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Complications and costs of management of acute spinal cord injury

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This study examined the complications and costs of management of patients with acute spinal cord injury (ASCI) in a regional, multidisciplinary acute spinal cord injury unit (ASCIU). Data were available to compute length of stay (LOS) on 191 of the first 220 consecutive patients managed in this unit from 1974 to 1981. Specific formulae for assessing hospital and medical costs were developed based on a systems analysis approach. The statistical analysis included multiple regression analysis for determining the effect of the principal admission characteristics of ASCI patients, the main types of complications, and the methods of management. The effects of these variables on LOS, costs per day (CPD), and costs per stay (CPS) were determined.

Age at admission, sex, and cause of accident had no effect on costs. As expected, increasing severity of injury to the spinal cord and to the vertebral column caused a significant increase in the mean LOS and CPS, and increasing total trauma load resulted in a significant increase in LOS and CPS. The LOS was shorter for patients admitted sooner after trauma. Respiratory, gastrointestinal, thromboembolic and genitourinary complications and decubitus ulceration were all associated with marked increases in LOS and CPS. The annual mean CPS decreased dramatically during the period of the study from 1974–81 due mainly to a decrease in LOS. Multiple regression analysis showed that severity and level of the spinal column and spinal cord injury, and the presence of complications had the most significant effects on duration and cost of care. The study also suggests that a specialized, multidisciplinary regional unit for ASCI patients is associated with a reduction in LOS and cost of care.

Keywords: spinal cord injury; cost of care; length of stay; complications.

Introduction

The financial cost of caring for patients with acute spinal cord injury (ASCI) is enormous. For example, in 1975 Kraus *et al*[1] estimated an 'annual cost to the United States for support and treatment of all persons with a spinal cord injury of two billion dollars', and in 1990 Stripling[2] estimated that this figure had risen to four billion dollars annually. Management of spinal cord injured patients can be divided into three phases, each of which entails specific costs. The initial phase includes evacuation from the accident scene to an acute care institution and hospital care until discharge from the acute care institution(s). The costs in this phase include resuscitation, transportation, acute medical and/or surgical management and initial rehabilitation. The second or rehabilitation phase includes the costs of therapy, counselling, treatment of medical complications and continuing hospitalization if required. The third or community phase may involve costs for vocational, home and social support in addition to continuing medical or surgical care. Return to a previous phase may be required

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due to complications. Mildly injured patients may require only acute care, while those with severe injuries may require lifelong hospitalization.

In most countries there is now a trend for patients with an acute, traumatic spinal cord injury to be cared for in a regional, specialized unit in one or both of the acute and rehabilitation phases of care. Where the acute and rehabilitation facilities are in different institutions, the costs of care for each phase can be readily identified. For patients included in the present study, the acute spinal cord injury unit (ASCIU) at Sunnybrook Medical Centre, Toronto, provided the acute care while rehabilitation was undertaken at Lyndhurst Hospital, Toronto. The present study examined the cost of acute care defined as the cost incurred between admission and first discharge from the ASCIU. The purpose of the study was to analyze the factors influencing cost, especially complications and the effect of treatment in a regional, specialized unit. Costs incurred prior to admission to the unit were not included. Although there have been other studies of the cost of acute care of patients with ASCI,[3–5] the present report is unique in that it computes the cost in a population treated in an ASCIU and measured yearly after the initiation of the unit. It is also the first paper to systematically analyze the effect of the complication rate on the length of stay and costs of care.

Patients and methods

Study population

The first 220 consecutive patients admitted to the ASCIU, Sunnybrook Medical Centre, Toronto, from the time of its establishment in 1974 to 1981, were considered for entry into this study. Nineteen patients were excluded because they had been admitted more than 30 days after injury, or had received definitive management of their spinal injury at another institution prior to transfer to the unit. Not considered for inclusion were patients treated in the ASCIU with injuries involving the vertebral column or spinal nerve roots without injury to the spinal cord, patients wtih injuries below L2 and one patient with a gunshot wound. In all, 201 patients with closed spinal cord injury were included in the present study.

Admission variables

Information on each patient was gathered prospectively and included 11 admission variables: age, sex, presence and type of preexisting spinal abnormalities, type of accident causing the injury, delay between the accident and admission to the unit, the level and type of injury to the vertebral column, the level and severity of the cord injury, and the anatomical location and severity of nonspinal injuries. For classification of the severity of the cord injury, the 10 point spinal cord injury severity scale[6] was used: grade 1—complete cord injury with no preservation of voluntary motor or sensory function below the level of the lesion; grades 2–9—decreasing degrees of incomplete cord injury (a grade 7 patient has sufficient strength to walk); and grade 10—normal motor and sensory function. Patients graded 10 on admission usually had cord concussion with neurological deficits which resolved during the interval between the accident and admission to hospital. Injuries to the vertebral column were classified into five main types according to a previously published method.[7] When radiological studies failed to show any evidence of spinal trauma, the designation was 'normal' even with a preexisting condition such as cervical spondylosis. Injuries to other body regions were assessed by an anatomical injury severity score based on that of Baker *et al*[8] to quantify the total trauma burden. Spinal and nonspinal injuries were recorded for each patient and an injury severity score (ISS) was calculated based on the method described by Greenspan *et al*.[9]

Analysis of complications

Five groups of complications were analyzed. A respiratory complication was defined as one episode of atelectasis, pneumonia, aspiration pneumonitis or severe respiratory insufficiency. A thromboembolic complication was one episode of either iliofemoral

thrombosis or pulmonary embolism. Complications affecting the gastrointestinal tract were either stress ulceration leading to clinically observed gastrointestinal hemorrhage or prolonged paralytic ileus which delayed institution of enteral feeding. Genitourinary complications included acute infectious episodes such as bacteriuria associated with pyrexia, pyelonephritis or acute epididymo-orchitis. Pressure sores were defined as significant erythema, or deeper skin involvement at a pressure point, although depth and anatomic location were not distinguished in the present analysis. A complication score was calculated for each patient by adding a single point for the first episode of a complication in each of the five complication categories to a maximum total of five points. Recurrent complications in a given category were not included.

Analysis of treatment

Patients were divided into two groups depending on whether or not surgery was used for treatment of the spinal cord injury. Surgery included procedures for operative decompression, reduction or fusion or combinations. Management in the halo vest was not considered surgical treatment. An analysis of the results of surgical versus conservative management in the ASCI group has been reported previously.[10] Non-spinal surgery such as for genitourinary complications was not included.

Cost analysis

The ease of obtaining cost data varies with the system of payment for healthcare costs in a given location. Where there is itemized billing for each patient for drugs, equipment, hospital and physician services, the cost of treatment for an individual patient is more readily available.[3,5] Conversely, in a system where most or all of the costs are paid by a centralized government agency, records of usage of equipment or services may not be kept for individual patients, and thus determining the cost of management for an individual patient may be more difficult. In the province of Ontario, government medical insurance pays for hospital expenses, without direct patient invoicing for such items as drugs, hotel costs, operating room expenses, physiotherapy and occupational therapy, while other costs such as physician fees and some equipment charges are billed individually according to a schedule of fees. Because of the lack of direct accounting of all individual patient costs, it was necessary to develop a cost analysis system. CSF Ltd, of Ann Arbor, Michigan, a systems analysis consulting firm, was contracted to produce a model for determining the cost of care for patients in the ASCIU. The model included a system for assessing the medical, nursing and rehabilitation service costs and also the facility, equipment and supply expenses for each patient.

The cost analysis system involved four steps: (1) the segregation of costs into two broad categories: hospital costs and physician costs; (2) the identification of cost components for each of these two categories; (3) a review of data availability for each cost component; and (4) the development of a cost equation for each category.

Hospital costs The components included in the hospital costs formula were labor, equipment, supplies and facilities. It was necessary to determine whether each component varied for ASCI patients as compared to the 'average' patient, and whether the data quantifying that component were readily available. For example, with respect to labor, it was recognized that ASCI patients required more nursing hours per patient than most patients. Conversely, it was concluded that costs for facilities, equipment and supplies for ASCI patients did not differ significantly from the average patient. For example, specialized equipment regularly in use for ASCI patients such as halo devices[11] and ripple mattresses were not excessively expensive and were usually reused. Thus, for hospital costs, the difference in labor costs was identified as the major factor influencing costs for ASCI patients.

Four categories of personnel were identified for specific quantification of labor costs: ward nurses, radiology department staff, operating room staff and staff in the physiotherapy and rehabilitation services. To obtain the nursing costs for ASCI patients,

CSF Ltd performed a detailed analysis of nursing activities in the neurosurgical intensive care unit (NICU) and the neurosurgical ward nursing unit (NNU). It should be noted that the NICU did not admit patients requiring mechanical ventilation. It was calculated that 6 hours of nursing care per patient per day was required for the NICU and 4 hours per day for the NNU. These figures are comparable to those obtained by Bugaresti *et al*[12] from the study institution. With a knowledge of the nursing hourly wage and the LOS in the two locations, the total nursing cost for each ASCI patient and the mean nursing cost per patient per day were derived. A similar calculation was performed to determine the daily nursing costs for an average nonASCI patient. Similar calculations were made for other nonphysician labor costs for diagnostic radiology (as cost per examination), operating room procedures (as cost per procedure), and physiotherapy and rehabilitation services (as cost per attendance). From the patients' records the total number of such examinations, procedures or attendances was obtained to calculate the total cost for each category for each ASCI patient. The mean daily labor costs for these categories per ASCI patient, and the costs for an average nonASCI patient were also obtained.

Physician costs The analysis of physician costs included five major medical components: attending physicians in the ASCIU; residents and interns assigned to the ASCIU; surgeons and anesthetists performing operative procedures; nonneurosurgical medical consultations; and radiologists. Costs were calculated on the basis of the published schedule of fees on a per service basis. Data concerning rates of pay and average hours worked for interns and residents were obtained. From each patient's record the total number and cost of operative procedures, medical consultations and radiological examinations was determined for all 201 patients. With this data and LOS per patient, the mean daily cost of medical services per patient per day was calculated.

Total costs formula For each patient, the total cost per stay (CPS) was calculated by multiplying the daily hospital and physician costs by the LOS in days. In addition, for each patient, an average cost per day (CPD) was calculated by dividing the CPS by the LOS.

Data analysis

Data were coded for computer entry using standardized coding sheets and initially processed at the University of Toronto Computer Centre using the Statistical Package for the Social Sciences (SPSS) with final analysis performed using Statistical Analysis Systems software package for PC (SAS, Cary, NC, USA). Initial statistical analysis was performed using 2-tailed *t*-tests, analysis of variance (ANOVA) and linear regression analysis. Further analysis using stepwise multiple regression techniques was performed to identify statistically significant relationships between the admission and treatment variables, cost and LOS.

The period 1974–1981 encompassed by this study was characterized by high rates of inflation in Canada, and to remove the effect of inflation from the present analysis all costs were calculated in 1974 Canadian dollars. To convert the costs to 1992 Canadian or US dollars, the 1974 Canadian dollar figures should be multiplied by approximately four.

Results

Of the 201 patients entered into the study, complete data to allow calculation of costs were available in 191, and for these the average LOS was 49.8 days, the average CPD was $214 and the average total CPS was $10,035 (in 1974 Canadian dollars).

Patients who died in hospital

Fourteen patients died during the first hospitalization. These patients differed significantly in admission variables, treatment regime, LOS and cost from those surviving to first discharge. Although the sex distribution and type of accident leading to injury were similar in both groups, those dying were older, with a mean age of 57.1 years as compared to 32.7 years for the remainder of the group (2-tailed *t*-test, $p < 0.001$) and had a higher frequency of cervical injuries,

85.7% as compared to 60.5% for survivors (chi square, $p = 0.06$). While the severity of the cord injury was not significantly different in the two groups (mean cord injury severity score 2.2 and 3.4 for fatalities and survivors, respectively, (2-tailed t-test, $p = 0.073$), the ISS was increased in the fatalities (mean ISS 32.7 and 24.6 for nonsurvivors and survivors, respectively; 2-tailed t-test, $p < 0.001$). The majority of fatalities (78.6%) were treated nonoperatively, partly due to the large proportion of cervical injuries which were treated primarily with halo external stabilization (20%), whereas only 42.2% of survivors were treated nonoperatively (chi square, $p = 0.009$). The median LOS for fatalities and survivors was 21 days and 49 days, respectively. One patient, who died after a stay of 332 days, skewed the results for mean duration of stay and cost of treatment and, therefore, this atypical patient was excluded from further analysis. The mean LOS for the other 13 fatalities was 20.5 days which was significantly shorter than the mean LOS of 49.5 days for survivors (2-tailed t-test, $p = 0.0035$). For the fatalities the mean CPD was $292 as compared to $212 for the survivors, a significant difference (2-tailed t-test, $p < 0.001$). This increased CPD was mainly due to the increased use of NICU facilities by the fatalities. Indeed, 12 of the 13 fatalities were managed entirely in the NICU where the daily hospital costs were higher due to increased nursing utilization. The use of the operating room, radiology and rehabilitation facilities, on a per day basis, was similar for survivors and fatalities (2-tailed t-test, operative procedures per day, $p = 0.89$; radiology examinations per day, $p = 0.24$; and rehabilitation attendances per day, $p = 0.47$) as was the mean CPD while in the NICU (2-tailed t-test, $p = 0.15$) (Table I). However, daily medical costs were higher for the fatalities.

In summary, when compared to those discharged alive, the 14 patients who died during acute treatment were older, had more severe combined spinal and nonspinal injuries (ISS) and had a higher frequency of cervical injury. These circumstances usually resulted in nonoperative management, entirely in the NICU which resulted in increased daily costs due to increased use of nursing time but not operating room, radiology or rehabilitation facilities. However, despite the increased mean CPD, the fatalities had a lower mean CPS due to the shorter LOS. Because of these major differences between the fatalities and survivors, the former were eliminated from further analysis to allow identification of factors other than survival which influenced duration and cost of care.

Overall length of stay

For the remaining 177 patients who were alive at first discharge, the mean LOS was 49.5 days, of which a mean of 16.0 days were spent in the NICU and a mean of 33.2 days were spent in the NNU (Table I). The mean CPD and CPS for survivors to first discharge was $212 and $10,148, respectively.

Table I Summary of resource utilization for survivors and nonsurvivors

	NICU		NNU
	Survivors $n = 177$	Nonsurvivors $n = 13$	Survivors $n = 177$
Stay (mean)	16.0	20.2	33.2
Cost per day (CPD) (mean $)	212	292	212
Operative procedures/day	0.13	0.14	0.012
Radiographic exams/day	1.36	1.67	0.23
Rehabilitation visits/day	1.9	2.0	0.95
Consultations/day	0.29	0.28	0.024

NICU = Neurosurgical intensive care unit.
NNU = Neurosurgical nursing ward unit.

Sex
The mean LOS, the mean CPD and the mean CPS for female patients were all slightly lower than for males but the differences were not significant (2-tailed *t*-test, LOS, $p = 0.28$; CPD, $p = 0.13$; CPS, $p = 0.35$).

Age
LOS, CPD and CPS were examined in relation to patient age at admission and no significant relationship was identified (linear regression: LOS, $p = 0.65$; CPD, $p = 0.34$; CPS, $p = 0.60$).

Accident
The types of accident causing ASCI were categorized into five groups: motor vehicle accidents, including automobile drivers and passengers, motorcyclists, bicyclists and pedestrians; accidents during sport and recreational activities; work related accidents; accidents occurring in the home, primarily falls; and a miscellaneous group including assaults, suicide attempts and others. There were no significant differences found for LOS, CPD or CPS among the accident categories (ANOVA: LOS, $p = 0.22$; CPD, $p = 0.49$; CPS, $p = 0.31$).

Level of injury
For the majority of patients the clinical level of the ASCI was found to coincide with the most significant vertebral column lesion as defined by radiological examination. In the 13 cases in which radiological examination revealed no abnormality, the clinical level of the cord injury was used to define the injury level. Cervical injuries were the most common (60.5%) followed by thoracolumbar (21.5%) and thoracic (18.1%) injuries (Table II). Patients with injuries at the cervical level had the highest mean CPD ($216). The mean CPD decreased the more caudal the injury, a significant relationship, but there was no effect of level of injury on LOS or CPS (Table II) (ANOVA: LOS, $p = 0.94$; CPD, $p = 0.022$; CPS, $p = 0.89$).

Type of spinal column injury
Table III shows the effect of the type of bony injury on mean LOS, mean CPD and mean CPS. Patients with cord injury but without radiological evidence of trauma to the vertebral column had a shorter mean LOS, and lower mean CPD and mean CPS than those with radiological evidence of disruption of the vertebral column. There

Table II Duration and cost of care related to level of spinal cord injury ($n = 177$)

Level of injury	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
Cervical (C1–C7/T1)	107	49.9	216	10342
Thoracic (T1–T11)	32	50.1	207	9763
Thoracolumbar (T11/12–L1/2)	38	47.7	204	9926

Table III Duration and cost of care related to type of spinal column injury ($n = 177$)

Type of spinal column injury	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
Normal	12	20.7	194	4059
Dislocation only	5	41.0	207	8258
Fracture dislocation	75	59.6	212	11989
Compression fracture	11	41.6	207	8453
Burst fracture	63	44.6	216	9446
Other	11	52.1	208	10824

was a significant association between increased disruption of the spinal column and LOS which was reflected in higher CPS, but CPD was not affected (ANOVA: LOS, $p = 0.0046$; CPD, $p = 0.12$; CPS, $p = 0.0026$).

Severity of spinal cord injury

Scored on the 10 point Spinal Cord Injury Severity Scale[13] patients with more severe cord injury had significantly longer LOS and higher CPS (Table IV). Indeed, the mean LOS increased from about 30 days for patients with mild injuries (grades 7, 8 and 9) to about 60 days for patients with more severe injuries (grades 1 and 2) while mean CPS increased from about $6,000 for patients with milder injuries to about $12,000 for patients with severe cord lesions, both highly significant findings. However, severity of cord injury had no effect on CPD (linear regression: LOS, $p = 0.0066$; CPD, $p = 0.48$; CPS, $p = 0.0062$). The anomolously long mean LOS and high mean CPS recorded for patients in the grade 10 group (normal sensory and motor function) were due primarily to the effect on this small subgroup of one patient admitted with cord concussion who then deteriorated to a complete cord lesion following which he had a protracted stay due to multiple complications.

Total trauma burden (ISS)

Table V shows the relationship between the total trauma burden defined as the ISS, and the duration and cost of care. All three variables increased with increasing ISS, although the relationship was significant for only the LOS and CPS (linear regression: LOS, $p = 0.045$; CPD, $p = 0.68$; CPS, $p = 0.010$).

Table IV Duration and cost of care related to severity of spinal cord injury ($n = 177$)

Grade of cord injury[a]	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
1	82	52.6	211	10836
2	26	70.2	208	13860
3	0	—	—	—
4	12	33.7	214	7019
5	0	—	—	—
6	2	33.5	200	6569
7	41	38.2	215	7957
8	8	33.1	218	6680
9	2	20.0	199	7634
10	4	69.7	204	13750

[a]See text for description

Table V Duration and cost of care related to injury severity score ($n = 177$)

Injury severity score	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
1–10	2	3.0	206	620
11–20	72	40.2	214	8230
21–30	74	56.3	209	11356
31–40	18	61.7	208	12796
41–50	11	53.5	225	11980

Time delay to admission
Although the CPD and CPS were not significantly altered by increased delay to admission, the LOS was prolonged significantly for patients admitted later to the unit (Table VI, linear regression: LOS, $p = 0.032$; CPD, $p = 0.11$; CPS, $p = 0.14$).

Surgical treatment
Patients were classified as having surgical management if they underwent at least one spinal operation following admission to the unit. Six patients underwent a second spinal procedure but they are not differentiated in the present analysis. Nonsurgical patients were those who did not undergo spinal surgery, although they may have had other operative procedures such as tracheostomy or laparotomy.[10] The surgical group included 102 patients while the remaining 75 were treated nonsurgically. Although patients treated surgically had longer mean LOS, reduced mean CPD and higher mean CPS than those managed conservatively, these differences were not significant (2-tailed t-test, pooled variance estimate: LOS, $p = 0.26$; CPD, $p = 0.82$; CPS, $p = 0.25$).

Complications
The occurrence of any one of the five types of complication significantly increased both the mean LOS and mean CPS, approximately doubling the mean LOS with a concomitant increase in the mean CPS (Table VII). The frequency with which patients had more than one type of complication is shown in Table VIII. There was a highly significant relationship between increasing numbers of types of complications and increasing LOS and CPS while CPD was not affected (linear regression: LOS, $p < 0.001$; CPD, $p = 0.21$; CPS, $p < 0.001$).

Year of admission
Table IX details the mean LOS, mean CPD and mean CPS according to the year of admission to the unit (all calculations in terms of 1974 dollars). The CPD rose yearly from $180 in 1974 to $228 in 1981, a significant finding (linear regression, $p < 0.001$). However, the mean LOS decreased throughout the study period, from 136.7 to 34 days, as did the mean CPS, from a high of about $25,000 in the early part of the study to about $9,000 in the later years. Both changes were highly significant (linear regression: LOS, $p < 0.001$; CPS, $p < 0.001$). Further examination of LOS revealed that the decrease in overall LOS was primarily due to decreased stay in the NNU, while the time patients were in the NICU remained relatively constant throughout the study period (linear regression: duration of NICU care, $p = 0.61$; duration of NNU care, $p > 0.001$).

Further statistical analysis
Stepwise multiple regression analysis was performed with LOS, CPD and CPS as the dependent variables and age, sex, accident type, level of spinal injury, type of vertebral column injury, severity of cord injury and total trauma score (ISS) included as independent variables (Table X). The severity of cord injury (grade) was the most significant

Table VI Duration and cost of care related to time delay to admission ($n = 177$)

Interval from accident to admission (hrs)	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
0–3	47	48.1	214	10335
4–6	64	50.7	212	10385
7–12	26	44.2	210	9143
13–24	14	44.6	212	9250
25–48	10	41.5	217	8729
>48	16	66.5	202	11960

Table VII Duration and cost of care related to complications (n = 177)

Complication type	Number of patients	Mean length of stay (LOS) (days)	p	Mean cost per day (CPD) ($)	p	Mean cost per stay (CPS) ($)	p
Respiratory							
Absent	134	43.0	[c]	209	[a]	8653	[c]
Present	43	69.7		218		14809	
Thromboembolic							
Absent	148	46.0	[b]	213	[a]	9599	[a]
Present	29	67.3		202		12951	
Gastrointestinal							
Absent	166	46.5	[c]	212	NS	9557	[c]
Present	11	94.1		206		19072	
Genitourinary							
Absent	62	33.6	[c]	216	NS	7020	[c]
Present	115	58.1		209		11835	
Cutaneous							
Absent	151	44.2	[c]	212	NS	9114	[c]
Present	26	80.0		207		16155	

2-tailed t-test:
[a] $p < 0.05$
[b] $p < 0.01$
[c] $p < 0.001$

Table VIII Duration and cost of care related to number of types of complications (n = 177)

Number of types of complications	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
0	47	26.8	217	5691
1	67	44.4	211	9130
2	40	64.0	207	12889
3	16	80.9	212	16283
4	6	100.0	209	21005
5	1	72.0	208	14943

Table IX Duration and cost of care related to year of admission (n = 177)

Year of admission	Number of patients	Mean length of stay (LOS) (days)	Mean cost per day (CPD) ($)	Mean cost per stay (CPS) ($)
1974	3	136.7	180	24881
1975	9	105.1	188	19107
1976	23	44.7	198	9098
1977	27	50.1	208	10066
1978	27	47.5	207	9510
1979	26	42.2	218	9110
1980	35	49.3	218	10555
1981	27	34.0	228	7614

factor affecting LOS and CPS: both increased with increased severity of cord injury. CPD increased with the level of injury, the cost being higher with more cephalad injuries, and with increased disruption of the vertebral column.

A second multiple regression analysis was carried out with the following additional independent variables: year of admission, time interval from accident to admission to the unit, treatment (surgical or nonsurgical) and complication score (Table XI). These latter variables were included to assess the effect of the overall system of management on LOS and cost. LOS was increased by the frequency of complications (complication score) and by the delay to admission to the unit. LOS decreased during the study period. CPD was also related to the year of admission but, in contrast to LOS, CPD increased throughout the study period. CPD was also influenced by the severity of the spinal cord injury. Like LOS, CPS was increased with increased frequency of complications. However, despite the increased CPD during the study, the CPS decreased during the 1974–81 study period as shown by the association between CPS and year of admission (Table XI).

Discussion

To determine the exact costs of care for patients with ASCI would have required the costing and recording of all material and labor used during treatment, and an apportionment of the capital and services costs of the hospital. To accurately acquire all these data for a large number of patients with ASCI would have been prohibitively costly. Therefore, a systems analysis approach was used in the present study based on a

Table X Results of multiple regression analysis showing dependence of length of stay, cost per day, and cost per stay on patient admission characteristics

Rank	Length of stay		Cost per day		Cost per stay	
	(LOS)	*p*	(CPD)	*p*	(CPS)	*p*
1	Grade	0.0066	Level	0.0072	Grade	0.0062
2	–		Fracture type	0.024		

Admission variables entered:

sex; age; cause = cause of accident; level = level of spinal injury; fracture type of vertebral column injury; grade = severity of cord injury (see text); ISS = severity of combined spinal and nonspinal injuries.

Table XI Results of multiple regression analysis showing dependence of length of stay, cost per day, and cost per care on patient admission characteristics and system of management

Rank	Length of stay		Cost per day		Cost per stay	
	(LOS)	*p*	(CPD)	*p*	(CPS)	*p*
1	Comps	0.0001	Year	0.0001	Comps	0.0001
2	Year	0.0001	Grade	0.029	Year	0.0001
3	Interval	0.036	Cause	0.048		

Independent variables entered:

sex; age; cause = cause of accident; level = level of spinal injury; fracture = type of vertebral column injury; grade = severity of cord injury (see text); ISS = severity of combined spinal and nonspinal injuries; interval = delay from accident to admission; year = year of admission; comps = complication score; status = mortality at end of first hospitalization; treatment = surgical or nonsurgical.

mathematical model which was an approximation of the average cost per day of managing an average patient in the institution housing the ASCIU. Some of the assumptions and limitations of the model require examination. In the hospital cost formula the main components identified were nursing costs, and staffing for diagnostic radiology, operating rooms, and physical and rehabilitation medicine services which were calculated as an average cost per patient per 'unit' usage, the unit varying with each department. For example, for rehabilitation medicine, the unit was one attendance by an occupational or physiotherapist, either on the ward or in the department. In contrast, expenditure on facility costs, hotel and maintenance costs and therapeutic supplies such as drugs, dressings, catheters and intravenous sets, were assumed to be the same for an ASCI patient as for an average patient treated at this center. This was probably a valid assumption because during the period of this study, equipment such as automatic turning beds, which have a high capital cost, were not in regular use. Indeed, the initial cost of halo equipment, the only specialized equipment used regularly, was not high, and halos were reused. The only specific drug therapy used frequently during the study period was a high dose of a corticosteroid which was not expensive.

The nursing costs were estimated by CSF Ltd following an on-site study and an average figure for nursing hours per patient day was derived for the NICU and the NNU. Unfortunately, this method neglected any significant differences in nursing requirements between different patient categories such as cervical injuries versus more caudal injuries, but to collect the necessary data for individual patients would not have been practical. The other shortcoming in the hospital costs formula was the lack of a surcharge for the surgical intensive care unit where patients requiring mechanical ventilation or invasive monitoring were treated. This unit had higher capital costs due to the use of expensive monitoring equipment and higher personnel costs due to increased staff-to-patient ratios for both nurses and physicians. In the current study, stay in the surgical intensive care unit was included in the NICU stay, which therefore considerably underestimates the nursing care costs.

The medical costs formula allowed a better approximation of individualized costs due to the availability of data concerning items of service. The accuracy was increased by the inclusion of an estimate of the normally hidden, and often ignored, costs of junior medical staff working in the ASCIU.

A final limitation of the methods for the determination of costs is related to the presence of a 400 bed wing at Sunnybrook (total beds: 1300) for chronic domiciliary care for elderly veterans, the costs for which were included in the hospital cost formula. The admixture of these chronic care beds with lower costs than the acute care beds causes the hospital costs to be underestimated. Indeed, it was the opinion of the systems analysts (CSF Ltd), that if the costs had been based solely on acute patients, the results would have been about 30% higher. Thus, in 1974 Canadian dollars, the actual CPS considering the above two shortcomings was likely about $15,000 rather than $10,035, the calculated figure. The CPS in 1992 Canadian or US dollars would be approximately $60,000.

Despite these limitations, the current method was very useful for determining the effect of many patient variables and methods of management on the relative cost of managing ASCI patients, and provided a consistent approximation of costs for each patient. The mean cost of $10,035 exceeds the cost reported by the National Head and Spinal Cord Injury Survey sponsored by the National Institute of Neurological and Communicative Disorders and Stroke.[4] The survey found that the direct-care plus indirect cost averaged $8,863 per patient in 1974 dollars with the direct-care cost being approximately half the total. The present study assessed only direct-care costs and thus the survey's comparable figure would be approximately $4,432.0. However, the survey showed a much shorter LOS of 9.4 days, probably due to the termination of LOS at discharge from the initial hospital, and exclusion of any additional necessary stay for management of the ASCI at a

second acute care hospital. Conversely, in another study of ASCI patients by Webb *et al*[5] the mean LOS was 184 days for initial hospitalization and the mean cost was $28,637 in 1974 United States dollars. The mean CPD was $169 which is similar to the findings in the present study.

In the present study, there was no significant effect of sex, age and type of accident on LOS or costs. These results contrast with those reported by Charles *et al*[3] who found that males had longer LOS and higher costs of care and that patients injured in motor vehicle accidents had the longest LOS and highest costs compared to other etiological groups. However, it should be noted that these investigators analyzed the costs for both the acute and rehabilitation phases while the present report examined only the acute phase. Indeed, their report reveals that the duration and cost of acute care was similar when grouped by sex, age and type of injury. Furthermore, their statistical methods were not fully detailed, and the significance levels cited to support their statement that 'male patients take longer and cost more to rehabilitate' was low ($p = 0.10$), while no significance levels were given to support their conclusion of higher costs and longer LOS for victims of motor vehicle accidents. It is possible that the present study may have failed to detect a variation in LOS or costs due to type of accident because the categories used to classify the accidents were broad. For instance, the category 'motor vehicle accident' included automobile drivers and passengers, motorcyclists and pedestrians. Similarly, the accidents classified as 'sports or recreation activities' included more than 15 different types including diving, hockey, motor sports and gymnastics. Thus, it is possible that these classifications were too broad to show an effect of cause of injury, although we think it is more likely that the cause of ASCI is relatively less important in determining LOS and costs than several other factors noted below.

Patients with increased severity of spinal injury due to either increased disruption of the vertebral column (Table III) or more severe spinal cord injury (Table IV) required longer and more costly acute hospitalization. However, there was no relationship found between the severity of spinal injury and the daily cost of management, indicating that more severe injuries result in longer hospitalization, and therefore, greater overall costs, rather than more expensive resources. The one likely exception is the patient requiring mechanical ventilatory care and, as noted above, the cost of this was not specifically determined.

The level of the cord injury had a significant effect on CPD, with cost increasing as the level of injury progressed cephalad (Table II). Patients with cervical injuries would have higher day to day costs due to increased nursing requirements, and the need for the care of complications, particularly respiratory complications which require increased use of radiology, intensive care facilities for mechanical ventilation, and more physiotherapy to treat lung congestion.

Increased severity of the combined spinal and nonspinal injuries, denoted by the ISS, was associated with longer acute care and total cost, but there was no effect on CPD. When all patients, survivors and nonsurvivors, were included in the analysis, increased ISS was associated with increased CPD resulting from the increased costs associated with the management of nonsurvivors almost entirely in the NICU. However, when the 14 patients who died during first hospitalization were excluded from the analysis this effect was lost. The 177 patients who survived to discharge showed that increasing ISS did not effect CPD, but caused a linear increase in LOS and CPS (Table V). Although the report of Semmlow and Cone[14] of traumatized patients not confined to ASCI documented increased duration and cost of care with increasing severity of injury, the present study is the first analysis of injury severity on the costs of care in patients with ASCI.

Two variables related to the overall system for the management of patients with ASCI were assessed, the time interval to admission and the issue of surgical management. The time interval between the accident and admission is a measure of the first aid organization of the system for evacuation and transportation of patients to

appropriate facilities. One of the benefits of establishing an organized unit was the reduction of time between injury and admission, in that 50% of the patients admitted to the ASCIU reached the unit within 5 hours of injury compared with 13 hours prior to the establishment of the unit. It had been hoped that such direct, speedy transfer would result in improved outcome, possibly as a result of decreased secondary injury to the cord, improved resuscitation and reduced incidence of complications. Although patients reaching the unit more than 48 hours after injury had a longer LOS and a higher CPS costs, neither of these differences was statistically significant (Table VI). However, LOS had a significant relation to delay (Tables VI and XI) and increased LOS must cause increased CPS. With regard to surgical management, the analysis was restricted to differentiating patients undergoing one spinal operation from those managed without spinal surgery. The intended benefits of surgical treatment included early decompression of neural elements to improve recovery and the early attainment of stability of the vertebral column, through instrumentation and fusion, to hasten mobilization.[7] However, surgery had no effect on either LOS or cost.

Several authors have described the numerous complications which can occur during the initial hospitalization of ASCI patients,[15,16] and the possible lowering of the complication rates by management in an ASCIU.[3,5,16,17] However, the present paper is the first to systematically analyze the effect of the complication rate on the LOS and costs of care. All five types of complications caused major increases in the LOS and CPS (Table VII). Three of the five, gastrointestinal, genitourinary, and cutaneous complications, increased the total cost by increasing the LOS without a significant increase in the CPD. In contrast, the occurrence of either respiratory or thromboembolic complications increased both the mean CPD as well as the mean LOS. Given the model used to calculate the costs, the increase in CPD associated with the presence of respiratory complications probably resulted from increased utilization of the NICU for management of respiratory failure. While single complications increased both LOS and the CPS, the effect of multiple complications was additive because both LOS and CPS increased directly with the number of types of complications (Table VIII).

The analysis of LOS and costs by year of admission revealed several trends (Table IX). CPD increased steadily during the study at least partly due to the increased use of new technological advances, such as computerized tomography. However, of major importance is that the mean CPS decreased dramatically, mainly due to the steady, marked decline in the LOS (Table IX). It is noteworthy that despite increased utilization of services signified by increasing CPD, this was associated with a decreased LOS and decreased total costs.

When the relationships between the admission variables, LOS and cost of acute care were examined, the most important factors were those related to the nature of the spinal injury itself (Table X): the more cephalad and severe the cord injury, the greater the LOS and the higher the CPS. In contrast, such variables as age, sex, and type of accident leading to injury were not found to significantly alter LOS, CPD or CPS. However, when variables related to patient management were included in the multiple regression analysis, the frequency of complications and the year of admission were found to have a significant effect on duration and cost of management (Table XI). Indeed, the presence of complications was found to be the most important factor leading to increased cost and length of acute care. The association of year of admission with increased CPD, but decreased LOS and CPS strongly suggests that the establishment of the ASCIU was an important factor is modifying these outcome measures. Reduction in the incidence of complications such as pressure sores,[18–20] joint contractures[21] spinal instability[17] and urinary tract infections[22–24] has been shown by others to be related to admission to specialized units, and some of these studies included patients in the acute phase of care.[13,21,22,24] Donovan and Dwyer[25] and Johnston and Keith[26] found that reduction of complications in the acute phase was highly cost effective be-

cause of reductions in LOS. Comparison between specialized approaches to care and nonspecialized care by various authors shows that mean LOS was reduced by 20 to 50% and cost of care decreased by 20 to 25%.[3,13,17,27] Recently, Heinemann *et al*[17] showed that initial treatment in an ASCIU versus nonspecialized care in a general hospital was associated with a significantly greater daily rate of functional improvement during the subsequent rehabilitation phase of care.

In our opinion the decreased LOS and CPS were associated with a number of improvements directly related to the establishment of the unit. For example, the unit developed guidelines for referral which were disseminated among ambulance personnel, referring physicians and hospitals. These guidelines resulted in safer transportation, and more prompt referral with less frequent off-loading at an intermediate hospital. The unit achieved concentration of skilled and experienced personnel, including physicians, nurses and therapists which contributed to the shorter and less expensive treatment. Although the occurrence of complications was not progressively reduced during the course of the study, complications were usually detected early and treated effectively, thus minimizing the duration and cost of hospitalization. It is also likely that innovations in management by the unit staff, especially the use of halo devices for patients with major ASCI[11] and the use of intermittent catheterization of the bladder, also contributed to these improvements. The increased CPD reflects the increased intensity of management and the use of new technology which also likely contributed to these improvements. There was no evidence to suggest that the marked reduction in LOS was due to a change in the severity of injury of the patients being admitted.

Conclusions

The present study examined the LOS, CPD and CPS for 191 patients with ASCI admitted to a regional, specialized ASCIU. Age at admission, sex, and cause of accident leading to injury did not have a significant effect on either LOS or cost of management. In contrast, increasing severity of injury to the spinal cord and to the vertebral column with increased bony disruption caused a significant increase in LOS and CPS, but did not influence CPD. Increasing total trauma load (ISS) resulted in a significant increase in LOS and CPS. The more cephalad the injury, the higher the CPD.

The time interval from the accident to admission to the unit was found to affect LOS: the duration of acute care was shorter for patients admitted sooner, although there was no effect on CPD or CPS. When the effect of spinal operative treatment was examined, no effect on LOS, CPD, or CPS was found.

Respiratory, gastrointestinal, thromboembolic and genitourinary complications and the presence of decubitus ulceration were all associated with significant increases in the LOS and CPS. The presence of respiratory or thromboembolic complications was also associated with a significant increase in the CPD.

There was a progressive and statistically significant increase in the CPD over the 1974–81 period of the study, probably due to several factors including increased utilization of the intensive care unit, and to new technological improvements. However, more importantly, the CPS decreased dramatically from 1974 to 1981, due mainly to a decrease in the mean LOS throughout the study period.

Multiple regression analysis showed that the variables related to the severity and level of the spinal column and spinal cord injury, and complications had the most significant effects on duration and cost of acute care.

The study suggests that a specialized, regional unit for the management of patients with ASCI is associated with a reduction in LOS and cost of care.

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