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Resource Utilization and Costs in Adolescents Treated for Cancer in Pediatric vs Adult Institutions

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Abstract

Background: Adolescents with cancer can receive care in pediatric or adult institutions. Survival often differs by locus, but little is known about relative health care utilization and costs. We estimated these in a population-based cohort of adolescents.

Methods: All Ontario adolescents (15.0–17.9 years) diagnosed with cancer between 1995 and 2010 were identified from provincial cancer registries. We compared health care resource utilization (hospitalizations, emergency department visits, same-day surgeries, outpatient chemotherapy, radiation, diagnostic/laboratory tests, physician services, home care) and costs (2012 Canadian dollars) during four discrete care phases—prediagnosis (60 days), initial (360 days), continuing (variable), and terminal (360 days)—between adolescents treated in pediatric vs adult institutions, for the whole cohort and within seven diagnostic categories. All statistical tests were two-sided.

Results: Of 1356 eligible adolescents, 691 and 665 were treated in adult and pediatric institutions, respectively. Hospitalization rates were higher in pediatric institutions during prediagnosis (14.9% vs 6.9%, $P < .001$), initial (95.1% vs 73.3%, $P < .001$), and continuing phases (43.2% vs 34.4%, $P = .002$), but similar (96.1% vs 96.3%, $P = .93$) during the terminal phase. Average length of stay was higher at pediatric institutions within most diagnoses and phases. For all diagnoses, median initial phase costs were higher in pediatric than adult institutions (eg, leukemia: \$153 926 vs \$102 418 per 360 days, $P < .001$; lymphoma: \$65 025 vs \$19 846, $P < .001$, respectively).

Conclusions: The costs of caring for adolescents with the same malignancy are considerably higher in pediatric than adult institutions during most phases. Resource utilization, particularly hospitalization, drives much of the cost difference, making these data applicable to other jurisdictions.

Cancer is the leading cause of nonaccidental death in adolescents in developed countries (1). In Canada, approximately 400 people age 15 to 19 years are diagnosed with cancer annually, and 70 die (2). Survival improvements in adolescents have lagged behind those observed in younger children and older adults (3–7) as a consequence of patient, disease biology, and health care system factors. Locus of cancer care is as an important contributor to adolescent cancer outcomes (8). Adolescents can receive care in a pediatric or adult hospital; in most jurisdictions, neither is designed for the needs of adolescents who are transitioning from childhood to adulthood (9), resulting in a

paucity of expertise and variations in care and treatment intensity between sites. Survival disparities according to locus have been observed in several cancers (10–20). Adolescents with acute lymphoblastic leukemia (ALL) (10–13) or pediatric-type sarcomas (21,22) often have superior survival when treated in pediatric centers or in pediatric clinical trials (23). Adolescents with adult-type malignancies such as carcinomas may experience better outcomes in adult centers (23).

Superior survival in specific centers might result from availability of disease-specific expertise, higher volumes of patients with a particular cancer, or better clinical trial access. One factor

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that contributes to better outcomes for some cancers is more intense therapies in pediatric settings (14,24), which often use higher chemotherapy doses, shorter intervals between courses, or additional chemotherapy agents. However, health care utilization by adolescents treated in different centers, and the associated costs, have not been well studied. Such data are crucial for informing future research focused on the development of the most cost-effective care models. We used population-based data from Ontario, Canada, to estimate the utilization of medical services and associated costs for adolescents treated in pediatric vs adult institutions. As Canadian and US institutions employ the same therapeutic protocols, we believe that these findings are generalizable to the United States.

Methods

Cohort Creation

This descriptive costing study was approved by the Research Ethics Boards of the University of Toronto and Sunnybrook Health Sciences Centre. Patients were identified from the Ontario Cancer Registry (OCR), which captures all new cancer diagnoses except nonmelanoma skin cancer (25), and the Pediatric Oncology Group of Ontario's Networked Information System (POGONIS), a registry of children and adolescents treated for cancer at the province's five pediatric cancer centers, which treat approximately 46% of adolescents (9). The cohort included adolescents (15.0–17.9 years) who were diagnosed with their first cancer between January 1, 1995, and June 30, 2010. Patients treated in a pediatric center were classified as “pediatric institution,” whereas those treated in an adult regional cancer center (RCC) or community hospital were classified as “adult institution.” All radiation therapy is delivered at RCCs, so pediatric institution patients could have received radiation in an adult center. Patients were followed until death or the end of our analysis period, December 31, 2010. We looked forward to December 31, 2011, to determine whether patients had died within one year after December 31, 2010, so that they could be correctly allocated to the terminal phase (see below).

OCR and POGONIS data were linked to population-based health administrative databases at the Institute for Clinical Evaluative Sciences using unique encoded patient identifiers. The Canada Health Act requires that all medically necessary care be provided universally and paid for by the government; thus these databases document the use of all such health care resources by all provincial residents. We determined the following health care encounters: hospitalizations, emergency department (ED) visits, same-day surgeries (including biopsies, lumbar punctures, and blood transfusions), outpatient chemotherapy, radiation therapy, outpatient diagnostic/laboratory tests, physician services, and home care. Databases included the Ontario Health Insurance Plan Claims Database (OHIP; physician billings for inpatient and outpatient services, as well as outpatient laboratory and diagnostic tests), the National Ambulatory Care Reporting System (NACRS; patient visits to ambulatory care settings including same-day surgery, outpatient clinics, and emergency departments), the Discharge Abstract Database (DAD; hospitalizations), the Cancer Care Ontario Activity Level Reporting System database and POGONIS (radiation therapy), the New Drug Funding Program data (NDFP; costs of newer injectable cancer drugs), and the Ontario Home Care Administrative System Database and Home Care Database (home care) (26,27). Outpatient drug costs, including oral

chemotherapy administered outside of hospitals, were determined from the Ontario Drug Benefit (ODB) Program, which insures families on social assistance or whose drug costs are high relative to their income. In our sample, 48.5% of patients had an ODB drug claim at some point during the analysis period. Outpatient drug costs not covered by this program could not be captured.

Cancers were classified according to the International Classification of Childhood Cancer (ICCC; 3rd ed.) (28). The 12 ICCC categories were grouped into the seven most common malignancies of adolescence: leukemia, lymphoma, central nervous system (CNS) tumors, bone and soft tissue sarcomas, germ cell tumors, thyroid carcinomas, and all other cancers. We described comorbidity by categorizing all ICD-9 and ICD-10 diagnostic codes in hospital records and physicians' billing data in the year before diagnosis into one of 29 aggregated diagnosis groups (ADG), a unit in a population-patient case-mix adjustment system (29), which relates to health care utilization in patients of all ages (30). We used the Statistics Canada Postal Code Conversion file and data from the 2001 Canada Census to obtain neighborhood-level median household income and rurality (31,32).

Analyses

To assess whether the severity of specific diagnostic categories differed between patients treated at pediatric and adult centers, we compared white blood cell count in patients with ALL and stage at diagnosis in patients with lymphoma and bone or soft tissue sarcoma (localized vs metastatic). We compared survival for each cancer by institution type using a Kaplan-Meier approach.

We employed a phase-based approach to estimate utilization and costs across the cancer care trajectory from prediagnosis to death (26). This is an established method for costing that addresses the fact that some patients may not contribute data to the entire care trajectory (32,33). We defined four phases: prediagnosis (60 days before diagnosis), initial (360 days after diagnosis), terminal (360 days before death, for patients who died before December 27, 2011), and continuing (time between initial and terminal or end of observation) (33,34). All patients had 60 days in the prediagnosis phase. Deceased patients had up to 360 days of their last days of life within the study observation period assigned first to the terminal phase. The remaining time between diagnosis and the start of the terminal phase was assigned to the initial phase, and then to the continuing phase (33,35). For patients who did not die, the first 360 days after diagnosis and within the observation period were allocated to the initial phase, and any remaining time to the continuing phase. We used these phase lengths for all patients, recognizing that duration of initial active therapy varies for individuals and types of cancer. Utilization and costs were standardized to 60 days for the prediagnosis phase and 360 days for other phases.

Health care utilization, reported as the percentage of patients who used each health care resource in each phase, was compared between adolescents treated at pediatric centers and adult centers using chi-square tests. We quantified the frequency of hospitalizations and ED visits and the length of hospital stay per admission during each phase for each ICCC category. We summarized these data using both means and medians as measures of central tendency and compared them between care loci using independent samples *t* tests for means and nonparametric Kruskal-Wallis tests for medians. Costs

Table 1. Characteristics of patients aged 15–17 years at diagnosis by locus of care

Characteristics	Adult institution	Pediatric institution	Total	P*
Total, No. (%)	691 (51.0)	665 (49.0)	1356 (100)	
Age at diagnosis				
Mean $\pm$ SD, y	16.35 $\pm$ 0.75	15.74 $\pm$ 0.77	16.05 $\pm$ 0.82	<.001
Median (IQR), y	17 (16–17)	16 (15–16)		
15–15.9 y, No. (%)	117 (16.9)	307 (46.2)	424 (31.3)	<.001
16–16.9 y, No. (%)	217 (31.4)	227 (34.1)	444 (32.7)	
17–17.9 y, No. (%)	357 (51.7)	131 (19.7)	488 (36.0)	
Sex, No. (%)				
Female	356 (51.5)	301 (45.3)	657 (48.5)	.02
Male	335 (48.5)	364 (54.7)	699 (51.5)	
Residence, No. (%)				
Rural	90 (13.0)	80 (12.0)	170 (12.5)	.58
Urban	601 (87.0)	585 (88.0)	1186 (87.5)	
Neighborhood income quintile, No. (%)				
1 (lowest)	97 (14.0)	111 (16.7)	208 (15.3)	.21
2	123 (17.8)	117 (17.6)	240 (17.7)	
3	162 (23.4)	125 (18.8)	287 (21.2)	
4	157 (22.7)	174 (26.2)	331 (24.4)	
5 (highest)	≤ 151 (≤ 21.9)	≤ 137 (≤ 20.6)	≤ 289 (≤ 21.3)	
Missing	≤ 5 (≤ 0.8)	≤ 5 (≤ 0.8)	≤ 5 (≤ 0.4)	
ADG count, No. (%)				
0	30 (4.3)	20 (3.0)	50 (3.7)	.21
1–4	410 (59.3)	378 (56.8)	788 (58.1)	
5–9	239 (34.6)	248 (37.3)	487 (35.9)	
≥ 10	12 (1.7)	19 (2.9)	31 (2.3)	
Status on December 31, 2011, No. (%)				
Dead	107 (15.5)	152 (22.9)	259 (19.1)	<.001
Alive	584 (84.5)	513 (77.1)	1097 (80.9)	
Diagnostic group, No. (%)				
Leukemia	50 (7.2)	126 (18.9)	176 (13.0)	<.001
Lymphoma	156 (22.6)	238 (35.8)	394 (29.1)	
CNS tumor	51 (7.4)	83 (12.5)	134 (9.9)	
Bone and soft tissue sarcoma	99 (14.3)	102 (15.3)	201 (14.8)	
Germ cell tumor	109 (15.8)	52 (7.8)	161 (11.9)	
Thyroid carcinoma	123 (17.8)	24 (3.6)	147 (10.8)	
Other cancer	103 (14.9)	40 (6.0)	143 (10.5)	

*P values for continuous variables were based on independent samples t test for means, and nonparametric Kruskal-Wallis test for medians. P values for categorical variables were based on chi-square tests. All tests were two-sided. Further information about histologic distribution, stage, and risk factors is presented in [Supplementary Table 1](#) (available online). ADG = aggregated diagnosis groups; CNS = central nervous system; IQR = interquartile range.

were estimated from the perspective of the payer, the Ontario Ministry of Health and Long-term Care. In Ontario, patients do not incur co-payments or deductibles; all medically necessary health care services are covered by the public third party payer. Each record of an inpatient hospitalization, ED visit, outpatient chemotherapy visit, or same-day surgery visit is assigned a resource intensity weight (RIW), reflecting utilization of resources such as drugs, procedures, tests, and personnel (excluding physician services). In addition, each episode of hospital-based care has an associated unit cost termed “cost per weighted case” (CPWC), which is a weighted cost of all resources used during a standard hospital stay. Following standard methods, we estimated the costs of these resources by multiplying the RIW by the CPWC for the year of use (36,37). Due to the complex needs of children, pediatric hospitals have higher CPWC than the average adult hospital in Ontario (36). Therefore, we used hospital-specific CPWC for the two pediatric hospitals and the three hospitals with pediatric oncology facilities in Ontario, and the provincial mean CPWC for all adult hospitals. Costs for other resources (physician services, diagnostic imaging/laboratory testing, and radiation therapy) were estimated using

standard methods (36). Costs for physician services and diagnostic imaging/laboratory tests were obtained by multiplying the number of visits by the unit cost associated with the billing code; costs for radiation therapy were obtained by multiplying the number of fractions by an estimated unit cost (25,26,36).

We estimated total direct resource-specific costs in each phase, stratified by cancer type, for patients treated in a pediatric vs adult institution (38). Costs were reported in constant 2012 Canadian dollars (39). As costs were not normally distributed, we compared median costs between center types for each phase of care and diagnostic category using Kruskal-Wallis tests.

A P value of less than .05 was considered statistically significant, and all statistical tests were two-sided.

Results

Between 1995 and 2010, 1356 adolescents were treated for cancer in either a pediatric (n = 665) or adult (n = 691) institution (Table 1). Patients treated at pediatric institutions were statistically significantly younger, more likely to be male, and more

likely to have died during follow-up. Rurality, neighborhood income quintile, and number of ADGs were similar between groups. Leukemias, lymphomas, and CNS tumors were more commonly treated in pediatric institutions; germ cell tumors, thyroid cancers, and “other” malignancies were more commonly treated in adult institutions. The relative proportion of leukemia types (ALL vs other leukemias) and lymphoma types (Hodgkin vs non-Hodgkin lymphoma) did not differ between institution types ([Supplementary Table 1](#), available online). Among the 103 adolescents treated for “other” cancers in adult centers, 42.7% had melanomas. Among the 40 treated in pediatric institutions, there were few skin cancers, but 17.5% had renal tumors. There were similar proportions of other/unspecified carcinomas in both groups (41.7% vs 42.5%, respectively). There were no statistically significant differences between institution types in white blood cell count in patients with ALL or localized vs metastatic disease in patients with bone or soft tissue sarcoma ([Supplementary Table 1](#), available online). However, patients treated for lymphoma at pediatric centers were statistically significantly more likely to have stage III or IV disease than those treated at adult centers. There were no differences in survival between type of center in any of the diagnostic groups ([Supplementary Table 2](#), available online).

Table 2 documents the use of the eight health care resources during each phase. Hospitalization rates were statistically significantly higher in patients treated in pediatric institutions compared with those treated in adult institutions during the prediagnosis (14.9% vs 6.9%, $P < .001$), initial (95.1% vs 73.3%, $P < .001$), and continuing phases (43.2% vs 34.4%, $P = .002$) but similar (96.1% vs 96.3%, $P = .93$) during the terminal phase. Patients treated at pediatric centers were statistically significantly more likely to visit an ED during the prediagnosis (38.2% vs 22.9%, $P < .001$) and initial phases (66.9% vs 48.9%, $P < .001$) and to use home care resources during the initial and continuing phases.

As the distribution of diagnoses differed between institution types, we compared the number and length of hospitalizations and the number of ED visits for each diagnostic group. During the initial phase, patients with leukemia, lymphoma, sarcomas, germ cell tumors, and “other” cancers treated in pediatric centers had a statistically significantly higher average number of hospitalizations and a longer average length of stay (Table 3). During the terminal phase, most diagnostic groups had similar numbers and lengths of hospitalization in each institution type. Little difference was observed in ED visits (Figure 1; Supplementary Table 3, available online).

Figure 2 and Supplementary Table 4 (available online) show median costs by care locus for each phase of care by diagnostic category. The terminal phase had the highest costs, followed by the initial phase. In the initial phase, costs were statistically significantly higher in pediatric institutions for all diagnoses (eg, leukemia: \$153 926 vs \$102 418 per 360 days, $P < .001$; lymphoma: \$65 025 vs \$19 846, $P < .001$, respectively). During the terminal phase, median costs in pediatric institutions were statistically significantly higher for sarcomas (median difference = \$58 065, $P = .01$) and other tumors (median difference = \$61 102, $P = .02$). A sensitivity analysis (using the provincial average CWPC for both pediatric and adult institutions) narrowed the cost differences between pediatric and adult institutions, but most remained statistically significant, suggesting that the observed differences were mainly due to differences in utilization.

Table 2. Number and proportion of patients using each health care resource in adult vs pediatric institutions by phase of care

Health care resource	Prediagnosis phase (per 60 d)			Initial phase (per 360 d)			Continuing phase (per 360 d)			Terminal phase (per 360 d)		
	Adult No. (%)	Pediatric No. (%)	P*	Adult No. (%)	Pediatric No. (%)	P*	Adult No. (%)	Pediatric No. (%)	P*	Adult No. (%)	Pediatric No. (%)	P*
No. of patients in phase	691	665		652	616		585	558		107	152	
Inpatient hospitalization	48 (6.9)	99 (14.9)	<.001	478 (73.3)	586 (95.1)	<.001	201 (34.4)	241 (43.2)	.002	103 (96.3)	146 (96.1)	.93
Same-day surgery	24 (3.5)	14 (2.1)	.13	238 (36.5)	239 (38.8)	.40	177 (30.3)	204 (36.6)	.02	34 (31.8)	40 (26.3)	.34
Emergency department	158 (22.9)	254 (38.2)	<.001	319 (48.9)	412 (66.9)	<.001	405 (69.2)	380 (68.1)	.68	95 (88.8)	122 (80.3)	.07
Physician service	624 (90.3)	625 (94.0)	.01	641 (98.3)	616 (100)	.001	582 (99.5)	554 (99.3)	.66	107 (100)	151 (99.3)	.40
Diagnostic/laboratory test	492 (71.2)	521 (78.4)	.002	632 (96.9)	611 (99.2)	.004	572 (97.8)	543 (97.3)	.61	105 (98.1)	149 (98.0)	.95
Chemotherapy	0	0	–	265 (40.6)	422 (68.5)	<.001	63 (10.8)	156 (28.0)	<.001	75 (70.1)	93 (61.2)	.14
Radiation	0	0	–	19 (2.9)	110 (17.9)	<.001	7 (1.2)	22 (3.9)	.003	38 (35.5)	66 (43.4)	.20
Home care	7 (1.0)	8 (1.2)	.74	244 (37.4)	389 (63.2)	<.001	95 (16.2)	161 (28.9)	<.001	85 (79.4)	124 (81.6)	.67

P values were based on two-sided chi-square tests.

Table 3. Number of hospitalizations and length of stay by diagnosis for each phase of care

ICCC group	Phase of treatment											
	Prediagnosis (per 60 d)			Initial (per 360 d)			Continuing (per 360 d)			Terminal (per 360 d)		
	Adult	Pediatric	P*	Adult	Pediatric	P*	Adult	Pediatric	P*	Adult	Pediatric	P*
Leukemia, No.	50	126		42	107		32	96		18	39	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-0)	.04	4 (2-6)	5 (4-8)	.003	1 (0-4)	1 (0-3)	.51	6 (3-9)	4 (3-7)	.33
No. of hospitalizations, mean ± SD	0.08 ± 0.27	0.25 ± 0.53		4.10 ± 2.91	6.21 ± 4.04		2.03 ± 2.46	2.32 ± 4.49		5.56 ± 3.11	4.85 ± 3.31	
Total LOS, median (IQR)	0 (0-0)	0 (0-0)	.05	49 (23-73)	63 (36-111)	.02	3 (0-19)	2 (0-14)	.63	87 (47-126)	62 (32-164)	.91
Total LOS, mean ± SD	0.22 ± 0.91	0.64 ± 2.27		54.55 ± 43.93	77.17 ± 54.64		14.84 ± 23.80	21.40 ± 50.34		92.33 ± 67.55	96.90 ± 82.90	
Lymphoma, No.	156	238		146	228		133	213		20	31	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-0)	.37	0 (0-1)	4 (2-7)	<.001	0 (0-1)	0 (0-1)	.34	4 (2-6)	4 (3-10)	.39
No. of hospitalizations, mean ± SD	0.07 ± 0.36	0.08 ± 0.37		1.26 ± 2.64	4.47 ± 3.53		0.77 ± 1.56	1.00 ± 2.10		4.65 ± 3.63	5.84 ± 4.27	
Total LOS, median (IQR)	0 (0-0)	0 (0-0)	.39	0 (0-1)	4 (2-7)	<.001	0 (0-3)	0 (0-5)	.27	47 (20-78)	75 (17-139)	.23
LOS, mean ± SD	0.22 ± 1.29	0.26 ± 2.02		8.51 ± 21.24	30.27 ± 30.08		4.62 ± 11.96	8.06 ± 21.18		56.80 ± 48.73	86.55 ± 77.05	
CNS tumor, No.	51	83		46	76		42	68		11	20	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-0)	.78	1 (1-2)	1 (1-3)	.40	0 (0-2)	0 (0-1)	.23	4 (1-5)	2 (1-5)	.42
No. of hospitalizations, mean ± SD	0.20 ± 0.40	0.27 ± 0.56		2.15 ± 2.51	2.46 ± 3.31		1.24 ± 1.87	0.85 ± 1.68		4.00 ± 3.03	3.35 ± 3.18	
Total LOS, median (IQR)	0 (0-0)	0 (0-0)	.89	8 (4-14)	11 (6-31)	.06	0 (0-9)	0 (0-5)	.37	31 (9-73)	46 (10-68)	.82
LOS, mean ± SD	0.71 ± 1.70	0.86 ± 2.25		20.15 ± 35.23	24.49 ± 30.48		6.31 ± 10.37	6.43 ± 15.32		44.36 ± 39.22	55.00 ± 61.93	
Bone and soft tissue sarcoma, No.	99	102		88	92		75	77		38	47	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-0)	.13	7 (1-13)	14 (4-19)	<.001	1 (0-2)	1 (0-4)	.15	8 (4-11)	5 (2-9)	.13
No. of hospitalizations, mean ± SD	0.08 ± 0.27	0.17 ± 0.42		7.43 ± 6.99	12.38 ± 7.89		2.05 ± 3.54	3.12 ± 4.87		7.82 ± 5.15	6.32 ± 5.30	
Total LOS, median (IQR)	0 (0-0)	0 (0-0)	.15	36 (5-76)	80 (26-113)	<.001	2 (0-12)	4 (0-19)	.22	46 (23-65)	32 (9-77)	.45
LOS, mean ± SD	0.52 ± 3.11	0.46 ± 1.34		44.61 ± 42.05	74.79 ± 52.82		11.01 ± 19.31	17.08 ± 28.68		46.55 ± 27.89	51.00 ± 50.01	
Germ cell tumor, No.	109	52		107	50		97	45		7	7	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-1)	<.001	1 (1-2)	4 (2-7)	<.001	0 (0-1)	0 (0-1)	.42	3 (0-7)	5 (4-7)	.30
No. of hospitalizations, mean ± SD	0.10 ± 0.33	0.40 ± 0.69		1.64 ± 1.84	4.48 ± 3.17		0.81 ± 2.17	0.62 ± 0.94		3.71 ± 3.45	6.57 ± 5.38	
Total LOS, median (IQR)	0 (0-0)	0 (0-2)	<.001	5 (2-10)	28 (6-51)	<.001	0 (0-3)	0 (0-4)	.42	31 (0-63)	48 (37-114)	.11
LOS, mean ± SD	0.17 ± 0.70	1.33 ± 2.88		8.17 ± 9.66	33.64 ± 29.64		4.44 ± 13.68	4.13 ± 11.69		32.14 ± 26.79	69.29 ± 44.26	
Thyroid carcinoma, No.	123	24		123	24		117	24		-	-	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-0)	.37	2 (1-2)	2 (2-2)	.50	0 (0-1)	0 (0-1)	.73	-	-	
No. of hospitalizations, mean ± SD	0.03 ± 0.18	0.00 ± 0.00		1.79 ± 0.84	1.92 ± 0.65		0.46 ± 0.91	0.58 ± 1.06		-	-	
Total LOS, median (IQR)	0 (0-0)	0 (0-0)	.37	6 (3-8)	6 (5-8)	.56	0 (0-2)	0 (0-3)	.68	-	-	
LOS, mean ± SD	0.15 ± 1.21	0.00 ± 0.00		5.86 ± 3.34	6.21 ± 2.34		1.53 ± 3.49	2.13 ± 3.99		-	-	
Other cancer, No.	103	40		100	39		89	35		13	8	
No. of hospitalizations, median (IQR)	0 (0-0)	0 (0-0)	.001	1 (0-1)	1 (1-5)	<.001	0 (0-1)	0 (0-1)	.02	2 (1-3)	4 (3-6)	.05
No. of hospitalizations, mean ± SD	0.05 ± 0.22	0.28 ± 0.55		0.94 ± 1.26	3.13 ± 3.69		0.63 ± 1.53	1.51 ± 2.99		2.31 ± 1.55	3.88 ± 1.73	
Total LOS, median (IQR)	0 (0-0)	0 (0-0)	.002	2 (0-7)	13 (3-34)	<.001	0 (0-1)	0 (0-4)	.03	16 (5-40)	52 (11-66)	.26
LOS, mean ± SD	0.22 ± 1.17	0.85 ± 1.90		5.16 ± 8.46	24.67 ± 41.25		3.21 ± 8.53	8.37 ± 21.46		34.62 ± 48.02	55.75 ± 58.64	

*P values for were based on independent samples t test for means, and nonparametric Kruskal-Wallis test for medians. All tests were two-sided. CNS = central nervous system; ICCC = International Classification of Childhood Cancer; IQR = interquartile range; LOS = length of stay.

Figure 1. Mean number of emergency department visits by diagnosis for each phase of treatment. CNS = central nervous system.

Discussion

This population-based study of 1356 adolescents treated over a 15.5-year period revealed that patients treated in pediatric centers used more health care resources and incurred higher costs than those treated in adult centers.

More than 95% of adolescents treated in pediatric centers were hospitalized during the initial phase, compared with 73% of those treated in adult centers. Similarly, the proportions of patients hospitalized during the prediagnosis and continuing phases were higher in pediatric institutions. Some of the observed differences in hospitalization could be due to differences in cancer type. Most patients with leukemia and lymphoma, which can lead to immune system dysfunction and admissions for fever or infection, were treated in pediatric institutions. Most patients with germ cell tumors and thyroid cancers, which may be treated by surgery alone or with less myelosuppressive chemotherapy (40–42), were treated in adult institutions. To address these differences, we conducted analyses stratified by diagnostic category; these revealed persistent differences in hospitalizations and ED visits between treatment loci. Despite no differences in the distribution of ALL vs other leukemias or in total white blood cell count in those with ALL, adolescents treated for leukemia in pediatric centers were more likely to be hospitalized during the initial phase and spent an average of 22 more days in the hospital during that period than those treated in adult centers. Pediatric centers frequently use more intensive therapies for leukemia than adult centers. A Dutch study (42) demonstrated that adolescents treated for ALL on a pediatric trial received an extra course of therapy, a longer duration of

maintenance therapy, and shorter intervals between courses (one week vs up to four weeks) compared with adolescents treated on an adult trial (11). Similarly, adolescents treated according to the French FRALLE-93 pediatric protocol received higher doses of several chemotherapies and had shorter intervals between courses compared with adolescents treated on the adult LALA-94 trial (10). In both cases, the pediatric trials afforded better survival.

Adolescents with sarcomas treated in pediatric centers also had more hospitalizations and longer lengths of stay despite similar distributions of localized vs metastatic disease at diagnosis. In a previous study, pediatric patients with Ewing sarcoma received more cycles of chemotherapy (median of 16 vs 10) and higher cumulative doses of alkylating agents than adult patients (14), and had better survival (three-year EFS 70% vs 43%), which the authors attributed to differences in treatment intensity. Beyond therapeutic intensity, adult and pediatric centers may differ in care philosophy regarding in-hospital vs outpatient chemotherapy, inpatient vs outpatient treatment of febrile neutropenia (43), or their threshold for hospital admission in general.

Differences in hospitalization during the initial phase were reflected in marked differences in median costs for each diagnostic category. During the initial phase, leukemia treatment in a pediatric center cost \$51 000 more than in an adult center. The cost differential for sarcoma was more than \$127 000. The use of higher CPWCs for pediatric centers contributes to some of this difference. However, our sensitivity analysis indicated that factors such as higher resource use and longer hospital stays are also important drivers of costs.

Figure 2. Median standardized total cost in each care phase by diagnosis and locus of care. CAD = Canadian dollar; CNS = central nervous system.

Utilization of health care resources in the terminal phase did not differ between institution type, although costs were generally higher in pediatric institutions. Ninety-six percent of patients who died during or within one year after the study were hospitalized during the terminal phase, and more than 80% visited an ED. Patients with leukemia spent, on average, more than 90 of their last 360 days of life in the hospital, and patients in most other diagnostic groups had a median length of stay of at least one month, regardless of where care was received. Prior research has shown that adolescents and young adults with terminal cancer are likely to receive intensive end-of-life care such as chemotherapy, emergency room visits, or intensive care unit admission (44). These rates exceed benchmarks advocated in older adults (45).

This study has numerous strengths. It includes a population-based cohort of adolescents treated in Canada's most populous province. Given Ontario's publicly funded health care system, we captured all care encounters, a considerable strength compared with studies that have focused on single institutions, small jurisdictions, or limited types of health care resources (46–51). We believe that our findings of higher utilization in pediatric cancer centers than adult cancer centers are generalizable to other jurisdictions, even those without universal health insurance, as the lack of uniformity in the location of adolescent cancer care is a global challenge (52).

This study should be interpreted in the context of several limitations. First, we could not capture psychosocial services (eg, psychology, social work), all outpatient medications, and complementary and alternative medicine because they are not covered by Ontario's public health care plan. Second, although

we explored the possibility of employing multivariable modeling techniques, given the small sample sizes within individual diagnostic categories and the many relevant risk factors that would need to be included in the model, we were not able to undertake this type of analysis. Nonetheless, descriptive cost studies can provide important input to inform health care planning. Finally, we could only compare stage at diagnosis between care loci for some of the cancer diagnoses and therefore cannot conclude definitively that differences in utilization and cost for other diagnoses were not driven in part by differences in the stage of disease treated at different institution types.

In summary, we demonstrated that for most health care resources, and across most types of cancer, adolescents treated in pediatric centers have higher resource utilization than those treated in adult centers, except during the terminal phase of care. The higher utilization, particularly for hospitalization, translates into substantially higher costs of care in pediatric centers, although some of these differences are a consequence of the higher CPWC for pediatric institutions. As the adolescent and young adult cancer care system evolves, clinicians and policy-makers must consider the higher costs of care in pediatric centers in the context of survival and other health outcomes, acceptability to patients and families, accessibility, and equity.

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