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Time-Driven Activity-Based Costing to Estimate Cost of Care at Multidisciplinary Aerodigestive Centers

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Objectives/Hypothesis: Providing high-value healthcare to patients is increasingly becoming an objective for providers including those at multidisciplinary aerodigestive centers. Measuring value has two components: 1) identify relevant health outcomes and 2) determine relevant treatment costs. Via their inherent structure, multidisciplinary care units consolidate care for complex patients. However, their potential impact on decreasing healthcare costs is less clear. The goal of this study was to estimate the potential cost savings of treating patients with laryngeal clefts at multidisciplinary aerodigestive centers.

Study Design: Retrospective chart review.

Methods: Time-driven activity-based costing was used to estimate the cost of care for patients with laryngeal cleft seen between 2008 and 2013 at the Massachusetts Eye and Ear Infirmary Pediatric Aerodigestive Center. Retrospective chart review was performed to identify clinic utilization by patients as well as patient diet outcomes after treatment. Patients were stratified into neurologically complex and neurologically noncomplex groups.

Results: The cost of care for patients requiring surgical intervention was five and three times as expensive of the cost of care for patients not requiring surgery for neurologically noncomplex and complex patients, respectively. Following treatment, 50% and 55% of complex and noncomplex patients returned to normal diet, whereas 83% and 87% of patients experienced improved diets, respectively. Additionally, multidisciplinary team-based care for children with laryngeal clefts potentially achieves 20% to 40% cost savings.

Conclusions: These findings demonstrate how time-driven activity-based costing can be used to estimate and compare patient costs in multidisciplinary aerodigestive centers.

Key Words: Aerodigestive center, multidisciplinary care, time-driven activity-based costing, laryngeal cleft.

Level of Evidence: 2c.

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INTRODUCTION

With healthcare costs rising, leaders in business have suggested restructuring of the United States healthcare delivery system.[1,2] They recommend shifting away from specialty-centered care to care centered on specific diseases, including expected comorbidities and complications. In this model, patients seek treatment from an integrated practice unit (IPU), which is a multidisciplinary clinic comprised of all necessary medical and nonmedical specialists required to treat a patient during an entire cycle of care. This model of care streamlines diagnosis and treatment, facilitates the accurate measurement of healthcare outcomes and cost, and increases convenience for both patients and providers. Many clinician groups have already shifted toward this model of care with great success. Disease centers focused on multidisciplinary diabetic care have demonstrated reduced complications in diabetic foot care.[3] Combined data from dedicated heart failure clinics have shown multidisciplinary care can decrease the rate of hospitalizations.[4] Studies have demonstrated the benefits of IPUs in oncology including faster diagnosis times and decreased time to treatment.[5] And studies on multidisciplinary care in head and neck oncology have suggested improved outcomes due to proper treatment course selection and adherence to speech and language pathology recommendations.[6–8]

Multidisciplinary aerodigestive care centers exist in medical centers across the country. They specialize in caring for children with breathing and swallowing difficulties, providing specialist care in gastroenterology (GI), pulmonology (Pulm), otolaryngology (ear, nose, and throat [ENT]), and speech–language pathology (SLP). Difficulty swallowing can be due to an array of disease processes, overlapping each of these pediatric

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subspecialties.[9,10] Prior to the restructuring of these providers into IPUs, patients were required to see specialist providers one at a time, over a several-week period, with each assessing patients for disorders falling under its specialty's umbrella. Once providers confidently ruled out diagnoses specific to their specialty, the patient would be referred to one of the other relevant subspecialists. In addition to poor health outcomes, such as inadequate weight gain, recurrent aspiration pneumonias, and interstitial lung disease, delays in diagnosis can lead to unwelcome health systems consequences such as unanticipated physician office visits, emergency room visits, and hospital admissions. For these reasons, condition-specific IPUs form to consolidate specialists into the same clinic, enabling initial evaluations and diagnostics to be performed in parallel instead of in sequence. Prior studies have demonstrated cost savings from decreased number of visits to the operating room as well as fewer parking passes paid for by parents when visiting the clinic (and presumably less time off from work imposed on the parent).[11] However, although delivering better outcomes, grouping clinicians together could cause total costs to increase. The impact of IPUs on total costs for specific diseases has yet to be determined.

Traditional cost accounting may be accurate for assigning costs to entire departments or operating units but not at the individual resource level. Time-driven activity-based costing (TDABC) presents a novel method for understanding costs and allows for a precise stepwise cost estimation.[12] TDABC does this by defining the cycle of care, outlining the steps involved throughout the entire cycle of care, identifying the resources (hospital spaces, equipment, personnel) used during each step, and the cost per minute for each of these resources. In this fashion, TDABC allows for a bottoms-up approach to understanding healthcare cost, based on actual clinical and administrative processes, and provides a novel methodology to predict the financial impacts of potential quality-improvement initiatives.

In this study, we used TDABC to model the cost of care of one patient population being seen at an IPU dedicated to aerodigestive disorders. We elected to model the cost of care for patients with laryngeal clefts given their utilization of the pediatric specialties represented in aerodigestive centers. These patients typically require initial evaluations by pediatric pulmonologists, gastroenterologists, otolaryngologists, and speech–language pathologists, and frequently use all these services until their dysphasia symptoms resolve.[13] In this report, we demonstrate the use of TDABC to estimate costs in a pediatric aerodigestive center.

MATERIALS AND METHODS

Patient Population

TDABC was used to estimate the cost of care of patients diagnosed with a type 1 laryngeal cleft seen at the Massachusetts Eye and Ear Infirmary (MEEI) Multidisciplinary Aerodigestive Center. Patients seen at the center between 2008 and 2013 were included in this study. The MEEI Institutional Review Board granted access to patient charts for purposes of this project. Only patients who were seen in follow-up at least 1 year after diagnosis (if the patient did not undergo surgical correction of the laryngeal cleft) or 1 year after surgical correction of the cleft were included in the TDABC analysis. Retrospective chart review was performed to categorize patients as complex (i.e., having neurologic comorbidities including seizure disorder, chromosomal abnormality, developmental delay, hypotonia on initial physical exam) or as noncomplex (i.e., patients without neurologic comorbidities based on review of their initial visit documentation).

TDABC

The patient care cycle started at the patient's initial visit to the aerodigestive center. The end of the care cycle was set at either 1 year following diagnosis or 1 year following surgical repair, depending on whether or not the patient required surgical repair of their cleft. Care cycle maps, or diagrams detailing each interaction between the patient and the airway center during a single care cycle, were constructed to outline each step of care that needed to be accounted for in the TDABC analysis. Next, each step in the care cycle map needed to be outlined in separate process maps detailing each interaction between the patient and hospital personnel, the minutes of duration for each interaction, the space in which each interaction took place, and the equipment required for each step. These process maps were designed to capture all interactions between the patient and the four specialists represented at the airway center: ENT, GI, Pulm, and SLP. Process maps were developed via discussions with physicians, nurses, and administrative assistants in the clinic and hospital and subsequently verified by directly observing patients through all steps of the care cycle. The length of time of each step within each process map was documented during these observations. To estimate the potential cost benefit of operating a multidisciplinary center, a traditional model was created by separating the ENT, GI, and Pulm visits into separate clinics. SLP was assumed to see patients in the ENT clinic.

Next, the capacity cost rate, or the cost per minute for each hospital or clinic employee, space, and equipment, were calculated. Capacity cost rates were derived by dividing the yearly salaries for each employee by the total number of minutes in a year each employee was available to provide direct service to the patient (i.e., excluding weekend time, vacation, educational, and administrative time). Salaries were provided by hospital leadership at MEEI. and when unavailable, salaries were obtained from Salary.com for appropriate estimates for the Boston, Massachusetts area. Capacity cost rates were calculated for hospital and clinic spaces by dividing total rent and maintenance costs by time available for clinical productivity. For equipment, capacity cost rates were derived from cost of purchase, estimated useful life, cleaning and maintenance costs, and depreciation rates. Once these were calculated, the cost for each provider, space, and equipment for each step could be calculated by multiplying each resource's capacity cost rate by the length of time the resource was used at each step. These costs were added to quantify the total cost of each step, and the total costs of each step were summed to arrive at a total cost for each process map. The total care cycle cost was then obtained by adding the costs of each process map. In this study, individual patient cost was reported relative to the most expensive individual patient to avoid disclosing sensitive financial information of MEEI.

Retrospective review of actual costing data was performed to calculate average costs for each patient group to compare to costing estimates obtained with TDABC.

Noncosting Outcomes

Retrospective chart review was performed to identify the date of initial visit for each patient, date of triple endoscopy, and date of laryngeal cleft repair as applicable. The number of visits to the aerodigestive center were quantified during the care cycle of each patient by documenting the number of notes entered in patient charts. Additionally, the number of videofluoroscopic swallow studies (VFSS) was also noted for each patient. VFSS are utilized to document aspiration or deep laryngeal penetration of liquids for purposes of guiding dietary advancement to thin liquids following cleft repair. However, it has become important, given adherence to the ALARA (as low as reasonably acceptable) principle, to minimize radiation exposure to the pediatric population by decreasing dependence on VFSS.[14,15] Lastly, the diet consistency for each patient at the end of the care cycle was obtained from a previous dataset published by our group.[16]

RESULTS

Care Cycle and Process Maps

Care cycle maps are shown in Figure 1. Figure 1A depicts the care cycle for a patient at the MEEI aerodigestive center. The care cycle is divided into three phases. Phase 1 includes the initial visit. Phase 2 begins at the triple endoscopy procedure and ends at either 1 year post triple endoscopy or if the patient undergoes laryngeal cleft repair. Phase 3 begins when the patient undergoes cleft repair and ends 1 year after the patient's surgery. Therefore, patients who undergo conservative treatment or diet modification alone do not enter phase III. Patients who fail conservative management enter phase III. Figure 1B depicts the care cycle of a patient being seen by three different specialty clinics. An example of one process map, the initial visit, is shown in Figure 2. Depicted is each substep and the amount of time, in minutes, required for each substep to be completed.

Patient Costs and Outcomes

Between the years of 2008 and 2013, 53 patients were evaluated and found to have type 1 laryngeal clefts at the MEEI aerodigestive center. Of these patients, 15 (28%) were known to have neurologic comorbidities. Table I indicates the patient breakdown, and Table II depicts the average number of follow-up visits and VFSS during the care of these patients.

Costing data are presented in Figure 3. Each box and whisker plot represents the minimum, first quartile, median, third quartile, and maximum individual patient cost in each category. The relationship between cost distributions of noncomplex and complex patients completing phases II and III or only phase II are depicted in Figure 3A. Noncomplex patients undergoing cleft repair cost nearly five times more than noncomplex patients requiring conservative treatment. Meanwhile, complex patients undergoing cleft repair cost just over 3 times as much as complex patients treated with conservative management alone. These differences are due to the additional cost of the laryngeal cleft repair as well as the cost of a 24-hour observation period in the pediatric intensive care unit at neighboring Massachusetts General Hospital for Children. Figure 3B shows relative cost distribution of patients based on diet at the end of 1 year following cleft repair. Interestingly, relative cost distribution of patients progressing to normal diet at 1 year after cleft repair were similar to patients remaining on thickened diets. Recalculating patient costs according to the traditional model increases the costing distribution in each patient group (Fig. 3C). Percent increase in mean cost in patients not undergoing cleft repair in a traditional model was 40%, whereas for patients undergoing cleft repair, the percent increase in mean cost was roughly 20% (Fig. 3D). Average TDABC costs and actual costs obtained from review of financial documentation are presented in Figure 3E.

Figure 4 presents a radar chart, as previously used to describe healthcare quality, that depicts both cost and outcomes data for laryngeal cleft patients at the MEEI aerodigestive center.[17] Cost is portrayed as the reciprocal of cost relative to the lowest cost group (i.e., closer to 100 means lower cost). Similarly, the average number of VFSS for each group is portrayed as a reciprocal relative to the lowest average number of VFSS (i.e., closer to 100 means fewer average VFSS). The remaining parameters, percent returning to normal diet and percent with improved diet at 1 year, are graphed as raw percentages. The diet outcomes, although not the primary focus of this article and the subject of another recent publication focusing specifically on outcomes of the same population of children treated at MEEI,[16] showed that for noncomplex patients, 55% returned to a normal diet by 1 year, whereas 87% experienced improved diet. For complex patients, 50% returned to a normal diet by 1 year, and 83% experienced improved diet overall.

DISCUSSION

In this study, TDABC was used to estimate the costs of four different groups of patients with laryngeal clefts. Clinically, these patients can be stratified based upon conditions that may predispose the patient to difficulty feeding such as seizure disorders, developmental delay, or hypotonia secondary to chromosomal abnormalities. Many studies have not stratified patient outcomes by neurological status.[18–24] Given the differences in outcomes between these groups previously reported by our group,[13] this study sought to explore the possibility of costing differences between patients with and without neurologic comorbidities. Prior evidence would suggest that patients with neurologic comorbidities tend to benefit less from surgical repair, which is interesting considering the results of this study suggest the greatest contributor to patient cost was undergoing cleft repair. In this study, differences in cost and outcomes between noncomplex and complex patients who underwent cleft repair were relatively minor. This may reflect changes in clinical practice for these patients relative to the older dataset previously published by our group such as VFSS utilization.[16] It is important to note that neurology and genetics follow-up visits were not quantified in this assessment, as these specialties are not typically included in pediatric airway centers. Because we now better

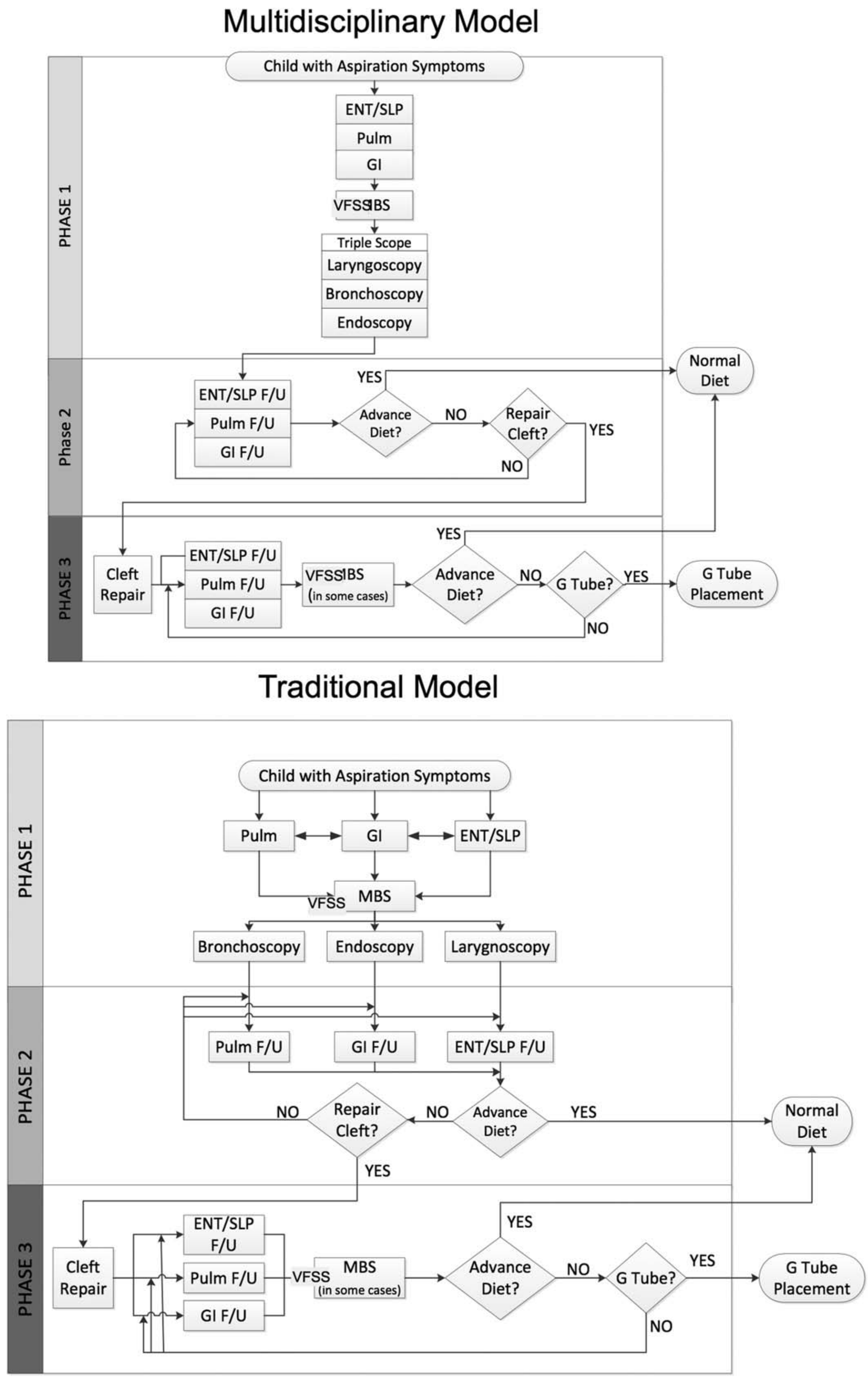


Fig. 1. Care cycle maps for patients being seen in a multidisciplinary aerodigestive center (top) or in a traditional model of care (bottom). Care cycles can be divided into three phases of care. Phase 1 is diagnosis of the laryngeal cleft. Phase 2 is conservative treatment with thickened diets. Phase 3 is surgical management combined with thickened diets. ENT = otolaryngology (ear, nose, and throat); F/U = follow-up; GI = gastrointestinal; G tube = gastrostomy tube; IBS = irritable bowel syndrome; Pulm = pulmonary; SLP = speech-language pathology; VFSS = videofluoroscopic swallow studies.

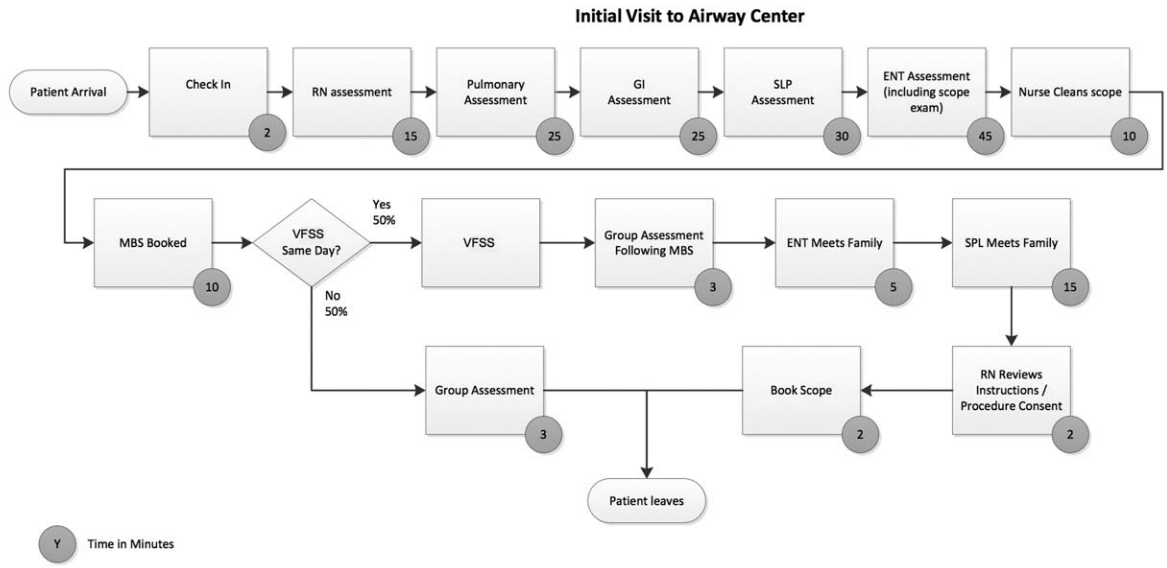


Fig. 2. Example process map of initial visit to the MEEI aerodigestive center. Each box represents an interaction or event that takes place during the patient's visit. Length of time, in minutes, of each step is denoted by the value indicated in the circle at the right lower corner of each box. ENT = otolaryngology (ear, nose, and throat); GI = gastrointestinal; MBS = modified barium swallow; RN = registered nurse; SLP = speech–language pathologist; SPL = speech language pathology; VFSS = videofluoroscopic swallow studies.

understand our clinic's cost through TDABC, the aerodigestive center may now enter discussions to set up bundled payments with more confidence. Lastly, using TDABC to map out patient care cycles can help identify time consuming or expensive steps that can be targeted by future process improvement projects.

Although simple and easy to use, TDABC comes with its own limitations. The accuracy of costing estimation using TDABC is only as good as the data used to quantify each step of every process map. For example, in this study, many of the salaries for the hospital personnel involved in these care cycles were obtained from the MEEI financial support offices; however, remaining salaries were obtained from Salary.com. The presented analysis is still useful in that it helps clarify the relative difference in cost of care for these four patient groups. Additionally, TDABC was used to estimate the potential cost savings of operating a multidisciplinary aerodigestive center over a traditional model utilizing separate specialty clinics. However, two assumptions were made: 1) triple endoscopy procedures would be performed during three separate visits to the operating room and 2) the number of follow-up visits between multidisciplinary and traditional models would not be different. Unfortunately, a traditional model does not exist in Boston, Massachusetts, so it is unclear how the number of follow-up visits would change under a traditional model. Despite this limitation, this analysis does provide useful information in that the triple endoscopy and cleft repair are the most expensive components of these patients' care cycles. So if a traditional model does exist in clinical practice, the total cost may not differ significantly from a multidisciplinary model if the procedures performed in the operating room are performed in tandem and not separately. Additionally, recent attempts by the Centers for Medicare and Medicaid Services to decrease cost of Medicare patients by bolstering care coordination have failed.[25] In federally qualified health centers involved in the study, aggressive care coordination resulted in increased healthcare utilization and expenditures. It is conceivable that a multidisciplinary aerodigestive center may also promote increased utilization of subspecialty care and may be more expensive than a traditional model that simply coordinates its procedures requiring anesthesia.

Next, costing estimates from TDABC can be inaccurate if unknown interactions with other medical

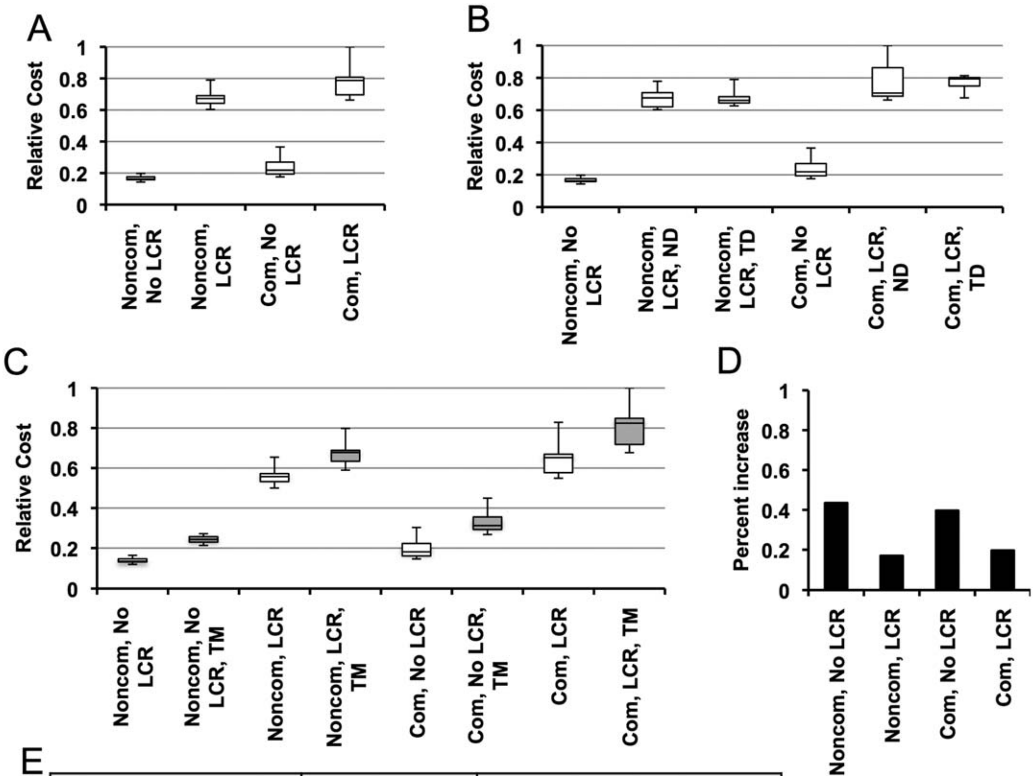
TABLE I.
Patient Demographics.

Total no. of patients	56
No. of noncomplex patients	39 (70%)
No. of patients not requiring cleft repair	12 (31%)
No. of patients requiring cleft repair	27 (69%)
No. of complex patients	17 (30%)
No. of patients not requiring cleft repair	6 (35%)
No. of patients requiring cleft repair	11 (65%)

TABLE II.
Patient Clinic Utilization.

Patient Group	ENT	SLP	GI	Pulm	VFSS
Noncomplex, no cleft repair patients	2.15	1.62	2.84	2.38	0.92
Noncomplex, cleft repair patients	5.58	3.21	3.85	5.72	1.61
Complex, no cleft repair patients	2.33	2	2.83	2	1.5
Complex, cleft repair patients	4.55	3.09	4.65	1.72	1.72

ENT = ear, nose, and throat; GI = gastroenterology; Pulm = pulmonology; SLP = speech-language pathology; VFSS = videofluoroscopic swallow studies.



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Patient Group	Average Cost	Average TDABC Estimate
Noncom, No LCR, ND	3236.86	1954.08
Noncom, No LCR, TD	6412.28	1917.56
Noncom, LCR, ND	9516.86	7708.89
Noncom, LCR, TD	10259.90	7649.72
Com, No LCR, ND	12694.76	2794.73
Com, LCR, ND	8903.31	8848.90
Com, LCR, TD	9575.08	8733.97

Fig. 3. Time-driven activity-based costing (TDABC) data of Massachusetts Eye and Ear Infirmary (MEEI) Pediatric Aerodigestive Center. (A) Relative costs of noncomplex patients (Noncom) and complex patients (Com) who did not have laryngeal cleft repair (No LCR) or did have laryngeal cleft repair (LCR). (B) Relative costs of all patients with diet outcomes indicated: normal diet (ND) 1 year after cleft repair or thickened diet (TD) 1 year after cleft repair. (C) Costing estimates comparison of the multidisciplinary MEEI aerodigestive center (white box and whisker plots) with a hypothetical traditional model (TM) (gray box and whisker plots). (D) Percent increase in cost of the traditional model relative to the multidisciplinary model for each patient group. Each box and whisker plot represents the minimum, first quartile, median, third quartile, and maximum individual patient cost in each category. Costing data are presented relative to the cost of the most expensive patient to avoid disclosing sensitive financial information. (E) Comparison of true average cost for each patient group with the respective TDABC estimates.

providers are not included in the care cycle maps. For example, the healthcare environment in Boston, Massachusetts is very complex. Not only do pediatric subspecialists exist at MEEI and Massachusetts General Hospital for Children, but specialists exist at alternative hospitals. The electronic medical records used at MEEI and Massachusetts General Hospital for Children were accessible for this project; however, those of other local healthcare institutions were not. Therefore, it is feasible the costing data presented in this study could be underestimates of their true costs. Reliably documenting utilization of local healthcare resources will not only be important in health services research, but it will be critical in understanding patient cost for attempting novel reimbursement strategies such as bundled payments.

Lastly, the TDABC estimates for the patients in this study are less than the actual costs obtained from review of financial data. Although this is promising, we reiterate that this is pilot data that needs further testing in a single-institution, prospective, longitudinal study where cost data can be carefully tracked, as well as in multicentered studies to assess the generalizability and possible regional differences of such findings. Such studies are currently underway, which are coupling cost data gathering with outcomes data to investigate the value

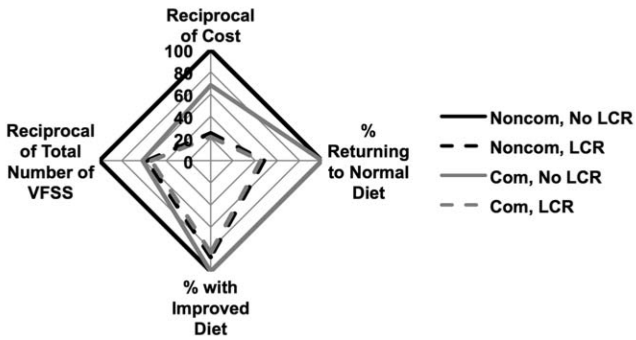

Fig. 4. Radar chart comparing the four patient groups based on cost, diet outcomes, and average number of videofluoroscopic swallow studies (VFSS). Cost is portrayed as the reciprocal of cost relative to the lowest cost group (i.e., closer to 100 means lower cost). Similarly, the average number of VFSS for each group is portrayed as a reciprocal relative to the lowest average number of VFSS (i.e., closer to 100 means fewer average VFSS). Color of the line denotes the patient group. Com = complex patients; LCR = had laryngeal cleft repair; No LCR = did not have laryngeal cleft repair; Noncom = noncomplex patients.

proposition for caring for children in a multidisciplinary aerodigestive center and to begin to pull together cost data that could theoretically be used to establish metrics for bundled billing.

CONCLUSION

This study utilized a novel costing methodology known as TDABC to estimate the cost of care of patients receiving treatment at a multidisciplinary pediatric aerodigestive center. TDABC can be used to better understand costs by stratifying patients according to certain comorbidities and treatment options. This information can help providers and healthcare managers understand the financial implications of healthcare delivery via multidisciplinary centers or more traditional models of care. By presenting costing data in conjunction with outcomes in the form of radar plots, a value-based model for specific patient populations nationally can be appreciated. In summary, TDABC will continue to be a useful tool in optimizing the use of pediatric aerodigestive centers.

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