TDABC in the context of existing studies in brachytherapy which have utilized this methodology. © 2021 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Introduction

Activity-based costing (ABC) is a method of cost accounting which was developed in the manufacturing industry during the 1970s and 1980s [1]. Though it offered a useful translation of indirect overhead costs into direct costs, this methodology relied heavily on data collected from employees and posed a heavy burden of time and cost on companies [2]. Time-driven activity-based costing (TDABC) is a modified method of ABC which allows managers to estimate resource demands, thus promoting efficiency and prioritizing accuracy over precision [2,3]. With increasing emphasis on value-based healthcare, which requires estimation of both quality and costs, TDABC has been presented as a useful application to inform process improvement in healthcare, better organize care, and facilitate new reimbursement models [4].

TDABC has been streamlined into seven steps for healthcare organizations. The steps include: (1) select medical condition, (2) define care delivery chain, (3) develop process maps, incorporating direct and indirect capacity-supplying resources, (4) estimate time required for all activities and resources, (5) estimate cost of supplying patient care resources, (6) estimate capacity of each resource and calculate capacity cost rate, (7) calculate total cost of patient care [5]. Creation of process maps allows managers to identify redundancies and rate-limiting factors which can be minimized to improve costs and efficiencies [6]. This methodology has demonstrated benefit across numerous medical specialties including anesthesiology, surgery, and nephrology by quantifying cost savings associated with specific changes in practice [6–8]. For example, at the Brigham and Women’s Hospital, TDABC analysis demonstrated decreased operating cost and procedure wait times by shifting the majority of colonoscopy procedures from the main hospital to the ambulatory clinic [6]. TDABC has been increasingly utilized in oncology across multidisciplinary clinics to meet needs of growing patient volumes, improve enrollment in clinical trials, and streamline workflow to provide quality patient care [9].
personnel, and discrepancies in reimbursement which influence clinical practice. The TDABC model can thus be applied to brachytherapy to improve efficiency, optimize the role of ancillary staff in treatment planning and care delivery, and implement shorter fractionation schedules when clinically appropriate to promote value-based care. Applying TDABC towards value-based healthcare is especially important for brachytherapy since it is generally more expensive to deliver than external beam radiation therapy. There has been a decreased use of brachytherapy even when it is evidentially indicated, possibly due to the discrepancy between higher cost of brachytherapy treatment and reimbursement for care delivery.

This article represents a scoping review of existing studies in brachytherapy which utilize the TDABC methodology. These studies were identified through PubMed literature search using keywords “time-driven activity-based costing” and “brachytherapy.” Many of the studies refer to process mapping, which is a crucial step in the TDABC methodology as outlined above; we have shown a sample process map of treatment workflow for cervical cancer at our institution with estimated times based on previously published work (Fig. 1) [10]. We present the studies based on disease site to identify specific areas of concern and address potential solutions (Table 1). Ultimately, our findings suggest that employment of the TDABC methodology could potentiate changes to practice and incentives to improve patient care.

Prostate cancer

Prostate cancer is typically classified into three risk groups (low, intermediate, high) and treated with some combination of androgen-deprivation therapy, surgery, and/or radiation therapy which can include external beam radiation therapy (EBRT) or brachytherapy (BT). Despite evidence of improved relapse free survival in patients with intermediate- to high-risk prostate cancer with EBRT + low dose rate (LDR)-BT boost compared to dose-escalated EBRT alone, there has been an overall decline in use of BT boost [11,12]. TDABC analysis of delivery costs for treatment of intermediate- to high-risk prostate cancer found that attending physician time was 1.5 to 2 times longer for treatments which included BT; however, these increased time requirements were not matched by Medicare reimbursement rates resulting in approximately 3 fold increase in attending time spent per relative value unit (RVU) for BT compared to EBRT [13]. While the decline in use of BT boost for intermediate- to high-risk prostate cancer is likely multifactorial, TDABC analysis underscores the discrepancy between cost of care delivery and Medicare reimbursement as a potential disincentive for treatment with BT. Reformation of Medicare reimbursement policies in conjunction with value-based BT practices may enable appropriate compensation for evidence-based therapies.

Results of TDABC of competing therapies for low-risk prostate cancer reveal the sources of cost variation between treatments. A study at the University of California Los Angeles used TDABC to show greater cost for high-dose rate (HDR) vs. LDR brachytherapy, with personnel cost demonstrated as the greatest overall driver [14]. A second study defined TDABC as the sum of the costs of space, materials, equipment, and personnel to calculate costs of therapies for low-risk prostate cancer including robotic-assisted laparoscopic prostatectomy (RALP), cryotherapy, HDR and LDR brachytherapy, EBRT, and active surveillance. [15]. While the study was useful in highlighting areas for possible cost reduction strategies, it also drew attention to differences

![Fig. 1. TDABC process map for cervical cancer HDR brachytherapy.](image-url)
Table 1
Summary of recommendations from a scoping review of TDABC analyses in brachytherapy across various disease sites.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Issues raised by TDABC analyses</th>
<th>Potential solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostate Cancer</td>
<td>Discrepancy between cost of care delivery and Medicare reimbursement is a potential disincentive for treatment with BT. Brachytherapy costs vary based on institution and physician expertise. Imaging modalities used for treatment planning vary in cost and potentially long-term outcomes.</td>
<td>Reformation of Medicare reimbursement policies in conjunction with value-based BT practices may enable appropriate compensation for evidence-based therapies. Comparison of process maps for BT across institutions could generate cost estimates to facilitate fair reimbursement and elucidate efficient and affordable practices that may be generalized across institutions. Longitudinal studies comparing outcomes and costs between imaging modalities used in treatment planning may potentiate more durable value-based care.</td>
</tr>
<tr>
<td>Cervical Cancer</td>
<td>There is discrepancy between physician effort and cost vs. reimbursement to the point that cost of BT exceeds reimbursement. Treatment costs are escalated when more time is spent by expensive members of the treatment team (i.e. physicians). Shorter fractionation schedules, when clinically evidenced not to worsen outcomes, offer potential for cost savings.</td>
<td>Reconsideration of reimbursement policies for BT may eliminate barriers which currently hinder delivery of highest level of care. Redesigning workflow and potentially facilitating additional training within institutions such that all members of the treatment team are operating at the highest level of their skill. Further research including clinical trials and outcomes research may support standardization of shorter fractionation schedules. Practitioners must actively research cost reduction strategies to help potentiate a higher level of care.</td>
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<tr>
<td>Endometrial Cancer</td>
<td></td>
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<tr>
<td>Breast Cancer</td>
<td>BT techniques such as intraoperative therapies which shorten treatment time may still prove to be costlier, thus undermining their use.</td>
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in cost based on institution and physician expertise. For example, HDR and LDR brachytherapy costs at UCLA were calculated based on involvement of radiation oncology and anesthesiology residents, but these costs cannot be generalized to nonteaching hospitals where presumably attending salary is higher but procedure time is shorter [16–19]. Comparison of process maps for BT across institutions may not only help generate more generalized cost estimation to facilitate fair reimbursement, but also elucidate efficient and affordable practices used by certain institutions which could be potentially adopted by others.

Treatment planning method in prostate brachytherapy is another influence of total cost. Traditionally, treatment planning for prostate brachytherapy involves computed tomography (CT) or ultrasound imaging. Magnetic resonance imaging (MRI) simulation is a more expensive alternative which has been demonstrated to show greater soft tissue contrast, theoretically allowing for improvement in reproducibility, side effect profile, and outcomes compared to CT and ultrasound, although confirmation of these potential benefits require further evaluation [20]. Interestingly TDABC analysis shows that using MRI simulation increased prostate brachytherapy cost by only 1% compared to cost of traditional workflow [20]. This study only calculated costs over the course of one year, but further research as to whether MRI simulation improves long-term outcomes, thereby reducing long-term costs, is indicated.

Cervical cancer

The standard of care for treatment of locally advanced cervical cancer generally involves combined EBRT plus brachytherapy with concurrent chemotherapy [21]. There is evidence that treatment with EBRT and brachytherapy has improved overall survival compared to treatment with EBRT alone, but several studies have documented a decline in the use of brachytherapy for treatment of locally advanced cervical cancer [22–24]. Only 20% of the 3,000 cases that CMS used to calculate reimbursement for the Radiation Oncology Model included full guideline concordant care [25,26], which signifies both the logistical challenges of combination modality therapies that are delivered across multiple providers and potentially its declining use. A single-institutional study utilizing TDABC to compare cost of BT versus EBRT in treatment of cervical cancer showed that cost and personnel time involved for BT are nearly two-fold that of EBRT [27]. However, Medicare reimbursement for BT is significantly lower, to the point that delivery costs of BT exceed reimbursement [27]. Again, the overall decline in use of BT for treatment of cervical cancer is likely multifactorial, but there is a significant discrepancy between physician effort and cost versus reimbursement which may act as a major driver of poor compliance with brachytherapy. As argued by Bauer-Nilson et al., these findings warrant consideration of increased reimbursement for brachytherapy.

The utility of TDABC is that it provides a detailed breakdown of the cost of care delivery, thereby exposing processes which may be reformed to improve efficiency and decrease expenses. For example, although MR-guided brachytherapy is less common than MR-based brachytherapy, studies by Ning et al. evaluated the clinical utility and value contribution of an intraoperative MR-guided brachytherapy program using a novel MRI-positive line marker which reduced costs of this approach by eliminating the need for postoperative CT imaging [28,29]. The
cost of brachytherapy for treatment of cervical carcinoma may be further mitigated by altering fraction schedules provided that outcomes remain equivalent [30]. Additionally, expenses can be improved by ensuring that all members of the treatment team are operating at a level that fully utilizes their skill, allowing tasks to be redistributed to incorporate less-expensive staff whenever possible [30]. TDABC is a valuable tool which can be used to investigate and improve sources of cost burden, informing on opportunities to lower expenses of brachytherapy rather than having institutions abandon the therapeutic modality altogether.

Endometrial cancer

Cost reduction with use of fewer fractions has been demonstrated in vaginal cuff brachytherapy (VCB) for endometrial cancer. In intermediate- to high-risk early-stage endometrial adenocarcinoma, risk of recurrence is generally highest at the vaginal cuff and as such postoperative radiation therapy using either VCB, EBRT, or both is recommended when clinically warranted based on pathologic risk factors [31]. One single-institution study utilizing TDABC to compare costs of three-fraction VCB versus six-fraction VCB shows a 57% relative increase in delivery cost for treatment in six fractions [32]. A TDABC analysis at a second institution shows 42% increase in cost for treatment with five fractions versus three fractions [33]. Studies by Rovirosa et al. provide retrospective evidence that shorter fractionation schedules for postoperative brachytherapy in endometrial carcinoma do not appear to worsen outcomes [34]. This evidence supports shortening fraction schedules when appropriate in favor of lowering cost of brachytherapy. Again, it is important to note that both costs and treatment practices vary based on institutional factors, and as such proportion of cost reduction will vary as well. Ongoing clinical trials in conjunction with outcomes research may support standardization of shorter fractionation schedules.

Breast cancer

In treatment of early-stage breast cancer, whole breast radiotherapy (WBRT) is typically delivered over one to five weeks as adjuvant therapy following breast-conserving surgery. Brachytherapy-based accelerated partial breast irradiation (APBI) is an alternative to WBRT due to convenience compared to traditional longer courses of WBRT, with interstitial multicatheter-based techniques demonstrated to be non-inferior to WBRT in preventing ipsilateral breast tumor recurrence in women with low risk breast cancer. As with brachytherapy for other disease sites, brachytherapy-based APBI in TDABC analysis has been shown to be more expensive than WBRT, with greater physician expense as the major driver of cost [35]. Suralik et al. utilized TDABC to compare cost of traditional intraoperative radiation therapy (IORT) with a novel CT-guided HDR approach for IORT, which uses APBI techniques adapted to a single fraction, and found that costs for the latter were substantially higher [36]. Seemingly convenient treatment strategies may not always offer cost benefit. To help potentiate a higher level of care, practitioners must actively research cost reduction strategies using avenues such as TDABC.

Discussion

TDABC has emerged as an effective and insightful methodology as medical organizations increasingly emphasize the importance of value-based healthcare. As evidenced by TDABC analyses of brachytherapy across multiple disease sites, brachytherapy is generally more expensive to deliver than EBRT. The expense of brachytherapy is driven by numerous factors including but not limited to cost of materials, fractionation schedule, and the time of personnel, especially physicians. Modern trends show a decline in use of brachytherapy even when indicated based on level I evidence. A notable discrepancy between higher cost of brachytherapy treatment and reimbursement for care delivery may be influencing clinical deviation from evidence-based medicine. TDABC is a powerful tool which can be used by clinicians to argue for improvements in reimbursement models as well as to identify areas for cost reduction to judiciously implement changes in practice. TDABC may also be a complement to current valuation methods [37]. When applied to radiation therapy, the TDABC model can be used to identify areas of redundancy in workflow, better utilize ancillary staff in treatment planning and care delivery, and shorten fraction schedules when appropriate based on evidence [38].

Comparison of process maps from individual TDABC studies provides insight into aspects of process which are institution-specific and can be modified to improve cost efficiency. For example, when process maps of prostate cancer brachytherapy are compared between institutions, there is discrepancy between roles of members in the treatment team [13,15]. As demonstrated in process map by Laviana et al., utilizing dosimetrists as opposed to physicians for contouring organs at risk (OAR) reduces physician time and thus decreases cost [15]. Also demonstrated in process maps for prostate cancer treatment is overhead cost incurred from utilizing operating room resources [13]. Coordinating with anesthesiology to administer sedation within radiation oncology departments for brachytherapy procedures could further decrease cost and improve process efficacy. Analysis of process maps for endometrial cancer brachytherapy demonstrates that use of fiducial markers in treatment alignment demonstrates another potentially avoidable source of cost [33]. Finally, in brachytherapy, there is opportunity to optimize imaging efficiency by minimizing scanning time with use of 3D sampling perfection with application-optimized contrasts using different flip
angle evolution (SPACE) T2 images as opposed to 2D T2 weighted images [39,40].

There are some inherent limitations to TDABC which apply beyond just the healthcare field. For example, one drawback of this approach is that it incorrectly assumes a linear relationship between costs and activities, which leads to underestimation of marginal costs [41]. Additionally, organizations often face restraints on activity resources which are ignored by TDABC [41]. When applied to healthcare, there is no standardization of the seven-step process and thus institutions vary in their implementation of TDABC, particularly when estimating indirect costs [42], which limits the potential to extrapolate results from one site to another. For instance, indirect costs may account for 30-50% of total operating costs, and variation in allocating such costs can lead to gross underestimates of the true cost of care delivery [5]. In several medical specialties, TDABC-generated cost savings for healthcare consumers and payers are not necessarily shared by the institution or providers [6]. Within the field of oncology, most TDABC studies have fixated on the economics of cancer treatment [43]. Additional studies on costs of screening and diagnosis may further elucidate avenues for cost reduction.

The ability of TDABC to inform bundled payment reimbursement systems is yet to be demonstrated in published literature [5]. With the new alternative payment model (APM) proposed by Centers for Medicare & Medicaid Services (CMS), reimbursement is fixed per 90-day episode of care across radiation oncology physicians and clinics based on data on average Medicare reimbursements historically [44]. In this model, bundled reimbursement is primarily based on historical reimbursement, which incorporates institutional variations in fraction scheduling, imaging modalities, or treatment techniques during the baseline period. However, practices chosen for this model may benefit from applying methodologies such as TDABC to calculate their internal costs, expected margin per disease site or modality, and identify opportunities to improve cost efficiency and the quality of health outcomes. Initial APM proposal also threatens utilization of brachytherapy boost in prostate cancer and gynecologic cancers, despite known benefit of brachytherapy in these malignancies, through possible disincentivizing of care by two different providers. Given episodic payment, a provider of external beam radiation therapy may receive less reimbursement due to fee-for-service payment required to a brachytherapy specialist for brachytherapy boost. This further highlights the need to improve efficacy and efficiency of brachytherapy care provided through TDABC.

Conclusion

TDABC has demonstrated a growing role in the promotion of value-based healthcare. Studies in brachytherapy show that TDABC informs on costs of various treatment modalities, factors that affect cost within and among institutions, and discrepancies in reimbursement policies. Though this methodology provides only an estimate of cost and remains to be standardized in the healthcare world, TDABC has the potential to shape more cost-effective practices, facilitate improved payment models, and ultimately improve patient care. Implementation of alternative payment models augments the necessity to utilize methodologies such as TDABC to understand and mitigate departmental costs.

Disclosures

No acute or potential conflicts of interest exist.

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References


