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Surgical intervention in pediatric trauma at a level 1 trauma hospital: a retrospective cohort study and report of cost data

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Background: Given that the management of severely injured children requires coordinated care provided by multiple pediatric surgical subspecialties, we sought to describe the frequency and associated costs of surgical intervention among pediatric trauma patients admitted to a level 1 trauma centre in southwestern Ontario.

Methods: All pediatric (age < 18 yr) trauma patients treated at the Children's Hospital — London Health Sciences Centre (CH-LHSC) between 2002 and 2013 were included in this study. We compared patients undergoing surgical intervention with a nonsurgical group with respect to demographic characteristics and outcomes. Hospital-associated costs were calculated only for the surgical group.

Results: Of 784 injured children, 258 (33%) required surgery, 40% of whom underwent orthopedic interventions. These patients were older and more severely injured, and they had longer lengths of stay than their nonsurgical counterparts. There was no difference in mortality between the groups. Seventy-four surgical patients required intervention within 4 hours of admission; 45% of them required neurosurgical intervention. The median cost of hospitalization was $27 571 for the surgical group.

Conclusion: One-third of pediatric trauma patients required surgical intervention, of whom one-third required intervention within 4 hours of arrival. Despite the associated costs, the surgical treatment of children was associated with comparable mortality to nonsurgical treatment of less severely injured patients. This study represents the most recent update to the per patient cost for surgically treated pediatric trauma patients in Ontario, Canada, and helps to highlight the multispecialty care needed for the management of injured children.

Contexte : La prise en charge des enfants grièvement blessés nécessite la coordination des soins fournis dans le contexte de plusieurs surspécialités chirurgicales pédiatriques. Dans ce contexte, nous avons cherché à décrire la fréquence et les coûts des interventions chirurgicales chez les patients pédiatriques victimes de trauma admis dans un centre de traumatologie de niveau 1 dans le sud-ouest de l'Ontario.

Méthodes : Tous les patients pédiatriques (moins de 18 ans) ayant subi un trauma traités à l'Hôpital pour enfants du Centre des sciences de la santé de London entre 2002 et 2013 ont été retenus pour l'étude. Nous avons comparé les caractéristiques démographiques et les résultats cliniques des patients ayant subi une intervention chirurgicale et de ceux n'en ayant pas subi. Les coûts d'hospitalisation n'ont été calculés que pour le premier groupe.

Résultats : Parmi les 784 enfants à l'étude, 258 (33 %) avaient eu besoin d'une intervention chirurgicale; 40 % de ceux-ci avaient subi des interventions orthopédiques. Ces patients étaient plus âgés et plus grièvement blessés que les enfants n'ayant pas subi d'intervention chirurgicale, et leur séjour à l'hôpital était généralement plus long. Nous n'avons relevé aucune différence entre les 2 groupes quant à la mortalité. En outre, 74 des patients ayant subi une intervention chirurgicale ont dû être opérés dans les 4 heures suivant l'admission; 45 % d'entre eux ont eu besoin d'une intervention neurochirurgicale. Le coût médian d'une hospitalisation était de 27 571 $.

Conclusion : Le tiers des patients pédiatriques victimes de trauma ont eu besoin d'une intervention chirurgicale, et le tiers de ceux-ci ont dû être opérés dans les 4 heures suivant leur arrivée. Malgré les coûts, le traitement chirurgical des enfants était associé à un taux de mortalité comparable à celui du traitement non chirurgical des patients blessés moins grièvement. Cette étude est la source d'information la plus récente sur le coût par patient associé au traitement chirurgical des enfants victimes de trauma en Ontario, et elle met en évidence le besoin de soins de multiples spécialités.

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Trauma continues to be the leading cause of death and disability in children and teenagers younger than 15 years in Canada and the United States.[1,2] The management of injured children continues to evolve, with the establishment of level 1 pediatric trauma centres[3] and centralization of care with involvement of multiple disciplines.[4,5] Given that the management of severely injured children requires coordinated care provided by multiple pediatric surgical subspecialties,[2,5,6] we sought to describe the frequency, timing, associated costs and surgical subspecialties involved in the management of pediatric trauma patients at a regional lead trauma hospital in Canada.

It has been more than a decade since the cost of trauma care for children in Ontario has been profiled in the literature,[7] and to our knowledge a report on the costs of strictly surgically managed patients has never been performed in Ontario. The field of pediatric trauma care has evolved substantially over this timeframe, with rising medical costs and advancements in technology swaying trauma care in favour of nonsurgical management. As a result, the findings from this study can act as a timely update that will help us to better understand both human and financial resource planning for surgical management in pediatric trauma.

Methods

After receiving approval from our institutional review board, we retrospectively reviewed our trauma registry for all pediatric (age < 18 yr) trauma patients treated at the Children's Hospital — London Health Sciences Centre (CH-LHSC) between April 2002 and March 2013. The CH-LHSC is a tertiary-care university-affiliated hospital and a Trauma Association of Canada (TAC)–certified level 1 pediatric trauma centre in southwestern Ontario.[8] The CH-LHSC serves a geographic area of 19 000 km^2 with a pediatric population of more than 400 000.

Data were obtained from the CH-LHSC trauma registry. Data are prospectively collected and entered into the registry by experienced data analysts and undergo institutional and provincial quality reviews. Data obtained included age, sex, mechanism, intensive care unit (ICU) admission, injury severity score (ISS), Maximum Abbreviated Injury Scale (MAIS) score by body region and need for operative intervention. Patients undergoing surgical interventions were grouped according to the timing of their initial operation from the onset of admission to CH-LHSC: within 4 hours, 4–24 hours, and after 24 hours. These intervals were based on a previous study describing the timing of surgical intervention most likely to influence outcome in pediatric trauma.[1] Surgical procedures were identified using the Canadian Classification of Health Interventions, Tabular List (2003, 2006, 2009, and 2012 versions). For patients undergoing multiple surgical interventions either in a staged or concurrent fashion, the specialty performing the first operation was assigned as the most responsible surgical subspecialty (MRS).

Although the primary outcome in our study was mortality, we also examined secondary outcomes, including length of hospital stay, discharge disposition and in-hospital costs.

Owing to the availability of costing data, only patients treated between April 2011 and March 2013 were included for the cost report. The costing was calculated based on the Ontario Case Costing Initiative (OCCI) methodology,[9] which is a standardized process. We used a top–down approach when calculating each component cost that used both direct costs from patient charts when available and average values for such components as workload and supplies per patient when direct measures were not available. The total cost of patients' initial hospitalization was calculated as the sum of the direct labour, direct overhead, and fixed indirect and variable direct material (general supplies as well as patient-specific supplies) costs. These include labour costs supporting direct patient care, such as physician and nurse salaries; maintenance costs supporting direct patient care activities; fixed operating expenses from overhead functional centres, including administrative and human resources; and general and clinical supply costs. Monetary values are rounded to the nearest Canadian dollar.

Statistical analysis

Continuous data are expressed as medians and interquartile ranges (IQR), and categorical variables are reported as frequencies and percentages. We used the Shapiro-Wilk test to assess normality. Continuously distributed variables were compared using the independent samples t test or the Mann–Whitney U test if the data were not normally distributed. We used the Pearson χ^2 test to assess significance of categorical variables. We performed our statistical analyses using SPSS Statistics software version 23 (IBM Corp.). We considered results to be statistically significant at $p < 0.05$.

Results

There were 784 pediatric trauma patients admitted to CH-LHSC between Apr. 1, 2002, and Mar. 31, 2013, and 258 (33%) required surgical management (Table 1). These data were not normally distributed, therefore we used the Mann–Whitney U test to determine significance for continuous variables. The surgical cohort was older than the nonsurgical cohort (median 15 [IQR 10.0–17.0] yr v. median 12 [IQR 6.0–16.0] yr, $p < 0.001$), but the sex distribution between the 2 groups was similar ($p = 0.88$).

Motor vehicle collisions were the most common mechanism of injury in our study (Table 1); they accounted for a higher proportion of injuries among surgical patients than nonsurgical patients (69% v. 53%, $p < 0.001$). Conversely,

falls were more common among the nonsurgical group (27% v. 9%, $p < 0.001$). There were twice as many penetrating traumas in the surgical group (4% v. 2%, $p = 0.005$). Additionally, the surgical cohort had a higher median ISS than the nonsurgical group (25 v. 17, $p < 0.001$). There were no differences between the groups with respect to presence of tachycardia, hypotension, or neurologic status (as defined by the Glasgow Coma Scale [GCS]) on arrival to the trauma centre.

Our primary outcome was similar between the groups (Table 1); mortality in the surgical and nonsurgical groups was 5% and 7%, respectively ($p = 0.21$). However, the surgical cohort had a significantly longer median length of stay (LOS) in hospital than the nonsurgical group (median 9 [IQR 5–19] d v. median 5 [IQR 3–9] d, $p < 0.001$) as well as double the LOS in the special care unit (median 4 [IQR 1–9] d v. median 2 [IQR 1–4] d, $p < 0.001$). Additionally, fewer patients in the surgical group than in the nonsurgical group were discharged home (54% v. 70%, $p < 0.001$). Instead, a higher proportion of surgical patients were discharged home with support services (24% v. 16%, $p = 0.004$) or to a rehabilitation centre (14% v. 4.5%, $p < 0.001$).

Of the 258 patients who underwent surgical intervention, 74 (29%) patients were taken to the operating room (OR) within 4 hours, 90 (35%) between 4 and 24 hours, and 94 (36%) after 24 hours from arrival (Fig. 1 and Appendix 1, Table S1, available at canjsurg.ca/009817-a1). In our study, 30% of patients who sustained penetrating trauma underwent surgical intervention within 4 hours, whereas 10% of those who sustained blunt trauma patients were taken to the operating room within that same time frame. The pediatric orthopedic surgical service performed

Table 1. Clinical characteristics and outcomes of 784 pediatric trauma patients treated at Children's Hospital — London Health Sciences Centre between 2002 and 2013

Characteristic	Group; median (IQR) or no. (%)		*p* value
	Surgical (*n* = 258)	Nonsurgical (*n* = 526)	
Median age, yr	15 (10–17)	12 (6–16)	< 0.001
Male sex	176 (68.2)	356 (67.7)	0.88
Direct presentation to CH-LHSC	87 (33.7)	184 (35.0)	0.73
Injury type			
Blunt	243 (94)	511 (97)	0.042
Penetrating	10 (3.9)	5 (1.0)	0.005
Burn/other	5 (1.9)	10 (1.9)	0.97
Mechanism of injury			
Motor vehicle collision	170 (69.4)	259 (53.2)	< 0.001
Falls	23 (9.4)	131 (26.9)	< 0.001
Burn	7 (2.9)	14 (2.9)	0.97
Crush injury/cut or bite injury	28 (11.4)	43 (8.8)	0.23
Nonaccidental trauma	16 (6.5)	34 (7.0)	0.28
Other/unspecified	1 (0.4)	6 (1.2)	0.038
Median injury severity score	25 (16–34)	17 (16–26)	< 0.001
Outcome			
Death	13 (5.0)	39 (7.4)	0.21
Median hospital length of stay	9 (5–19)	5 (3–9)	< 0.001
Discharge disposition			
Home	131 (53.5)	343 (70.4)	< 0.001
Home with support services	60 (24.5)	78 (16.0)	0.004
Another acute care facility	15 (6.1)	26 (5.3)	0.61
Rehabilitation Facility	34 (13.9)	22 (4.5)	< 0.001
Other/CAS	5 (2.0)	18 (3.7)	0.25

CAS = Children's Aid Society; CH-LHSC = Children's Hospital — London Health Sciences Centre; IQR - interquartile range.

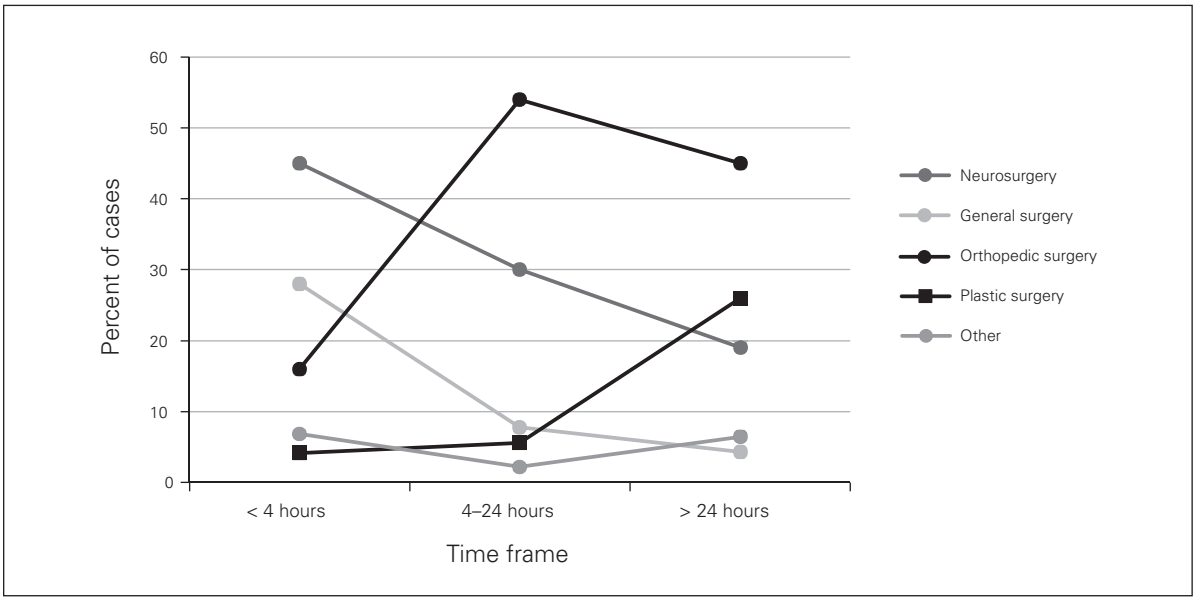

Fig. 1. Time to operative intervention by pediatric surgical subspecialties for pediatric trauma patients admitted to Children's Hospital — London Health Sciences Centre (CH-LHSC) between 2002 and 2013. Other pediatric surgical subspecialties include urology, thoracic surgery, cardiac surgery and vascular surgery.

the most operations (103 [40%] of all 258 operations), although they were more likely to perform interventions more than 4 hours after admission (Fig. 1). Neurosurgical interventions were the most common operations performed among the 74 patients undergoing surgery within 4 hours after admission (45% of cases in this time frame), followed by pediatric general surgery (28% of cases within the time frame). Orthopedic surgery (16%) was the only other subspecialty that was responsible for more than 10% of the surgical pediatric trauma population within 24 hours of admission (Fig. 1 and Appendix 1, Table S1).

We evaluated the hospitalization costs associated with 29 surgical pediatric trauma patients admitted to CHLHSC between April 2011 and March 2013 (Table 2) for which costing data were available. The median total cost was $ CAD 27 571 (range $4933–$226 374, IQR $34 003–$56 671). Direct labor costs (median $14 107) and fixed indirect costs (median $5866) accounted for the greatest proportion of costs in the treatment of surgical pediatric patients.

Discussion

The management of critically injured pediatric trauma patients requires carefully coordinated multidisciplinary care provided by multiple pediatric surgical subspecialties,[1,6,7] especially when multiple interventions are required. In this single-centre retrospective study, we showed that 33% of pediatric trauma patients underwent surgery during their admission. Although these patients were more severely injured than their nonsurgical counterparts, the mortality in both groups was similar. Moreover, 40% of patients undergoing surgery required orthopedic interventions, although patients requiring surgery within 4 hours after their admission most frequently required a neurosurgical procedure. Additionally, we showed that the median cost of hospitalization for pediatric trauma patients undergoing a surgical intervention was $CAD 27 571. Our study did not compare costing data between trauma patients undergoing surgical and nonsurgical interventions. But by comparing our median cost per patient to that reported in a study by Dueck and colleagues[7] ($2666 per pediatric trauma patient in Ontario between 1991 and 1997), our median value per patient is much higher, even when accounting for inflation costs between the 2 studies ($2666 in 1991 is equivalent to $3945 in 2013 based on 48% inflation, as per the Bank of Canada).[10] Furthermore, the cost values from the study by Dueck and colleagues[7] may be even lower if their sample contained only nonsurgically managed patients. As a result, this further emphasizes the greater cost associated with a pediatric trauma patient undergoing surgery.

The results of our study parallel those of Acierno and colleagues,[1] who observed that almost 31% of pediatric trauma patients in an American trauma registry needed surgery during their admission. Unlike patients in the present study, however, almost 57% of surgically treated patients required intervention emergently.[1] The substantially higher proportion of penetrating trauma in the United States likely explains this difference, as it is an independent predictor of the need for emergent surgical intervention.[1] Although we observed that a significantly higher proportion of penetrating trauma than blunt trauma required surgery, there was no statistically significant difference with respect to patients requiring emergent surgery within 4 hours after admission because of the limited volume of penetrating injuries. In an older Canadian study that mirrors our current experience, Singh and colleagues[11] showed that 41% of injured children required surgery, with 11% requiring urgent surgery within 2 hours of arrival, whereas an older retrospective study showed a lower rate of surgical intervention (21%) in more than 87 000 patients over a 14-year period.[12] Although the need for surgical intervention among children remains lower than that in the adult trauma population,[13,14] these results nevertheless collectively show a continued need for committed involvement by pediatric surgical specialties during the resuscitation and treatment of injured children.

With respect to hospital costs, Dueck and colleagues[7] observed that the mean cost was $CAD 7582 (median $2666) for pediatric trauma patients, with the presence of extremity injuries exhibiting a significant positive correlation with costs. However, that study did not include costs associated with nursing and included both surgical and nonsurgical patients. In a systematic review of cost-utilization studies in trauma (adult and pediatric), Willenberg and colleagues[15] reported a median per-patient cost of $22 448 for the treatment of acute trauma. Despite the variability among the studies included in the review, the presence and type of surgery[16,17] and higher ISS[7]

Table 2. Cost of treatment for patients requiring surgery between April 2011 and March 2013, in Canadian dollars and rounded to the nearest dollar

Factor	Direct labour	General supplies	Patient-specific supplies	Direct overhead cost	Fixed indirect cost	Total cost
Median	14 107	2889	145	2936	5866	27 571
IQR	19 960–33 267	3020–4464	640–1067	3602–6004	6613–11 021	34 003–56 671
Total	723 625	113 370	17 919	148 757	286 802	1 290 474

IQR = interquartile range.

independently predicted increased cost. The higher hospitalization costs observed in our study, therefore, are not surprising, given that we focused on surgical trauma patients, who had higher ISS than their nonsurgical counterparts. A possible explanation for the higher costs in our surgical population compared with the mixed population in the study by Dueck and colleagues[7] may be the need for surgical intervention, increased length of hospital stay and need for additional services and resources following discharge. The difference in cost per patient between our study and the study by Dueck and colleagues[7] has important implications with respect to health care resource management, both during the acute trauma treatment as well as postdischarge care, for which further investigation is needed to elucidate the true cost of care in pediatric trauma.

Limitations

Our study is limited by selection bias owing to its retrospective nature, especially given the statistically significant differences in injury severity and mechanism of trauma between the surgical and nonsurgical cohorts. A larger multi-institutional study incorporating propensity-matched analyses may allow for more rigorous comparison between the 2 groups. In addition, the unavailability of cost data for nonsurgical trauma patients precludes comparison of resource utilization in our study, but provides the basis for future investigations, particularly in the postdischarge phase of trauma care.

Conclusion

The results of our study emphasize the multispecialty care needed for the management of injured children and show the continued need for pediatric surgical involvement in all phases of trauma care. Additionally, this study provides a more reliable estimate of the costs involved in the hospitalization of injured children and provides the basis for future investigations into health care resource utilization during all phases of pediatric trauma care.

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Contributors: N. Merritt designed the study. All authors acquired and analyzed the data, wrote and reviewed the article, and approved the final version for publication.

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