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Interdisciplinary aerodigestive care model improves risk, cost, and efficiency

R. Paul Boesch[a,*], Karthik Balakrishnan[b], Rayna M. Grothe[a], Sherilyn W. Driscoll[a], Erin E. Knoebel[a], Sue L. Visscher[c], Shelagh A. Cofer[b]

[a] Department of Pediatric and Adolescent Medicine, Mayo Clinic Children's Center, Rochester, MN, USA
[b] Department of Otolaryngology, Head and Neck Surgery, Mayo Clinic, Rochester, MN, USA
[c] Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery, Mayo Clinic, Rochester, MN, USA

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ABSTRACT

Objective: This study sought to evaluate the impact of an interdisciplinary care model for pediatric aerodigestive patients in terms of efficiency, risk exposure, and cost.
Methods: Patients meeting a standard clinical inclusion definition were studied before and after implementation of the aerodigestive program.
Results: Aerodigestive patients seen in the interdisciplinary clinic structure achieved a reduction in time to diagnosis (6 vs 150 days) with fewer required specialist consultations (5 vs 11) as compared to those seen in the same institution prior. Post-implementation patients also experienced a significant reduction in risk, with fewer radiation exposures (2 vs 4) and fewer anesthetic episodes (1 vs 2). Total cost associated with the diagnostic evaluation was significantly reduced from a median of $10,374 to $6055.
Conclusion: This is the first study to utilize a pre-post cohort to evaluate the reduction in diagnostic time, risk exposure, and cost attributable to the reorganization of existing resources into an interdisciplinary care model. This suggests that such a model yields improvements in care quality and value for aerodigestive patients, and likely for other pediatric patients with chronic complex conditions.

1. Introduction

Improvement in the care administered to critically ill children and neonates has resulted in an expanding population of children with complex chronic multi-system diseases [1]. Children with aerodigestive disease represent a subset of this population with interrelated conditions affecting the airway, breathing, and feeding and swallowing. A recent consensus statement on pediatric aerodigestive care defines a pediatric aerodigestive patient as, "a child with a combination of multiple and interrelated congenital and/or acquired conditions affecting airway, breathing, feeding, swallowing or growth that require a coordinated interdisciplinary diagnostic and therapeutic approach to achieve optimal outcomes. This includes (but is not limited to) structural and functional airway and upper gastrointestinal tract disease, lung disease due to congenital or developmental abnormality or injury, swallowing dysfunction, feeding problems, genetic diseases, and neurodevelopmental disability [2]." The care of these patients is costly and complex, characterized by multiple procedures, heavy reliance on technology and multi-specialist care. Pediatric aerodigestive programs provide interdisciplinary care, coordinating evaluation and management among otolaryngologists, pulmonologists, gastroenterologists, speech language pathologists and other disciplines within a compressed timeframe, resulting in a summary plan of care. This process requires substantial institutional organization, dedication of resources, and cultural practice change amongst providers to be successfully implemented. Typically patients are referred to the aerodigestive program, an intake interview is conducted, a pre-scheduled itinerary is developed, multidisciplinary clinic consultations, testing and combined endoscopic procedures are performed, and a single unified care plan is developed and given to the family and referring physicians[2]. Recent publications have demonstrated clinical effectiveness, estimated decreased cost, reduction in anesthetic episodes and resource utilization, and reduced care-giver burden by aerodigestive programs [3–7]. Specifically, Collaco et al., estimated reductions in outpatient clinic charges based on median reduction in number of center visits achieved by coordinating appointments, documented a 41% reduction in anesthetic

* Corresponding author. Division of Pediatric Pulmonology, Department of Pediatric and Adolescent Medicine, Mayo Clinic Children's Center, 200 First Street SW, Rochester MN 55905, USA.
E-mail address: Boesch.Paul@mayo.edu (R.P. Boesch).

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episodes by coordinating procedures, and estimated a reduction in perioperative charges of $3490 for those patients undergoing combined procedures [3]. They followed up this study with a retrospective analysis of the costs of delivering care to clinically-defined aerodigestive patients in the two years before and after their inclusion in the multidisciplinary program [4]. They found a shift to increased outpatient costs which was dwarfed by much greater reduction in inpatient costs, which agrees with what has been found in other complex pediatric populations [8].

The Pediatric Aerodigestive Program (PAP) at the Mayo Clinic Children's Center was founded in 2012, based on the structure and ideals presented above. The PAP is unique in that it utilizes a formal set of inclusion criteria. This allowed us to identify a cohort of similarly-defined patients before and immediately after launch of the program. This created pre-aerodigestive and post-aerodigestive cohorts of patients whose outcomes could be expected to differ only based on the structural organization and implementation of the program itself, as there were no other changes in staff, resources, treatments technologies, or techniques. This study sought to compare the effect of multidisciplinary clinic reorganization on time to completion of aerodigestive workup, risk reduction in terms of number of radiologic studies and episodes of general anesthesia, and reduction in standardized costs for the care cycle. This is the first such study to utilize standardly-defined pre and post cohorts to directly evaluate the impact of the aerodigestive organizational structure on efficiency, risk reduction, and cost.

2. Methods

This study was reviewed and approved by the Institutional Review Board of the Mayo Clinic (IRB# 15–008116). The Pediatric Aerodigestive Program at the Mayo Clinic was launched in September 2012. Prior to this organization, complex pediatric patients were followed by multiple specialists with care coordinated virtually through the medical record, phone, and email. Hallmarks of the PAP include 1. pre-visit intake performed over the phone by the program coordinator, 2. development of evaluation itinerary based on best-practice guidelines applied to information obtained from intake, 3. shared clinic and operating room time for combined procedures, 4. post-evaluation team meeting to develop unified care plan, and 5. summary wrap up visit with patient and family. To facilitate efficient scheduling, dedicated appointment slots are held in reserve for aerodigestive patients including clinic appointments, operating room time, instrumental swallow studies, radiography, and polysomnography. The PAP utilizes a standard rubric of inclusion criteria for program entry [Table 1]. This study retrospectively identified a cohort of 16 patients who met these inclusion criteria in the 8 years prior to program launch, and is defined as the “pre-Aero cohort”. This was a convenience sample of complex pediatric patients who met the inclusion criteria. The first 23 consecutive patients who were evaluated in the PAP within 6 months of launch were identified as the “post-Aero cohort”. This study evaluated patients seen from 9/29/2004–2/13/2013. The electronic medical record and billing records were then retrospectively reviewed to determine the elements of the diagnostic evaluation, based on the presenting complaints. These elements were then tallied in terms of number of consultations, number and type of radiographic evaluations, number of anesthetic episodes, time required to complete the aerodigestive evaluation, and total standardized cost of all selected billed services. The time to complete the aerodigestive evaluation was defined as time from initial consultation until completion of diagnostic work up for the presenting problem.

Standardized costs were created by applying the Mayo Clinic Rochester Cost Data Warehouse methodology to the selected billed services [9]. All Current Procedural Terminology, 4th Edition (CPT4©) codes and approximately 90% of internal charge master codes were mapped to their 2013 equivalent values. Medicare 2013 reimbursement was assigned to all professional billed services identified by CPT4 codes, and the appropriate 2013 Medicare Cost Report cost-to-charge ratios were multiplied by the equivalent 2013 charges for all hospital billed services. Year of service hospital charges and cost-to-charge ratios were used for the approximate 10% of hospital services that could not be mapped to equivalent 2013 charge master codes. The resulting year of service standardized costs were inflated to 2013 with the Gross Domestic Product implicit price deflator.

Table 1
Inclusion criteria, Pediatric Aerodigestive Program, Mayo Clinic Children's Center.

Core Services	“Major” conditions	“Minor” Conditions
At least 2 needed, plus:	Either 2 major, or 1 major and 2 minor	
Otolaryngology	Airway stenosis¥	Developmental Delays
Pulmonology	Aspiration (known or suspected)	Feeding problems
Gastroenterology	Chronic lung disease	GERD
	Global CNS impairment	Laryngomalacia
	Chiari malformation	Noisy breathing
	Esophageal dysmotility	Recurrent chest infections
	Esophageal stricture	Tracheomalacia/ Bronchomalacia
	Genetic condition (listed)*	
	Laryngeal cleft (current or prior)	
	Sleep disordered breathing	
	Tracheoesophageal fistula (current or prior)	
	Tracheostomy	
	Vocal cord paralysis	

¥Subglottic stenosis, glottic stenosis, laryngeal web, laryngeal atresia, tracheal stenosis, complete tracheal rings
*Trisomy 21, CHARGE, 22q11, VATER/VACTERL, Pfeiffer, Opitz, craniofacial syndromes, Cornelia deLange, Crit du Chat

Mean ages between cohorts was compared using unpaired *t*-test for samples of unequal variance. Categorical variables were evaluated by chi square test or Fischer's exact test, depending on frequency. Due to the small sample size in each group, non-parametric tests were used, including the Mann-Whitney *U* test. Bonferroni corrections were used for multiple testing; repeating the testing with the more powerful Sidak correction produced identical results. Statistical analysis was done using Stata/SE 9 (StataCorp, College Station, TX).

3. Results

Sixteen pre-Aero and 22 post-Aero patients were included in this study. One post-Aero patient was excluded from the study as the patient's parents had not signed Minnesota Research Authorization for use of medical records.

No significant differences were found between study cohorts for gender, age, and referring complaints [Table 2].

The median time to completion of aerodigestive evaluation was dramatically reduced from 150 to 6 days ($p < 0.001$) [Fig. 1]. Median number of radiation exposures was reduced from four to two ($p < 0.001$) with a similar degree of reduction regardless of study type (CT, fluoroscopy, chest/abdominal plain radiography) [Fig. 2]. Median anesthetic exposures decreased from two to one ($p < 0.001$). Median number of specialists consultations also dropped from eleven to five ($p < 0.001$). The median standardized cost for aerodigestive evaluation was substantially reduced from $10,374 in the pre-Aero cohort to $6055 in the post-Aero cohort, which is a reduction of 41.6% ($p = 0.003$) [Table 3, Fig. 3]. Significant decreases were seen across most cost categories, including anesthesia ($p = 0.002$), clinic office visits and tests ($p = 0.02$), and radiology ($p = 0.001$). Laboratory/pathology ($p = 0.52$) and operating room (OR) facility ($p = 0.83$), and recovery room ($p = 0.08$) were not significantly different between the

Table 2
Characteristics of pre-Aero and post-Aero cohorts.

Characteristic	pre-Aero (n = 16)	post-Aero (n = 22)	p
Age (years)	2.7 (range 0.2–8.8)	3.7 (range 0.5–13.5)	NS[a]
Male	9 (56.3%)	7 (31.8%)	NS[b]
Chronic cough	4 (25.0%)	2 (9.1%)	NS[c]
Dysphagia	5 (31.3%)	13 (59.1%)	NS[c]
Feeding disorder	3 (18.8%)	6 (27.3%)	NS[c]
Failure to thrive	4 (25.0%)	7 (31.8%)	NS[c]
Gastroesophageal reflux	4 (25.0%)	8 (36.4%)	NS[c]
Evaluation for laryngotracheal reconstruction	1 (6.3%)	2 (9.1%)	NS[c]
Noisy breathing	5 (31.3%)	4 (18.2%)	NS[c]
Obstructive sleep apnea	4 (25.0%)	7 (31.8%)	NS[c]
Recurrent pneumonia	4 (25.0%)	8 (36.4%)	NS[c]
Stridor	3 (18.8%)	0 (0.0%)	NS[c]
Tracheostomy dependence	1 (6.3%)	3 (13.6%)	NS[c]

[a]Unpaired *t*-test.
[b]Chi square test.
[c]Fischer's exact test.

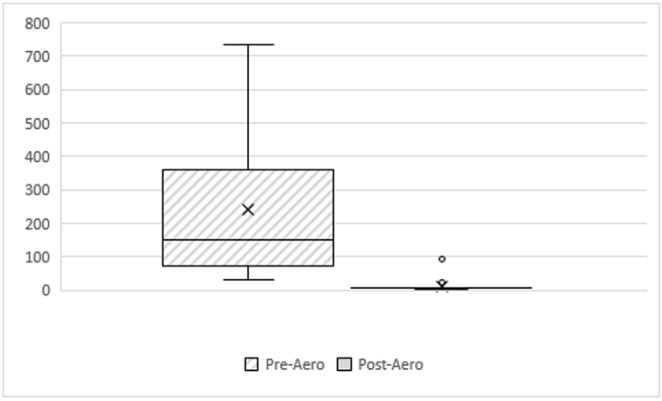

Fig. 1. Time to diagnostic evaluation completion (days).

two groups. Median costs related to operative evaluation only decreased from a median of $3783 to $3366, (p = 0.42) despite anesthetic episodes decreasing by 50%. The decrease in cost associated with radiology testing was especially large at $2264 to $484 (79% reduction; p = 0.001). The relative contributions to total cost for each category are demonstrated in Fig. 4.

4. Discussion

This study is unique in that, by selecting cohorts of medically complex aerodigestive patients meeting a standard set of inclusion criteria, before and after the reorganization of already existing specialists, resources, and technologies, the impact of the care model itself can be tested. In effect, a natural experiment became possible in this context, allowing the first description of true cost reductions associated with the implementation of a multidisciplinary aerodigestive program in addition to reductions in diagnostic time, and exposures to risk in terms of radiation and anesthesia. This study specifically evaluates the impact on the primary diagnostic episode, rather than the costs of on-going care.

This study shows that this described interdisciplinary approach to evaluation of aerodigestive patients substantially reduces the timeframe required to complete the diagnostic evaluation. Although not directly studied, this likely improves health outcomes by shortening the time to diagnosis and instituting an appropriate care plan many months earlier than was achieved by the more traditional model. Following initial PAP evaluation, family satisfaction surveys respondents repeatedly stated that the impact of seeing an entire medical team, focused together on the care of their child is very impressive. Furthermore, this model results in a single unified care plan and a single point of contact for the caregivers to improve clarity and lessen the burden of navigating a complex medical system. In other models of multidisciplinary care programs for medically complex children, caregiver strain and family satisfaction were found to be improved [10,11].

By coordinating a preplanned diagnostic itinerary and compressing the diagnostic timeline, fewer consultations and diagnostic tests resulted. This not only reduces cost and eliminates waste in the system, but also reduces potentially harmful exposures, such as to radiation and general anesthesia [12–16]. Medically complex children with chronic disease are more likely to require repeated radiographic tests and general anesthetics over the course of their lives, and therefore management through a program where these exposures can be reduced by half may be particularly beneficial.

In an era where there is increasing focus on the costs of healthcare and pressure to improve value, the finding of substantial cost reduction paired with timelier diagnosis is important. Our findings are in agreement with others that this integrated approach to care for medically complex patients is less expensive, though most previous studies have used theoretical rather than actual data [3,4,8,17]; our real-world data confirm the findings of these previous studies. On the surface, the prescheduling of multiple consultations and diagnostic tests for patients not yet seen by the health system might seem to favor over-scheduling of unnecessary tests and office visits. We found that the number of billed services of all types was actually markedly reduced. Much of this reduction was a result of the shortened time to complete the diagnostic evaluation, which reduced the number of repeated tests, particularly radiographic studies. Current research efforts include development of chief complaint-based diagnostic algorithms to allow even more resource-efficient prescheduling.

In terms of the particular contributors to cost reduction shown in Fig. 4, radiology was clearly dominant. It is not entirely clear why median radiology costs should decrease by 79% when the median number of studies decreased by 50%; it is possible that studies were

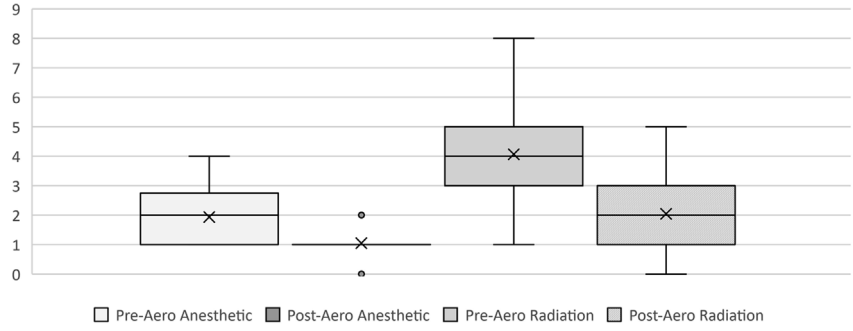

Fig. 2. Risk exposure (number of episodes).

Table 3
Comparison of standardized costs between pre-Aero and post-Aero cohorts ($).

	OR Procedures	Clinic	Radiology/Testing	Lab/Path	Other[a]	Total Cost
Pre-Aero						
Min	857	474	275	0	62	3306
25%	1797	925	644	483	375	7835
Median	3784	1421	2264	728	1161	10,374
75%	6992	1962	4659	2694	1994	15,155
Max	14,485	2518	8129	5806	3300	26,846
Post-Aero						
Min	0	227	0	0	163	720
25%	3084	551	80	342	365	4895
Median	3366	866	484	620	524	6055
75%	3822	1181	874	983	845	7585
Max	8303	2337	3090	4836	1699	17,717
Median comparison	p = 0.42	p = 0.02	p = 0.001	p = 0.52	p = 0.08	p = 0.003

[a] Includes costs related to: audiology, gastrointestinal nurse education visits, pharmacy, occupational therapy, physical therapy, speech language pathology and supplies.

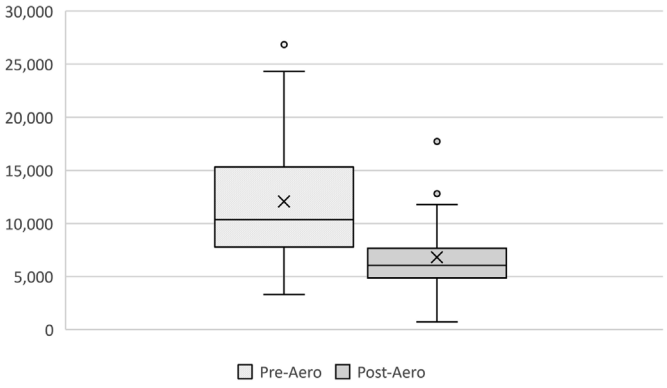

Fig. 3. Total standardized cost ($).

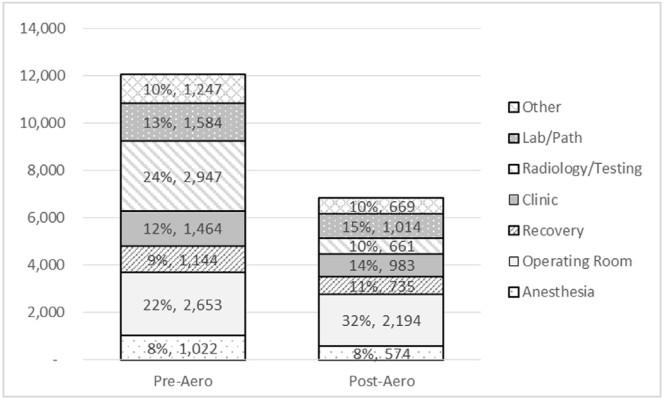

Fig. 4. Mean standardized costs by category ($).

selected and planned more efficiently, with fewer repeated or "shotgun" studies ordered. Our data did not explicitly address this question. While recovery room fee reduction trended toward significance, OR facility fees did not show a significant difference. The former may simply be a problem of power. The latter finding is a bit more surprising and more difficult to explain, given the decreased number of anesthetic exposures. It is possible that facility billing practices have changed over time, blurring any effects of coordinating procedures. Further study of this question may be warranted if this finding is corroborated at other centers. In order to determine statistically which components of cost were most important in overall cost reduction, a more complex principal components analysis might be useful; our study was neither designed nor powered for such an analysis, but future prospective data collection may need to be tailored accordingly.

This study is limited by its retrospective and single center design. The patient population within each cohort is variable in age and underlying diagnoses, and the sample size was small. Despite this, the effect size of the implementation of the care model was sufficiently large to overcome issues of power. Identification of subjects in the pre-Aero cohort was challenged by the fact that these patients were not part of a formal program and did not share uniform diagnoses or other characteristics that would have allowed collective retrieval from the medical record. This could have introduced some recall bias, though these patients did meet the aerodigestive inclusion criteria and the two cohorts were similar in terms of age and underlying conditions and comorbidities. This cohort was selected prior to launch of the PAP. There were no changes in technology, resources, or standards of care at our center between the pre and post-Aero cohorts that would have confounded our results. For these same reasons of sample size and heterogeneity, improvements in health outcomes could not be effectively evaluated. In order to truly understand the impacts of the aerodigestive approach on health-related outcomes, prospective collaborative research across multiple programs will be required.

This study directly assesses the improvements in diagnostic efficiency, reduction of risk exposure, and reduction in cost attributable to the aerodigestive care model itself, as outlined in the recently published consensus statement [2]. These findings are strengthened by their agreement with other similar studies of multidisciplinary care programs for aerodigestive and other medically complex children. We propose that this further supports the hypothesis that care delivery through an interdisciplinary aerodigestive care model is not only of high quality but also of good value.

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Conflicts of interest

The authors have no potential conflicts of interest relevant to this article to disclose regarding: 1) study design; 2) the collection, analysis, and interpretation of data; 3) the writing of the report; or 4) the

decision to submit the manuscript for publication.

Abbreviations

PAP- Pediatric Aerodigestive Program, OR- Operating room.

Contributors statement

Dr. Boesch conceptualized the study, performed data acquisition from medical records, summarized and analyzed results, drafted the initial manuscript, and reviewed and revised the manuscript.

Dr. Balakrishnan assisted with study design, statistical analysis, and reviewed and revised the manuscript.

Dr. Grothe performed data acquisition from medical records and reviewed and revised the manuscript.

Dr. Knoebel performed data acquisition from medical records and reviewed and revised the manuscript.

Dr. Visscher obtained and performed standardization of cost data, performed statistical analysis, and reviewed and revised the manuscript.

Dr. Driscoll conceptualized the study, identified the study cohorts, performed data acquisition from medical records and reviewed and revised the manuscript.

Dr. Cofer drafted and submitted the IRB, performed data acquisition from medical records and reviewed and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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