The utilization of health care resources by children born with a congenital surgical anomaly – the utility of a physician assistant

Gabrielle Derraugh BSc, MSc, PA-S2

Student #: 7801827

willi153@myumanitoba.ca

Supervisor: Dr. Suyin A. Lum Min

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ABSTRACT

Introduction: Children born with a congenital surgical anomaly require surgical correction and the care of a multidisciplinary team. Medical and surgical innovation has led to improved survival rates, exposing these children to morbidities, ultimately leading to increased healthcare costs. Physician assistants (PAs) are medical generalists that extend the services of physicians, improve access to care and decrease healthcare costs.

Methods: We performed a retrospective cohort study of children born with a congenital surgical anomaly between 1990-2017 using the Winnipeg Surgical Database of Outcomes and Management (WiSDOM) and the Necrotizing Enterocolitis Management and Outcomes (NEMO) database; a 10:1 date-of-birth matched control population was selected using the Manitoba Centre for Health Policy (MCHP). The median cost of consult services, procedures and follow-up services was compared for cases versus controls. A comparative advantage analysis was performed to examine the cost-effectiveness of PAs.

Results: Cases generally had a higher median cost for consults, procedures and follow-up services compared to controls. For services provided specifically by general surgeons, cases were found to incur a higher cost primarily for major surgeries. PAs were found to be twice as cost effective as doctors at providing approximately 75% of the care of these patients.

Conclusion: Children born with a congenital surgical anomaly had higher healthcare costs than controls. Most of this excess cost is incurred in consult services, major surgeries and follow-up services provided by specialists other than general surgeons. The implementation of PAs into the care of these patients is an effective means of reducing these costs.

INTRODUCTION

A congenital surgical anomaly is a medical condition present at birth that requires urgent surgical correction. Pediatric surgeons are responsible for the surgical care of these babies. Pediatric general surgery is the subspecialty responsible for the care of children from birth to approximately 17 years-of-age who require surgical management of conditions involving the head, neck, chest, abdomen and skin. In addition to a surgeon, children born with a congenital surgical anomaly require the immediate care of a multidisciplinary team (neonatology, pediatric anethesia, pediatric nurses, neonatal intensive care unit resources, etc.) and therefore can not be managed outside a tertiary care center.

Physician assistants (PAs) are medical practitioners who extend the services of physicians. They are trained as medical generalists and can be applied to almost any medical setting, with on the job training leading to specialization. The scope of practice of a PA is a reflection of the specialty of the supervising physician(s) with whom they work and the practice setting in which they work. According to the Canadian Association of Physician Assistants (CAPA), PAs take medical histories, conduct physical exams, order and interpret tests, prescribe medications, formulate treatment plans, perform minor procedures, provide patient counseling and preventative healthcare and assist in surgery.[1] PAs are widely incorporated into the American healthcare system where PA is one of the fastest growing healthcare careers. There are over 150,000 PAs practicing in primary care and virtually every medical specialty in the United States.[2] However, the PA profession within the Canadian public healthcare system is relatively new and restricted to certain provinces and specialties. There are approximately 800 practicing PAs in Canada, 500 of whom are based in Ontario.[1] Growing healthcare needs, doctor shortages and increasing costs have led to a global health crisis.[3-4] PAs have been found to be a cost-effective solution to this crisis – the total cost associated with a patient encounter is less when a PA delivers the care.[5-6] PAs have been shown to provide comparable or better care than physicians, increase accessibility and are cost-effective.[7-9] PAs provide a financial benefit to the medical education model because the 24-month PA post-graduate degree is shorter than the 4-year medical school and residency model for a physician. Additionally, given that PAs recieveless than half the salary of a physician and have a physician task substitution rate of 70-80%, there is a a long-term economic benefit.[10-13] While a PA cannot match the technical skill or experience of a surgeon, the skills needed to take histories, perform physical exams, indentify medical issues, perform minor procedures and manage common ailments are within the scope of practice of a qualified PA. PAs may therefore allow surgeons to focus on surgical procedures, ultimately improving efficiency and increasing access to care.

In Manitoba, Physician Assistants have become crutial members of the team caring for infants with congenital surgical anomalies. Disorders commonly managed by this multidisciplinary team include: congenital diaphragmatic hernia, gastroschisis, intestinal atresia, omphalocele, congenital lung lesion, esophageal atresia/tracheo-esophageal fistula, Hirschsprung disease, anorectal malformation and necrotizing enterocolitis.

Gastroschisis is a congenial anomaly in which a defect in the abdominal wall allows the baby's intestines to reside outside of the body cavity. Gastroschisis is one of the most common congenital surgical anomalies seen by pediatric general surgeons with an incidence of about 1 in every 2000 babies, and evidence suggests that the incidence is increasing.[14-15] Gastroschisis children are at risk of sepsis, short bowel syndrome, nutritional compromise and long hospital stays.[16] Children born with omphalcele also have their abdominal contents outside the body cavity but they are surrounded by a transparent sac. Children born with congenital diaphragmatic hernia – a birth defect where a hole in the diaphragm allows abdominal contents to protrude into the thoracic cavity - often have pulmonary hypoplasia and pulmonary hypertension.[17] Intestinal atresia is congenital defect in the intestinal lumen that results in complete or partial obstruction. Congenital lung lesions are abnormal lung growths that predispose the children to frequent respiratory infections.[18] Esophageal atresia is a discontinuity of the esophagus that is often associated with an abnormal connection between the esophagus and trachea. Hirschprung disease involves the maldistribution of intestinal nerve cells. Although the bowel is patent, there is functional dysmotility that impedes the progression of stool through the intestines. Children born with Hirschprung disease have been found to have a high prevalence of fecal dysfunction and a low quality of life.[19] Anorectal malformations are congenital anomalies involving the patency of the anus and/or the rectum, resulting in difficulties with bowel function.[20] Lastly necrotizing enterocolitis – inflammation of the intestine - is responsible for 1 in 10 of all neonatal deaths and is associated with neurodevelopmental disability and intestinal failure.[21] These surgical anomalies constitute the bulk of cases that are uniquely managed by pediatric general surgeons.

We hypothesized that children born with a congenital surgical anomaly utilized more healthcare resources than children without a congenital surgical anomaly. We also hypothesized that by including PAs in the care of these children with surgical anomalies we can decrease the clinical and financial burden on the healthcare system. To test these hypotheses the specific objectives of this study were as follows:

1. To determine if the cost of of healthcare resource utilization of congenital anomalies cases was greater than age-matched controls
2. To determine if the greater cost of treating cases versus controls was incurred in consultations, procedures or follow-up.

3. To determine if the addition of a physician assistant into the care of children with congenital surgical anomalies could reduce healthcare costs

METHODS

Creation of case and control cohort

Ethics approval was granted [*HS20964 (H2017:252)]*. The Winnipeg Surgical Database of Outcomes and Management (WiSDOM) and the Necrotizing Enterocolitis Management and Outcomes (NEMO) database were used to identify children born in Manitoba (from 1990-2017) with one of the following nine surgical anomalies: congenital diaphragmatic hernia, gastroschisis, intestinal atresia, omphalocele, congenital lung lesion, esophageal atresia/tracheoesophageal fistula, Hirschsprung disease, anorectal malformation and necrotizing enterocolitis. The WiSDOM and NEMO databases were linked to the *Manitoba Centre for Health Policy* (*MCHP*) – a repository of population-level data for all people living in Manitoba. A date-of-birth match control group was generated using the *Manitoba Health Insurance* registry – for each case 10 date-of-birth matched controls were anonymously identified. The cohort was created using SAS® statistical software.

Baseline characteristics

Baseline characteristics of children born with a congenital surgical anomaly and date-of-birth matched controls were compared. The baseline characteristics obtained from the *Hospital Abstracts* dataset included: sex, birth weight, gestational age, 1-minute Apgar, 5-minute Apgar and length of hospital stay at birth. One-tailed t-tests and chi-squared tests for variance (indicated if equal variance assumption was satisfied for t-test) were performed for continuous variables. Two-sided Fisher's exact tests were performed for categorial variables. Note, for the continuous variables, one-tailed t-tests tested the assumption that controls had greater means, except for length of hospital stay at birth in which the opposite direction was tested. This was done because the data suggested that controls had higher birth weight, gestational age, 1-minute Apgar and 5-minute Apgar. For sex there was no clear clinical assumption of gender differences in congenital anomaly patients, thus a two-sided test was used to test if there was statistically significant difference. The statistical analyses were performed using R® version 3.6.1.

Total cost of healthcare services

The total cost of healthcare services - including consult services, procedures and follow-up services – was examined for cases and controls. Consultations were identified using the *Medical Claims/Medical Services* dataset - an administrative dataset that contains all compensatory claims for medical services provided in Manitoba - using the tariff codes 8626, 8550, 8595 or 8664. Procedures were identified by the location in which the procedure was performed using the Intervention Location Code (INTLOC01) 01, 04 and 09 recorded in the *Hospital Abstracts* dataset. Follow-up services were identified using the *Medical Claims/Medical Services* dataset using the following tariff codes: 8546, 8540, 8732, 8498, 8733, 8499, 8735, 8470, 8736, 8471, 8509, 8734, 8529, 8552, 8404, 8555, 8558, 8560, 8562, 8564 or 8597.

The cost of each interaction was obtained using the net fee-for-service variable available in the *Medical Claims/Medical Services* dataset. For descriptive summaries, we used the total number of interactions for cases and controls and reported the mean, standard deviation and median fee for each group.

Examination of the raw data suggested that the data was skewed, with outliers heavily affecting the total cost of consultations. Therefore, we compared medians as opposed to means since t-tests are not appropriate for non-normally distributed data. A one-sided Wilcoxon rank sum test, which takes into account the median as well as the N for each sample, were performed to test if cases incurred higher fees than controls. P-values less than 0.05 were considered significant. The analysis was performed using R® version 3.6.1.

Consult services

The number of consultations with each of the three groups - general surgeons, other specialists and generalists - were compared between cases and controls. Consultations were identified using the *Medical Claims/Medical Services* dataset using the tariff codes 8626, 8550, 8595 or 8664. The type of healthcare provider was identified using the MDBLOCK variable. General surgeons were identified by code 041. The code specific to pediatric general surgeons (143) produced no results, therefore 041 was used with the assumption that it refered to pediatric general surgeons. The category of 'other specialists' included neurology (011), rheumatology (013), cardiology (014), gastroenterology (015), nephrology (016), immunology (017), genetics (018), pediatric (02), psychiatry (03), surgery (oral (040), cardiovascular (042), plastic (043), urological (044), orthopaedic (045), neurological (046), dental (047), periodontal (048), vascular (141), thoracic (142)), ophthalmology (051), ears nose and throat (052 and 053), dermatology (06), obstetrics and gynecology (09), emergency medicine (113), endocrinology (131), hematology (132), infectious disease (133), respiratory (134) and oncology (150-158). The third group of care providers the generalists, also known as general practitioners, family doctors or primary care providers, were identified by codes 11, 111-112, 114-116. The cost of each consultation was obtained using the net fee-for-service variable available in the *Medical Claims/Medical Services* dataset. For descriptive summaries, we used the total number of consults for cases and controls and reported the mean, standard deviation and median fee for each group.

Procedures

The cost of in hospital procedures – minor or major - were compared between cases and controls. Procedures performed by general surgeons were analysed separately from procedures performed by other specialists. The type of provider was identified using the MDBLOCK variable as defined above. General practitioners were not included in this analysis as they were unlikely to have provided in hospital procedures. The type of procedure – minor versus major – was defined by the location in which the procedure was performed using the Intervention Location Code (INTLOC01) recorded in the *Hospital Abstracts* dataset. A major procedure was defined as occurring in the main operation room (INTLOC01 = 01) and a minor procedure was defined as occurring in the outpatient department (INTLOC01 = 04) or the ambulatory operating room/ambulatory treatment room/day surgery unit (INTLOC01 = 09). The cost associated with each procedure was obtained using the net fee-for-service variable. Similar descriptive summaries as stated above were provided for general surgeons and other specialists.

Follow-up services

The cost of follow-up services were compared between cases and controls and classified by type of provider: general surgeon, other specialist or generalist. Follow-up services were identified using the *Medical Claims/Medical Services* dataset using the following tariff codes: 8546, 8540, 8732, 8498, 8733, 8499, 8735, 8470, 8736, 8471, 8509, 8734, 8529, 8552, 8404, 8555, 8558, 8560, 8562, 8564 or 8597. The type of provider was identified using the MDBLOCK variable – general surgeon, other specialist and general practitioner. The cost associated with follow-up services were obtained using the net fee-for-service variable available in the *Hospital Abstracts* dataset. Similar descriptive summaries were provided as used for consultation services and procedures.

Comparative advantage analysis

A subset of services that could be provided by a PA was identified in consultation with the Department of Surgery Section of Pediatric General Surgery at the Health Sciences Centre in Winnipeg, MB, and included: consulations, minor procedures and follow-up services. The number of these interactions and the fees billed for these interactions were summed.

A comparative advantage analysis was performed using the following equation:[22]

$$\frac{Wage_{Physician}(time_{Physician})}{Wage_{PA}(time_{PA})+Wage_{Physician}(time_{consultation})} \qquad (1)$$

The unit cost of performing a consult, minor procedure and follow-up visit was calculated using the hourly wage multiplied by the time spent performing the given task. Time for physician oversight of the PA must be considered and ranges from no time to *X* number of minutes depending the PA's level of experience. According to the Winnipeg Health Authority Collective Agreement, the salary of a PA ranges from $81,446 to $118, 475 – an average salary of $100,000 was used in our calculation.[23] PAs work 40 hours per week (or 2,080 hours per year) with an hourly cost of $48 per hour. Alternatively, pediatric general surgeons work 50 hours per week (or 2,600 hours per year) and have an estimated annual salary of $450,000, resulting in an hourly cost of $173 per hour. The physician cost-per-task was then compared to the PA cost-per-task. For values less than 1 a physician is more cost-effective, and for values greater than 1 a PA is more cost-effective.

RESULTS

Baseline characteristics

A total of 894 neonates were born with a congenital surgical anomaly in Manitoba between 1990-2017 (118 congenital diaphragmactic hernia (CDH), 172 gastroschisis, 40 congenital lung lesion, 79 esophageal atresia/trachea-esophageal fistula (EA/TEF), 96 anorectal malformation, 89 Hirschprung disease, 94 intestinal atresia, 50 omphalocele and 156 necrotizing enterocolitis (NEC)). A total of 8,937 age-matched controls were randomly selected. Compared to controls, CDH, gastroschisis, EA/TEF, omphalocele and NEC cases had significantly lower birth weights ($p<0.001$), gestational age ($p<0.001$), 1-minute Apgar ($p<0.001$) and 5-minute Apgar ($p<0.001$). All of the cases had significantly longer hospital admissions at birth ($p<0.001$) compared to controls. Congenital lung lesion cases had lower gestational age ($p<0.001$), 1-minute Apgar ($p<0.001$) and 5-minute Apgar ($p<0.001$), but no difference was found for sex or birth weight. Anorectal malformation cases had lower birth weight ($p<0.001$), gestational age ($p<0.001$), 1-minute Apgar ($p<0.001$) and 5-minute Apgar ($p<0.001$); there were more male anorectal malformations cases than controls ($p<0.001$). Hirschprung disease cases contained more males than controls ($p<0.001$). Hirschsprung cases and controls had similar birth weight, gestational age, 1-minute Apgar and 5-minute Apgar. Intestinal atresia cases had lower birth weight

($p<0.001$), gestational age ($p<0.001$) and 1-minute Apgar ($p<0.001$). Intestinal atresia cases and controls were not different with respect to sex or 5-minute Apgar. Table 1 summarises these results.

Table 1. Baseline characteristics for cases and controls

Anomaly	N	Sex (male)	p	BW (g) (mean) (sd)	p	GA	p	1' Apgar	p	5' Apgar	p	LOS	p
CDH	118	69 (58%)	0.25	3193 (786)		37.80 (3.27)		5.40 (2.64)		6.72 (2.44)		29 (48)	<0.001
controls	1177	619 (53)		3458 (590)	*<0.001	39.05 (1.92)	*<0.001	7.90 (1.61)	*<0.001	8.35 (1.99)	*<0.001	3 (6)	
GAS	172	85 (49%)	0.68	2684 (599)		36.33 (1.87)		6.37 (2.49)		8.01 (1.47)		45 (3)	<0.001
controls	1720	880 (51%)		3440 (600)	*<0.001	39.00 (2.03)	*<0.001	8.00 (1.60)	*<0.001	8.36 (2.04)	*<0.001	3 (8)	
CLL	40	12 (30%)	0.24	3297 (752)	0.17	37.87 (3.01)		6.92 (2.15)		8.16 (1.67)		11.80 (26.80)	<0.001
controls	400	203 (51%)		3415 (580)		38.95 (2.05)	*<0.001	8.03 (1.53)	*<0.001	8.39 (1.90)	*<0.001	3.09 (6.14)	
EA/TEF	79	44 (56%)	0.63	2615 (767)		36.97 (3.51)		6.40 (2.59)		7.62 (2.16)		25.7 (39.4)	<0.001
controls	790	415 (53%)		3428 (598)	*<0.001	39.02 (1.91)	*<0.001	7.90 (1.65)	*<0.001	8.40 (1.92)	*<0.001	3.6 (7.5)	
AM	96	66 (69%)	<0.001	3053 (828)		37.84 (2.91)		7.01 (2.38)		8.11 (1.94)		18.3 (47.9)	<0.001
controls	960	500 (52%)		3440 (586)	*<0.001	38.95 (2.16)	*<0.001	7.99 (1.53)	*<0.001	8.31 (2.16)	*<0.001	3.1 (5.1)	
HD	89	75 (84%)	<0.001	3395 (669)	0.28	38.95 (2.26)		7.76 (1.88)		8.44 (1.75)		10.2 (19.0)	<0.001
controls	890	412 (46%)		3451 (616)		38.94 (2.17)	0.51	7.92 (1.62)	0.24	8.29 (2.12)	0.23	3.4 (7.7)	
IA	94	49 (52%)	0.38	2699 (694)		36.04 (2.79)		7.31 (2.01)		8.20 (1.65)		30.5 (48.0)	<0.001
controls	940	445 (47%)		3425 (585)	*<0.001	39.05 (1.94)	*<0.001	7.99 (1.57)	*<0.001	8.37 (2.03)	0.19	3.1 (6.5)	
OM	50	29 (58%)	0.65	2878 (878)		36.90 (4.00)		6.53 (2.48)		7.71 (2.36)		43.9 (85.4)	<0.001
controls	500	272 (54%)		3424 (640)	*<0.001	38.91 (2.41)	*<0.001	7.98 (1.58)	*<0.001	8.33 (2.06)	*0.04	3.2 (5.6)	
NEC	156	82 (53%)	0.98	1689 (870)		30.9 (4.4)		6.09 (2.48)		7.44 (2.02)		54 (48)	<0.001
controls	1560	819 (52%)		3434 (605)	*<0.001	39.0 (2.0)	*<0.001	7.91 (1.53)	*<0.001	8.23 (2.18)	*<0.001	4 (8)	

BW = birthweight; GA = gestational age; LOS = length of stay at birth
CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tacheaoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung's disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis
P *<0.001 and *0.04 indicates left tailed test – controls greater than cases

Total cost of healthcare services

A significant difference was found for the median cost of healthcare utilization – including consult services, procedures and follow-up services - for all anomalies. Table 2 summarizes these results.

Table 2. Total cost of healthcare utilization – including consult services, procedures and follow-up services for cases and controls

Anomaly	**Total healthcare utilization**					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	15913	1224506.00	76.95	163.30	33.85	<0.001
controls	99827	3482582.00	34.89	51.86	25.55	
GAS	21646	1676710.00	77.46	133.13	36.75	<0.001
controls	131342	4890659.00	37.24	59.54	27.90	
CLL	5026	353305.00	70.30	152.33	32.40	<0.001
controls	29836	1095385.00	36.71	59.16	25.61	
EA/TEF	22152	1493093.00	67.40	131.44	32.70	<0.001
controls	80090	2693159.00	33.63	52.87	22.75	
AM	21440	1334890.00	62.26	120.13	32.76	<0.001
controls	81221	2741551.00	33.75	52.07	23.55	
HD	16096	994680.70	61.80	125.49	29.09	<0.001
controls	81051	2853863.90	35.21	58.24	25.05	
IA	14841	1069606.00	72.07	144.49	35.75	<0.001
controls	74748	2608111.00	34.89	53.66	25.50	
OM	7593	627508.60	82.64	140.08	37.70	<0.001
controls	39362	1413933.50	35.92	61.92	27.05	
NEC	22899	1333817.00	58.25	112.50	28.00	<0.001
controls	165216	5376315.00	32.54	51.30	21.00	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Consult services

Consult services – general surgeons

No difference was found for the median cost of consult services provided by general surgeons. Table 3.1 summarizes these results.

Table 3.1. Consult services provided by general surgeons for cases and control

Anomaly	Consults – general surgeons					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	188	19699.00	105.41	42.33	102.05	0.19
controls	171	18451.00	109.43	37.32	102.05	
GAS	317	35687.27	112.57	43.04	102.05	0.25
controls	223	25482.88	114.27	36.99	102.05	
CLL	67	6773.22	101.09	41.18	95.15	0.36
controls	50	5417.67	108.35	46.96	104.60	
EA/TEF	243	23278.41	95.79	40.84	86.50	0.99
controls	133	14860.60	111.73	41.74	115.55	
AM	238	25251.34	106.10	46.04	102.05	0.40
controls	157	17106.01	108.96	46.86	102.05	
HD	231	24632.69	106.64	44.46	102.05	0.96
controls	154	17330.28	112.53	40.41	110.28	
IA	157	16930.38	107.84	40.18	102.05	0.22
controls	137	15325.73	111.87	37.19	113.40	
OM	112	12154.43	108.52	39.90	102.05	0.83
controls	71	7978.48	112.37	35.12	115.55	
NEC	212	20681.32	97.55	44.20	87.51	0.99
controls	300	32497.49	108.32	41.14	107.15	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Consult services – other specialists

The median cost of consult services provided by other specialists was found to be significantly greater in CDH ($141.95 vs $138.80, $p<0.001$), gastroschisis ($162 vs $138.80, p<0.01), anorectal malformation ($130.95 vs $122.50), Hirschprung disease ($141.45 vs $130, p<0.001), intestinal atresia ($150.80, vs $130, p<0.001), omphalocele ($146.32 vs $138.80, p=0.03) and NEC cases ($129.25 vs $107, p<0.001). No difference was found for congenital lung lesion and EA/TEF. Table 3.2 summarizes these results.

Table 3.2 Consult services provided by other specialists for cases and controls

Anomaly	**Consults – other specialists**					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	630	89189.21	141.57	47.49	141.95	<0.001
controls	1619	218736.86	135.11	52.14	138.80	
GAS	780	120512.86	154.50	45.67	162.00	<0.001
controls	2191	292808.61	133.64	50.64	138.80	
CLL	192	25421.71	132.40	48.45	125.31	0.90
controls	482	65546.72	135.99	53.66	139.05	
EA/TEF	886	109476.15	123.56	51.67	121.25	0.42
controls	1305	162120.08	124.23	55.95	116.90	
AM	747	97965.95	131.15	58.01	130.95	0.01
controls	1272	157857.09	124.10	49.60	122.50	
HD	435	59318.97	136.37	46.43	141.45	<0.001
controls	1320	171162.96	129.67	50.20	130.00	
IA	568	81269.27	143.08	52.00	150.80	<0.001
controls	1158	153679.00	132.71	55.70	130.00	
OM	357	50760.60	142.19	48.91	146.32	0.03
controls	566	78285.56	138.31	51.53	138.80	
NEC	861	113579.41	131.92	50.29	129.25	<0.001
controls	2366	282439.81	119.37	52.29	107.00	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung's disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Consult services – generalists

No difference was found for the median cost of consult services provided by generalists. Table 3.3 summarizes these results.

Table 3.3. Consult services provided by generalists for cases and controls

	Consults - generalists					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	54	3771.82	69.85	24.37	66.60	0.77
controls	127	9161.94	72.14	24.66	66.60	
GAS	56	4212.19	75.218	18.45	67.37	0.35
controls	206	15392.24	74.72	21.48	66.61	
CLL	7	574.90	82.13	14.69	90.40	0.17
controls	39	2967.28	76.08	25.06	69.93	
EA/TEF	69	5710.08	82.75	54.75	66.60	0.17
controls	125	8790.74	70.33	22.26	66.60	
AM	40	3002.68	75.07	24.02	66.61	0.45
controls	132	9891.60	74.94	25.60	69.93	
HD	32	2205.17	68.91	18.20	65.43	0.48
controls	129	9330.61	72.33	21.04	66.88	
IA	38	2754.55	72.49	25.64	66.60	0.52
controls	116	8231.41	70.96	19.89	66.60	
OM	25	2092.79	83.71	37.79	80.60	0.11
controls	56	3918.25	69.97	24.58	64.90	
NEC	61	4135.72	67.80	19.47	66.60	0.90
controls	241	17454.71	72.43	22.19	66.60	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Procedures

Minor procedures – general surgeons

For minor procedures performed by general surgeons, no difference was for found in the median cost for anorectal malformation cases and controls ($72.49 vs $67.88, p=0.94). For CDH, gastroschesis, congenital lung lesion, EA/TEF, Hirschprung disease, intestinal atresia, omphalocele and NEC, the number of minor procedures was found to be less than 5. Therefore, due the MCHP, these values could not be reported. Table 4.1 summarizes these results.

Table 4.1 Minor procedures provided by general surgeons for cases and control

Anomaly	Minor procedures – general surgeons					
	Number(N)	**Cost $)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	na	na	na	na	na	na
controls	na	na	na	na	na	
GAS	na	na	na	na	na	na
controls	na	na	na	na	na	
CLL	na	na	na	na	na	na
controls	na	na	na	na	na	
EA/TEF	na	na	na	na	na	na
controls	na	na	na	na	na	
AM	78	7934.22	101.72	111.64	72.49	0.94
controls	2	135.76	67.88	12.50	67.88	
HD	na	na	na	na	na	na
controls	na	na	na	na	na	
IA	na	na	na	na	na	na
controls	na	na	na	na	na	
OM	na	na	na	na	na	na
controls	na	na	na	na	na	
NEC	na	na	na	na	na	na
controls	na	na	na	na	na	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis
*na indicates when numbers too small to report

Minor procedures – other specialists

We found a significantly higher median cost for minor procedures by other specialists for gastroschesis ($56.78 vs $21, p<0.001), EA/TEF ($46.95 vs $40, p<0.001), anorectal malformation ($46.95 vs $34.30, p<0.001) and NEC cases ($30 vs $30, p<0.001). No difference was found for intestinal atresia ($41.53 vs $37.05, p=0.09). For CDH, congenital lung lesion, Hirschprung disease and omphalocele, the number of minor procedures was found to be less than 5. Therefore, due to the MCHP, these values could no be reported. Table 4.2 summarizes these results.

Table 4.2. Minor surgeries provided by other specialists for cases and control

Anomaly	Minor surgeries – other specialists					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	na	na	na	na	na	na
controls	na	na	na	na	na	
GAS	132	11217.83	84.98	114.43	56.78	<0.001
controls	320	11121.95	34.76	47.75	21.00	
CLL	na	na	na	na	na	na
controls	na	na	na	na	na	
EA/TEF	1102	76987.76	69.86	73.66	46.95	<0.001
controls	410	25198.94	61.46	94.23	40.00	
AM	1104	77130.11	69.86	73.63	46.95	<0.001
controls	306	16833.52	55.01	79.72	34.30	
HD	na	na	na	na	na	na
controls	na	na	na	na	na	
IA	41	2106.69	51.38	35.11	41.53	0.09
controls	216	11819.75	54.72	80.44	37.05	
OM	na	na	na	na	na	na
controls	na	na	na	na	na	
NEC	141	6492.53	46.05	40.18	30.00	<0.001
controls	898	38669.61	43.06	61.34	30.00	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung's disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis
*na indicates when numbers too small to report

Major procedures – general surgeons

The median cost for major procedures performed by general surgeons was greater for CDH ($108.15 vs $89.71, p<0.001), congenital lung lesion ($102.05 vs $77.04, p=0.03) and intestinal atresia ($100 vs $88.45, p=0.03). No difference was found for gastroschisis, EA/TEF, anorectal malformation, Hirschprung disease, omphalocele and NEC. Table 4.3 summarizes these results.

Table 4.3. Major surgeries provided by general surgeons for cases and controls

Anomaly	Major surgeries – general surgeons					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	610	109184.25	178.99	187.89	108.15	<0.001
controls	280	35363.03	126.30	131.68	89.71	
GAS	1127	193931.49	172.08	195.19	97.99	0.31
controls	364	55051.59	151.24	166.54	102.05	
CLL	157	38380.97	244.46	374.88	102.05	0.03
controls	65	8797.66	135.35	184.59	77.04	
EA/TEF	992	144593.86	145.76	214.46	95.57	0.74
controls	247	34306.38	138.89	147.72	101.65	
AM	1232	128470.30	104.28	157.79	42.815	0.99
controls	202	26448.20	130.93	141.07	86.50	
HD	1494	163113.20	109.18	185.78	42.60	0.99
controls	215	28697.51	133.48	153.45	84.66	
IA	597	117769.37	197.27	249.68	100.00	0.03
controls	198	25671.90	129.66	153.56	88.45	
OM	443	67109.70	151.49	186.10	60.00	0.98
controls	144	25266.56	175.46	228.33	102.05	
NEC	475	72779.74	153.22	206.86	85.75	0.74
controls	449	56907.07	126.74	127.30	98.00	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Major procedures – other specialists

The median cost of major procedures performed by other specialists was found to be significantly greater for all anomalies. Table 4.4 summarizes these results.

Table 4.4. Major surgeries provided by other specialists for cases and controls

Anomaly	Major surgeries – Other specialists					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	4412	481969.59	109.24	218.462	50.00	<0.001
controls	10099	588131.05	58.237	89.0216	38.6	
GAS	6395	592111.85	92.59	136.022	50.00	<0.001
controls	11847	765433.21	64.61	115.862	41.15	
CLL	764	43626.42	57.103	58.211	44.25	0.003
controls	2555	158629.67	62.086	105.963	38.60	
EA/TEF	4731	312615.22	66.078	101.847	40.45	<0.001
controls	8379	445060.48	53.116	87.739	33.8	
AM	4925	368843.62	74.89	143.61	43.05	<0.001
controls	6550	353210.13	53.93	91.53	37.35	
HD	3669	220919.16	60.21	78.33	39.45	0.02
controls	5640	344722.52	61.12	100.30	38.90	
IA	4217	325728.73	77.24	129.66	40.95	<0.001
controls	5985	335529.01	56.06	96.62	37.95	
OM	2883	232151.55	80.52	117.74	44.90	<0.001
controls	3985	224819.64	56.42	110.00	37.75	
NEC	3833	341882.16	89.19	146.30	44.25	<0.001
controls	13591	732740.73	53.91	88.72	36.75	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Follow-up services

Follow-up services – general surgeons

CDH cases were found to have a significantly higher median cost for follow-up services by general surgeons ($49.05 vs $46, p<0.001). No difference was found for gastroschisis, congenital lung lesion, EA/TEF, anorectal malformation, Hirschprung disease, intestinal atresia, omphalocele and NEC. Table 5.1 summarizes these results.

Table 5.1. Follow-up services provided by general surgeons for cases and controls

Anomaly	Follow-up services – General surgeons					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	86	4346.48	50.54	7.23	49.05	<0.001
controls	22	981.59	44.61	5.66	46.00	
GAS	154	7567.66	49.14	10.65	46.90	0.70
controls	43	2121.41	49.33	7.35	48.10	
CLL	49	2385.86	48.69	9.26	46.90	0.51
controls	11	540.65	49.15	8.34	53.65	
EA/TEF	96	4181.15	43.55	7.82	44.08	0.98
controls	27	1347.51	49.91	12.51	46.90	
AM	185	8964.37	48.46	7.95	48.10	0.51
controls	20	967.15	48.36	6.58	48.45	
HD	275	12885.97	46.86	8.92	46.90	0.60
controls	23	1098.92	47.78	5.48	46.06	
IA	65	3241.23	49.87	7.61	53.65	0.08
controls	25	1190.96	47.64	6.46	46.90	
OM	77	3475.85	45.14	4.92	46.00	0.77
controls	12	546.13	45.51	6.82	46.90	
NEC	35	1613.81	46.11	8.12	46.90	0.92
controls	33	1615.60	48.96	6.51	48.30	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Follow-up services – other specialists

The median cost of follow-up services provided by other specialists was found to be signifiantly greater for all anomalies. Table 5.2 summarizes these results.

Table 5.2. Follow-up services provided by other specialists for cases and controls

Anomaly	Follow-up services – Other specialists					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	2770	167858.02	60.60	68.92	43.05	<0.001
controls	17747	835534.10	47.08	37.51	41.15	
GAS	2908	180185.86	61.96	63.54	49.75	<0.001
controls	24029	1172381.77	48.79	41.82	43.05	
CLL	911	50594.53	55.54	49.43	49.75	<0.001
controls	5398	251393.64	46.57	41.79	41.85	
EA/TEF	4730	232044.44	49.06	47.38	38.28	<0.001
controls	12492	528867.05	42.34	30.28	37.75	
AM	3913	203701.68	52.06	49.31	43.05	<0.001
controls	13714	605311.4	44.14	35.15	37.75	
HD	2332	130647.43	56.02	65.95	42.75	<0.001
controls	12885	590201.48	45.81	34.96	38.60	
IA	2379	131220.88	55.16	53.45	43.05	<0.001
controls	13219	611313.32	46.25	40.15	38.69	
OM	1370	86276.77	62.98	58.37	52.50	<0.001
controls	6977	330393.13	47.35	41.14	41.15	
NEC	3742	204837.28	54.74	70.73	38.60	<0.001
controls	25257	1043374.63	41.31	33.69	37.35	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Follow-up services – generalists

The median cost of consult services provided by generalists was found to be significantly greater for CDH ($31.85 vs $31.20, p<0.001), gastroschesis ($31.94 vs $31.85, p=0.04), EA/TEF ($29.11 vs $28.44, p<0.001), Hirschprung disease ($31.15 vs $30.06, p<0.001), intestinal atresia ($31.85 vs $30.55, p<0.001) and NEC ($28.04 vs $29.09, p=0.01). No difference was found for congenital lung lesion, anorectal malformation and omphalocele. Table 5.3 summarizes these results.

Table 5.3. Follow-up services provided by generalists for cases and controls

Anomaly	Follow-up services - generalists					
	Number(N)	**Cost($)**	**Mean($)**	**SD($)**	**Median($)**	**p**
CDH	2109	72984.41	34.61	17.04	31.85	<0.001
controls	27741	917856.17	33.09	16.56	31.20	
GAS	3366	117086.96	34.79	17.00	31.94	0.04
contros	37847	1305053.49	34.48	17.03	31.85	
CLL	839	28347.67	33.79	18.38	31.20	0.9
controls	7785	272960.18	35.06	18.19	32.76	
EA/TEF	2162	69112.85	31.97	16.27	29.11	<0.001
controls	22881	711119.23	31.08	16.07	28.44	
AM	2745	89101.55	32.46	16.85	31.15	0.32
controls	22735	733913.27	32.28	16.90	30.55	
HD	2374	80958.63	34.10	18.59	31.15	<0.001
controls	23049	743592.03	32.26	16.22	30.06	
IA	2009	67382.22	33.54	16.92	31.85	<0.001
controls	21343	691404.46	32.39	16.41	30.55	
OM	688	23059.05	33.52	17.75	31.85	0.84
controls	11424	382280.06	33.46	16.13	31.85	
NEC	3673	112055.95	30.51	16.09	28.04	0.98
controls	48921	1524517.43	31.16	16.36	29.09	

CDH = congenital diaphragmatic hernia; GAS = gastroschisis; CLL = congenital lung lesion; EA/TEF = esophageal atresia/tracheoesophageal fistula; AM = anorectal malformation; HD = Hirschsprung's disease; IA = intestinal atresia; OM = omphalocele; NEC = necrotizing enterocolitis

Comparative advantage analysis

We found that the comparative advantage – general surgeon vs PA cost-per service - was 2.55 for consult services, 2.07 for minor procedures and 1.99 for follow-up services (values greater than '1' indicate that a PA is more cost-effective). Major procedures were not compared as they are unlikely to fall within the PA's scope of practice. Table 6 summarizes these results.

Table 6. Comparative advantage analysis

Provider	Consult services			Minor procedures			Follow-up services		
	Time (min)	**Cost/ service($)**	**CA**	**Time (min)**	**Cost/ service($)**	**CA**	**Time (min)**	**Cost/ service($)**	**CA**
General surgeon	30	86.40	2.55	30	86.40	2.07	15	43.20	1.99
PA	35	33.76		45	41.76		20	21.76	
CA = Comparative Advantage PA = Physician Assistant									

DISCUSSION

We conducted a population-based study comparing the utilization of healthcare resources of children born with a congenital surgical anomaly compared to age-matched controls. We also examined if the implementation of a PA into the care of these patients can reduce healthcare costs. The results suggest that children born with a congenital surgical anomaly utilize a significantly larger amount of healthcare resources; however, resources specifically provided by general surgeons is most evident for major surgeries. The results also suggest that a PA can effectively manage approximately 75% of patient care and are more cost effective; thereby decreasing the financial burden and improving access to care.

Our first objective was to determine if survivors of surgical congenital anomlies incurred more expenses in the healthcare system than a child born without a surgical congenital anomaly. When the total expenses for each interaction with the healthcare system were compared for cases versus controls, the cases incurred greater expense regardless of the type of congenital surgical anomaly.

Our second objective was to describe the clinical setting in which cases were incurring greater costs than controls. To this end, we divided interactions with the healthcare system by type of providers (general surgeon, other specialists and general practitioners) and type of services (consults, procedures and follow-ups). Our results showed that the cost of a consultation or follow-up with a general surgeon was similar for cases and controls, except for CDH for whom general surgery consultations were costlier. The cost of major procedures performed by general surgeons for cases was similar to controls, except for CDH, CLL and intestinal atresia cases. All interactions, consults, procedures and follow-ups, with other specialists incurred more costs for cases than controls, regardless of the type of surgical anomaly. The cost of consultations with general practitioners incurred by cases was similar to controls, but follow-ups were more costly for CDH, gastroschisis, esophageal atresia, Hirschsprung disease and intestinal atresia. Therefore, our data suggests that the excess of healthcare expense incurred by congenital surgical anomaly cases occured with interactions with other specialties, not general surgeon or general practioners. This was surprising since general surgeons are highly involved in the initial care of congenital surgical anomaly patients.

The data suggests that outside of major procedures, the medical care provided by general surgeons does not cost our healthcare system more for children born with a congenital surgical anomaly than controls. The argument could therefore be made that PA’s might be more cost beneficial in other specialties. Many children born with a surgical anomaly have associated medical conditions, most commonly cardiac, genetic, renal and pulmonary. Special treatment for associated conditions may explain why interactions with other specialists provokes more cost per interaction. The increased cost per interation of other specialists suggests that special skills or training may be required to care for cases over controls. These special skill may not be easily transferable to a PA.

However, PAs may be helpful in the care of neonates born with a congenital surgical anomaly when expertise is not excessive, such as during consultations, minor procedures, and follow-up visits. For general surgery, only major surgical procedures demonstrated greater cost per interaction for cases than controls. Given that the salary of a PA is approximately one-third that of a pediatric general surgeon, the utilization of a PA may be a cost-effective, safe solution to the current physician shortage and healthcare crisis. As described in Jones et al., the theory of comparative advantage is an economic means by which to analyze the cost-beneift of two similar groups with different wages and productivity.[22] A physician may be more efficient than a PA at performing a specific task but due to the wage difference, a PA is a more effective choice. By allowing a pediatric surgeon to focus on the part of their surgical practice where expertise is manditory and having a PA take care of the more routine responsibilities, efficiency can be improved and patient safety protected. van de Brink et al.'s systematic review found that due to their reduced labor costs or increased effectiveness, PAs have the same or less cost of care compared to physicians.[7]

The PA education model allows for a reduction in cost related to time, tuition and lost income. The two year post undergraduate degree is significantly less than the six plus years of post undergraduate education of a physician; this allows for the licensing of more medical professionals in less time. The decreased time and cost of PA education also increases accessibility of the profession to low-income and rural communities improving diversity amongst medical providers.

A systematic review found that the addition of a PA resulted in the same or better quality of care, resulting in reduced complication rates, lower mortality, less hospitalizations and readmissions, and an improvement in patient quality of life.[7] Patient satisfaction of PAs did not significantly differ from satisfaction of a physician, however, patients were not always aware that their provider was a PA and not a physician.[7] PAs were also found to increase accessibility of care in emergency departments or acute care sites, with studies reporting a reduction in wait times and a reduction of patients leaving without being seen.[7]

It is evident by this research that there is a sizable economic and healthcare benefit to incorporating PAs into the medical model.

Limitations and Strengths

There are several limitations to our study. First, we were unable to report data for minor procedures for pediatric general surgeons due to a paucity of such interactions. Since minor procedures may be an aspect in which PAs can be involved in patient care, the absence of data limits our ability to analyze the utilization of this healthcare resource. Second, we used intervention location to categorize minor versus major procedure but this may not be a true representation of the expertise required to perform a procedure. Third, the comparative analysis was done using estimated salaries and time per service. Finally, we assumed that differences in the cost per interaction reflected increased expertise, this may not be true. Despite these limitations, our study is unique in that it encompasses a large sample size of children born with a congenital surgical anomaly for which outcome data is limited. We also used a large comprehensive repository of population-level administrative data, enabling us to collect data over a long period of time and select 10:1 date-of-birth matched controls from the general population.

Recommendation for future research and clinical practice

Future research should focus on prospective studies examining the effectiveness of PAs in healthcare. By increasing the amount of evidence available, further implementation into the healthcare system would be inevitable. Public campagnes are also needed to improve societies knowledge surrounding PAs scope of practice. Lastly, it is essential that departments examine their PAs scope of practice and seek to optimize it in order to provide the greatest benefit in that specific healthcare setting.

Conclusion

Our study found that children born with a congenital surgical anomaly incur greater overall cost to the healthcare system than date-of-birth matched controls. When costs per interaction were compared for pediatric general surgeons, other spectialists and general pracitioners, general surgeons tended to bill the same amount for cases versus controls, except when performing major surgical procedures where cases required greater renumeration. Other specialists appear to bill more per interaction for cases than controls at all interactions, consults, procedures anad follow-up, suggesting that special expertise is required for these interactions. Consults and follow-up care with pediatric general surgeons may be managed by a PA as the cost per interaction reflected no excessive expertise than that of an interaction with a child without a congental anomaly. Finally, PAs are potentially twice as cost effective as a physician at providing care of congenital surgical anomaly patients.

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