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Time-driven activity-based costing: A dynamic value assessment model in pediatric appendicitis☆

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ABSTRACT

Objectives: Healthcare reform policies are emphasizing value-based healthcare delivery. We hypothesize that time-driven activity-based costing (TDABC) can be used to appraise healthcare interventions in pediatric appendicitis.
Methods: Triage-based standing delegation orders, surgical advanced practice providers, and a same-day discharge protocol were implemented to target deficiencies identified in our initial TDABC model. Post-intervention process maps for a hospital episode were created using electronic time stamp data for simple appendicitis cases during February to March 2016. Total personnel and consumable costs were determined using TDABC methodology.
Results: The post-intervention TDABC model featured 6 phases of care, 33 processes, and 19 personnel types. Our interventions reduced duration and costs in the emergency department (−41 min, −$23) and pre-operative floor (−57 min, −$18). While post-anesthesia care unit duration and costs increased (+224 min, +$41), the same-day discharge protocol eliminated post-operative floor costs (−$306). Our model incorporating all three interventions reduced total direct costs by 11% ($2753.39 to $2447.68) and duration of hospitalization by 51% (1984 min to 966 min).
Conclusion: Time-driven activity-based costing can dynamically model changes in our healthcare delivery as a result of process improvement interventions. It is an effective tool to continuously assess the impact of these interventions on the value of appendicitis care.
Level of evidence: II, **Type of study:** Economic Analysis.

Although US healthcare spending is the highest (17.1% of gross domestic product in 2013) compared to similar high income countries, we experience worse health outcomes such as higher infant mortality, shorter life expectancy, and higher prevalence of chronic diseases [1]. Healthcare spending is expected to grow an average of 5.8% a year as a result of an aging population, economic growth, and the Affordable Care Act's coverage expansions [2]. These alarming findings have prompted significant healthcare reform efforts aimed at reducing the cost of healthcare. The passage of the Medicare Access and CHIP Reauthorization Act (MACRA) by Congress in 2015 signaled a shift toward value-based payment models for reimbursement. Value in healthcare is defined as the ratio of health outcomes achieved per dollar spent [3–6]. However, implementing a value-based system poses challenges: quality and cost can be difficult to quantify. Thus, healthcare providers are needed to lead the effort in evaluating new costing methodologies. Time-driven activity-based costing (TDABC) is a bottom-up costing methodology that combines cost of each resource with duration of resource use in order to value resource utilization [7].

The TDABC methodology has been successfully implemented in a number of specialties for assessment purposes, in particular, to engage providers in cost-conscious care redesign [8], identify unused operating room capacity in order to explore staffing decisions [9], model improvements in clinical efficiency in the outpatient clinic setting [10], and identify opportunities to improve cost data accuracy [11]. Beyond applying a TDABC methodology to identify areas of process improvement, we demonstrate how our TDABC model can be dynamically modified to

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show the value our interventions have on patient care workflow and cost. This is the first assessment of value generating interventions using a TDABC methodology applied to an entire hospital episode and to a common pediatric surgical condition, acute simple appendicitis.

1. Patients and methods

Institutional review board approval (H-37947) for this study was obtained. A comprehensive (pre-intervention) process map for the management of simple appendicitis was generated using electronic medical record time stamp data for patients undergoing an appendectomy at a tertiary care pediatric hospital during a 6-month period in 2013. All complicated appendicitis cases based on intra-operative findings (perforated or gangrenous) were excluded. Phases of care with prolonged wait times and high costs were identified through this process and three value generating interventions were developed to target these deficiencies [12]. Advanced practice providers were implemented to expedite surgical consultations from the emergency department in September 2015. Standing delegation orders for ultrasounds based on Pediatric Appendicitis Score were implemented in December 2015. This allowed patients with equivocal Pediatric Appendicitis Scores to have an ultrasound order placed in triage. A same-day discharge protocol for simple appendicitis patients was implemented by the end of January 2016.

Using our pre-intervention comprehensive process map as a baseline, we identified the phases of care and processes within each phase of care that were targeting by our interventions. Processes were eliminated and reorganized according to the new patient care workflow instituted since the implementation of these three interventions. A new comprehensive process map was generated through this remapping process (post-intervention).

1.1. Time-driven activity-based costing methodology

Time-driven activity-based costing involves identification of personnel and durations of interactions which are organized into process maps reflecting the actual patient workflow during the hospitalization. Next, costs are determined for each resource (personnel and consumables). Finally, total costs are calculated by synthesizing cost and time data.

Process mapping began first by reviewing the hospital units involved in a hospital episode from admission to discharge for children operated on for appendicitis. These were defined as the overarching phases of care. Each phase of care contained a detailed process map, reflecting the patient's perspective, i.e. only including processes with direct patient interactions. Thus, unused capacity and indirect costs were not included in our cost analysis. Our pre-intervention TDABC model included simple appendicitis patients hospitalized in January to March 2013 and July to September 2013, while our post-intervention model included simple appendicitis patients hospitalized in February and March 2016.

In order to assign durations to each process, we utilized time stamp data available from the institutional electronic medical record. As the TDABC methodology provides a granular view of the resources and costs involved, some processes did not have time stamp data available. For these processes we incorporated prospective observational data collected during a week-long pilot time study of surgical team workflow conducted in April 2015 as well as average estimates provided by personnel directly involved (e.g. child life and interpretation services).

Capacity cost rates (cost/min) for physicians were determined using 2015 Association for American Medical Colleges Medical School Faculty Salaries and Medical Group Management Association Academic Practice Compensation and Production Survey for Faculty and Management based on 1.0 full-time equivalent [13,14]. Capacity cost rates for non-physician labor costs were derived from hospital cost center data for fiscal year 2014. Post-intervention personnel capacity cost rates were kept constant to allow equivalent comparison of the impact of our interventions on total costs. Additionally, nursing and patient care assistant durations were weighted based on personnel to patient ratios for each phase of care since they were assigned the entire duration of the phase of care for monitoring [8]. This takes into account the fact that nurse monitoring is continuous and that they are assigned multiple patients during their shift.

Costs of each process are calculated by multiplying the capacity cost rate for the personnel type involved and the duration of involvement. Costs of consumables (pharmacy, laboratory, supplies, and food) were added to the sum of the process costs to attain a final total cost for the hospital episode. The steps of our TDABC methodology are outlined in Fig. 1.

1.2. Statistical analysis

Pre- and post-intervention durations (median minutes) and total personnel costs for each phase of care impacted by our interventions were compared. Because of the nonparametric distribution of data, medians and interquartile ranges (IQR) are reported. Statistical analysis was performed using the two-sided Mann–Whitney *U* test for nonparametric variables in IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, N.Y., USA). A p-value <0.05 was considered significant.

2. Results

There were 149 patients (68% male) with mean age of 12.5 $\pm$ 4.2 years in the pre-intervention model and 58 patients (60% male) with mean age of 11.3 $\pm$ 3.5 years included in the post-intervention model. The pre-intervention model included the following seven phases of care for a hospital episode: waiting room, emergency department, pre-operative floor, holding, operating room, and post-anesthesia care unit (PACU). There were 41 processes and 20 personnel types involved. Upon review of the current patient care workflow for simple appendicitis, we implemented triage-based standing delegation orders for ultrasounds in patients with equivocal Pediatric Appendicitis Scores to target the emergency department phase of care. The ability to order ultrasounds sooner if indicated would decrease wait times and expedite patient disposition. Surgical advanced practice providers in the emergency department impact not only the waiting room phase of care but also the emergency department phase of care. Patients with high suspicion for acute appendicitis based on Pediatric Appendicitis Scores and history obtained at triage triggers a consultation to the surgical advanced practice provider from triage. Advanced practice providers stationed in the emergency department facilitate faster consultation, communication with attending surgeon, and quicker posting of patients to the add-on operating room schedule. The third intervention, same-day discharge, targets the post-anesthesia care unit and hospital floor phases of care. Patients who meet discharge criteria during nursing assessments in the post-anesthesia care unit would be discharged home directly, thereby completely bypassing the hospital floor phase of care.

1. Identify phases of care for a hospital episode
2. Create process map of all direct interactions
3. Assign median time to complete each interaction
    a. Sources:
        i. Retrospective electronic time stamp data
        ii. Prospective observational data
        iii. Average estimates from personnel experts
4. Calculate capacity cost rates (cost/min) for each personnel type
5. Apply any weights or adjustments to the model
6. Determine costs of each process and phase of care
    a. Multiple capacity cost rates and durations for each process
7. Sum all costs (personnel and consumables) to obtain total costs

Fig. 1. Outline of 7 steps involved in implementing a time-driven activity-based costing methodology to an entire hospital episode.