Relationship of American Spinal Injury Association Impairment Scale Grade to Post-injury Hospitalization and Costs in Thoracic Spinal Cord Injury

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BACKGROUND: The lifetime economic burden of thoracic spinal cord injury (SCI) is known to be high, but evidence of variability of costs in relation to the American Spinal Injury Association Impairment Scale (AIS) grade is limited.

OBJECTIVE: To estimate lifetime economic costs of hospitalization by AIS grade in thoracic SCI.

METHODS: Using SCI Model Systems data from January 2000 to March 2016 from the National Spinal Cord Injury Statistical Center, we estimated mean total annual days of all-cause hospitalization by AIS grade among persons with thoracic SCI, based on assessments 1, 5, and 10 yr post-injury. We combined this information with secondary cost data and projections of life expectancy to estimate lifetime economic costs of hospitalization by AIS grade in persons aged 35 yr at time of thoracic SCI. Future costs were discounted to present value at 3% annually.

RESULTS: One year post-injury, mean total annual days of hospitalization ranged from 2.1 for persons with AIS-D injuries to 5.9 for those who were AIS-A. Similar differences were noted 5 and 10 yr post-SCI. The estimated net present value of expected lifetime costs of hospitalization following thoracic SCI at age 35 yr was $321 534, $249 514, $188 989, and $68 120 (2015 US$) for AIS-A, AIS-B, AIS-C, and AIS-D injuries, respectively.

CONCLUSION: Persons with less severe thoracic SCI, as reflected in AIS grade, spend fewer days in hospital over their lifetimes, leading to lower costs of inpatient care. Therapies improving AIS grade following thoracic SCI may provide cost savings in addition to addressing substantial unmet need.

KEY WORDS: AIS grade, Cost, Hospitalization, Lifetime, Spinal cord injury, Thoracic

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Traumatic spinal cord injuries (SCI) occur suddenly, often to persons involved in vehicular accidents or falls; victims of SCI typically are left with lifelong paralysis and functional impairment.[1] SCI are classified by neurological level of injury (NLI) and completeness of injury, as defined by the American Spinal Injury Association Impairment Scale (AIS) grade.[2] While NLI depicts residual function of unaffected spinal tissue above the injured area, AIS grade characterizes relative neural involvement and functional impairment at and below the level of injury and defines injury severity.[2] An initial neurological "incomplete injury" (AIS-B, C, or D) portends potentially greater improvement in functional status than an injury that is "complete" (ie, AIS-A).[3]

As a result of neurological injury and functional impairment, victims of SCI often experience a range of other medical problems, including (but not limited to) genitourinary, gastrointestinal, and respiratory conditions, and problems with skin integrity.[1,4-7] In their longitudinal study of 139 persons with SCI

ABBREVIATIONS: **AIS,** American Spinal Injury Association Impairment Scale; **NIDRR,** National Institute on Disability and Rehabilitation Research; **NLI,** neurological level of injury; **NIS,** National Inpatient Sample; **NSCISC,** National Spinal Cord Injury Statistical Center; **SCI,** spinal cord injuries

on the medical complications following SCI, Adriaansen and colleagues[8] noted that risks of several medical complications, including autonomic dysreflexia, edema, urinary tract infections, and pressure ulcers, are associated with degree of injury "incompleteness," but the authors do not report complications by AIS grade or NLI.

Although one might reasonably expect that the clinical and economic burden of SCI would vary in relation to injury severity, information in published literature is scant. DeVivo and colleagues,[9] for example, examined healthcare utilization and costs in 206 persons with SCI, stratifying subjects by NLI and AIS grades, as follows: (1) C1-4 AIS ABC, (2) C5-8 AIS ABC, (3) T1-S5 AIS ABC, and (4) any NLI AIS-D. Mean annual costs of hospitalization were reported to be highest among persons with AIS-A, AIS-B, or AIS-C injuries, irrespective of NLI, and lowest for AIS-D ($13 130 for T1-S5 AIS-A, AIS-B, and AIS-C vs $4507 for NLI AIS-D [2009 US$]). The same stratification scheme was used in a study by DeJong and colleagues[4] of rates of rehospitalization in 951 SCI patients, wherein it was reported that 35.3% of persons with AIS-A, AIS-B, or AIS-C paraplegia were rehospitalized in the year following injury compared with 23.8% among those with AIS-D injuries. Other researchers have estimated risks and costs of rehospitalization stratified by NLI (paraplegia or tetraplegia) and AIS grade (complete or incomplete injuries) using ICD-9 and ICD-10 codes. For example, Gabbe and Nunn[10] reported that 65.7% of persons with complete paraplegia (n = 35) and 29.1% of those with incomplete paraplegia (n = 79) were rehospitalized within 2 yr of injury. Finally, in a study involving 233 SCI patients, Dryden and colleagues[11] have reported that costs of rehospitalization in the first 6 yr following injury were twice as high among persons with complete paraplegia compared with those with incomplete paraplegia.

While published literature is informative, analyses of economic burden in relation to more granular classification of injury severity and neurological impairment may support understanding of the potential clinical and economic benefits of emerging therapies that may improve outcomes following SCI. To the best of our knowledge, incidence and costs of hospitalization following SCI have not been reported by discrete AIS grade (ie, A, B, C, and D, respectively). Our study examines this question.

METHODS

Data Sources

We used data from the SCI Model Systems database of the National Spinal Cord Injury Statistical Center (NSCISC; the "Database") to estimate lifetime costs of all-cause hospitalization in persons with thoracic SCI. The Database contains information of all persons who received treatment in US Model System centers during the year following SCI. Model SCI Systems are regional centers located across the USA that provide comprehensive care for persons with SCI and report data according to rigid criteria. Currently, there are 14 Model SCI Systems.[1,12] It has been estimated that the Database has information on approximately 6% of all incident SCIs in the USA.[13]

The Database contains information on patient demographics, clinical, and neurological status during acute SCI recovery and rehabilitation, and physician assessment of neurological status 1 yr post-injury; patient self-reports are also available for rehospitalization and days in hospital. Item wording may be found on the NSCISC website;[14] it is also described in annual NSCISC reports.[1]

Our study sample consisted of all persons in the Database with evidence of thoracic SCI occurring between January 2000 and March 2016. Study subjects were stratified based on their AIS grade at neurological assessment 1 yr post-injury; AIS status in the Database is described in Table 1.[2] It has been reported that spontaneous recovery beyond 1 yr,[15-16] including AIS grade conversion, is minimal, and that the majority of neurological recovery occurs in the first 6 mo following injury.[17] Persons in the Database with missing AIS status at 1 yr were excluded from our study sample.

All data that we received from NSCISC were aggregated and contained no patient identifiers. Our analyses were limited to persons with nonmissing values for AIS grade and information on hospitalization. The 2015 NSCISC Annual Report notes that information on rehospitalization is missing for <1% of the total sample.

Outcomes of Interest

For all persons in our study sample, we examined rates of hospitalization by AIS grade based on assessments 1, 5, and 10 yr post-injury. It is important to note that our study design was not longitudinal, but rather made use of all available data at each of these assessments. For example, someone who had participated in the registry for 10 yr or more could have contributed 3 observations to our analyses (ie, at 1, 5, and 10 yr post-injury), while someone who had recently entered the registry only would have contributed a single observation.

We calculated the percentage of subjects who reported they were hospitalized 1, 5, and 10 yr following injury, and their mean total days in hospital in each of these years, both in relation to AIS grade; this information was used to impute data for intercurrent post-injury years when such information was not collected by NSCISC. Specifically, information on days in hospital in the year following SCI was also used to estimate expected hospital days for the second year following injury. Values from the assessment 5 yr following SCI were used to estimate expected hospital days for years 3 through 7 following injury. Finally, values from the assessment 10 yr following SCI were used to estimate expected rates of inpatient utilization from year 8 through the remainder of life.

Costs were estimated for all documented hospitalizations using information on cost per admission and length of stay from the 2011 Healthcare Cost and Utilization Project National Inpatient Sample (NIS) for all admissions with a secondary diagnosis code of paraplegia (ICD-9-CM 344.1). In the NIS, costs of admissions are estimated based on total charges and Medicare cost-to-charge ratios.[18] To estimate the cost of each day in hospital, we divided mean cost per stay by mean length of stay for all of the above-described hospital admissions; the resulting estimate was $2601 (2015 US$). Each day in hospital among persons with thoracic SCI was assigned this cost, reflecting a healthcare perspective. Our projections of lifetime costs began at age 35 yr, which was the mean age at injury among persons in our sample. Survival projections were based on mortality data from the NSCISC for persons with thoracic injuries, stratified by AIS grade; survival data are summarized in Figure 1. Among persons with injury at age 35 yr, median-estimated life expectancy was 32 yr for AIS-A, 33 yr for AIS-B, 34 yr for AIS-C, and 39 yr for AIS-D. Future costs were discounted to present value at 3% annually, as

TABLE 1. ASIA Impairment Scale: International Standards for Neurological Classification of SCI

Grade	Classification	Motor or sensory involvement
AIS-A	Complete	No sensory of motor function is preserved in the sacral segments S4-S5.
AIS-B	Sensory incomplete	Sensory but not motor function is preserved at the most caudal sacral segments S4-S5, and no motor function preserved >3 levels below the motor level on either side of the body.
AIS-C	Motor incomplete	Motor function preserved at the most caudal sacral segments on voluntary anal contraction, or the patient meets the criteria for sensory incomplete (above) with motor sparing >3 levels. <50% of key muscle functions below the single NLI with muscle grade ≥3.
AIS-D	Motor incomplete	Motor incomplete status as with AIS C, and with at ≥50% of key muscle functions below the single NLI with muscle grade ≥3.
AIS-E	Normal	Motor and sensory function are normal.

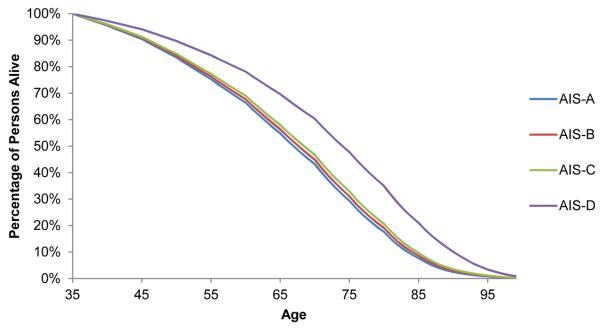

FIGURE 1. *Estimated lifetime survival by AIS grade among patients aged 35 yr at time of injury (NSCISC).*

recommended by the Second Panel on Cost-Effectiveness in Health and Medicine.[19]

Standard Protocol Approvals

Our study was reviewed and granted "exempt" status by the IntegReview IRB.[20] Informed consent was not needed because there was no patient contact, and all data that we received were provided in summary format only.

Statistical Analyses

Analyses of hospitalizations and days in hospital by AIS grade were conducted by NSCISC. Estimates of lifetime costs of hospitalization by AIS grade were conducted at PAI (Policy Analysis Inc, Brookline, Massachusetts), using Microsoft Excel 2010 (Microsoft Inc, Redmond, Washington). Significance testing was not performed, as there were no a priori hypotheses. As the primary data in our analysis were cross-sectional in nature, the Strengthening the Reporting of Observational Studies in Epidemiology criteria were used to evaluate the integrity of the analysis and reporting of findings.[21]

RESULTS

We identified a total of 1572 persons with information in the Database 1 yr following thoracic SCI; there were 1047 persons with information 5 yr post-SCI, and information 10 yr following

TABLE 2. ASIA Impairment Scale Grade 1 Yr Post-injury Among Persons With Thoracic Spinal Cord Injuries and Assessments at 1, 5, and 10 Yr, Respectively

	AIS-A	AIS-B	AIS-C	AIS-D	Total N
Year 1	931 (59%)	153 (10%)	193 (12%)	295 (19%)	1572 (100%)
Year 5	676 (65%)	99 (9%)	128 (12%)	144 (14%)	1047 (100%)
Year 10	720 (71%)	80 (8%)	124 (12%)	97 (10%)	1021 (100%)

injury was available for 1021 persons. Distributions of study subjects by AIS grade are reported in Table 2. Among persons with information in the Database 1 yr post-injury, 931 (59%) were AIS-A, 153 (10%) were AIS-B, 193 (12%) were AIS-C, and 295 (19%) were AIS-D. Age was inversely related to injury severity: mean age of persons with AIS-A injuries was 33 yr, while mean age of those with AIS-B, AIS-C, and AIS-D injuries was 35 yr, 36 yr, and 40 yr, respectively.

Among persons with information 5 yr post-injury, 676 (65%) were AIS-A, 99 (9%) were AIS-B, 128 (12%) were AIS-C, and 144 (14%) were AIS-D at their 1-yr post-injury assessment. Mean age among these persons was 37 yr for those who were AIS-A, 39 yr for those who were AIS-B, 39 yr for those who were AIS-C, and 44 yr for those who were AIS-D.

The breakdown by AIS grade was similar among persons with information 10 yr post-injury: 720 (71%) were AIS-A, 80 (8%) were AIS-B, 124 (12%) were AIS-C, and 97 (10%) were AIS-D at their 1-yr post-injury assessment. Mean age among these persons was 40 yr for those who were AIS-A, 41 yr for those who were AIS-B, 41 yr for those who were AIS-C, and 44 yr for those who were AIS-D.

Approximately 98% of persons with AIS grade also had information on hospitalizations. Persons with AIS-A thoracic SCI were consistently more likely to be hospitalized in comparison with those with incomplete thoracic injuries (Figure 2). In the year following acute injury, 36% of persons who were AIS-A were rehospitalized; corresponding figures for those who were AIS-B, AIS-C, and AIS-D were 34%, 29%, and 20%, respectively. Comparable percentages for persons 5 yr post-injury were 33%, 28%, 25%, and 26%, respectively; 10 yr post-injury, the figures

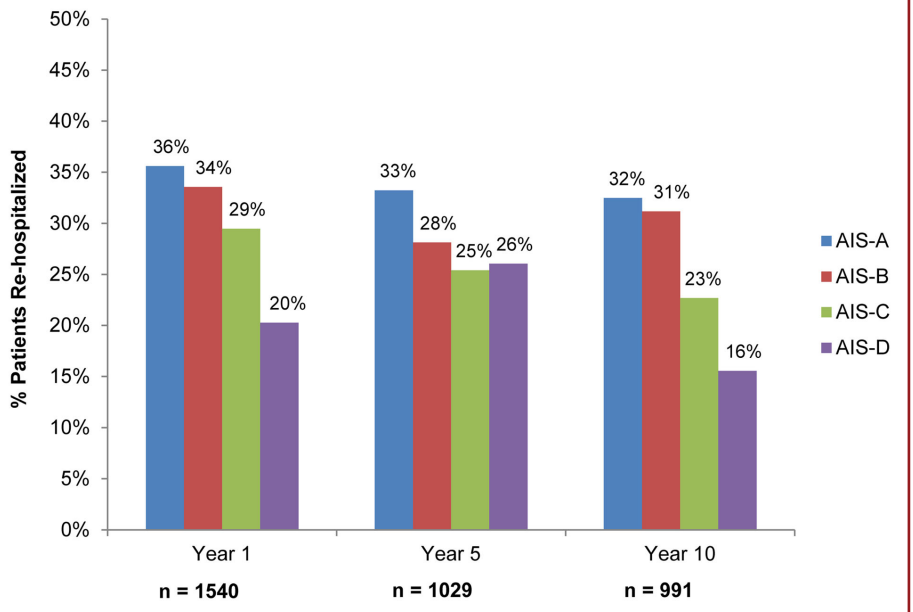

FIGURE 2. *Percentage of persons with thoracic SCI hospitalized 1, 5, and 10 yr post-injury (Source: NSCISC, Jan. 2000-Mar. 2016).*

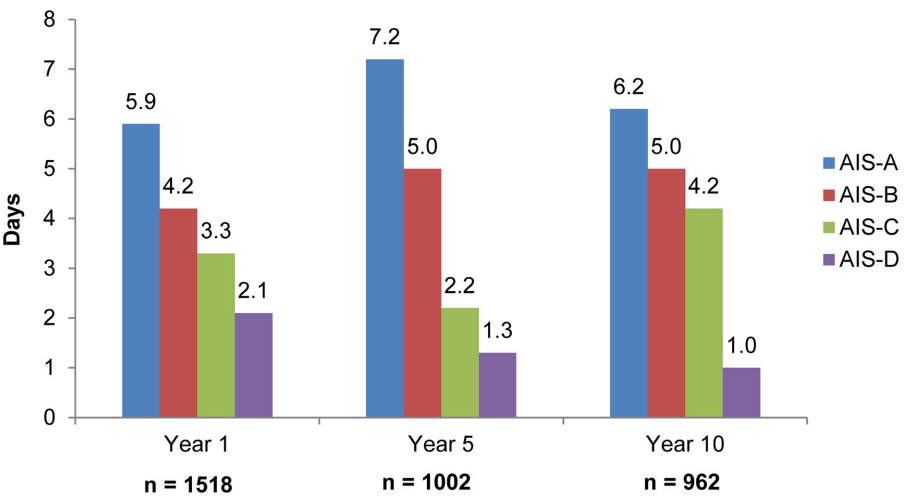

FIGURE 3. *Average number of days in hospital for persons with thoracic SCI 1, 5, and 10 yr post-injury by AIS status (Source: NSCISC, Jan. 2000-Mar. 2016).*

were 32%, 31%, 23%, and 16%. While the gradient in relation to AIS status was preserved at all time points, absolute risk of hospitalization appeared to decline over time.

Mean total days in hospital in the year following acute thoracic injury were highest among persons who were AIS-A (5.9 d), and were progressively lower for persons with AIS-B, AIS-C, and AIS-D injuries (4.2 d, 3.3 d, and 2.1 d, respectively; Figure 3). The gradient in mean total annual hospital days was preserved over time: 10 yr following thoracic SCI, our estimates ranged from 6.2 d for persons who were AIS-A to 1.0 d for those with AIS-D injuries.

Combining our estimates of mean total annual days of hospitalization by AIS grade, daily cost of hospitalization, and life expectancy, we estimated that (discounted) lifetime expected costs

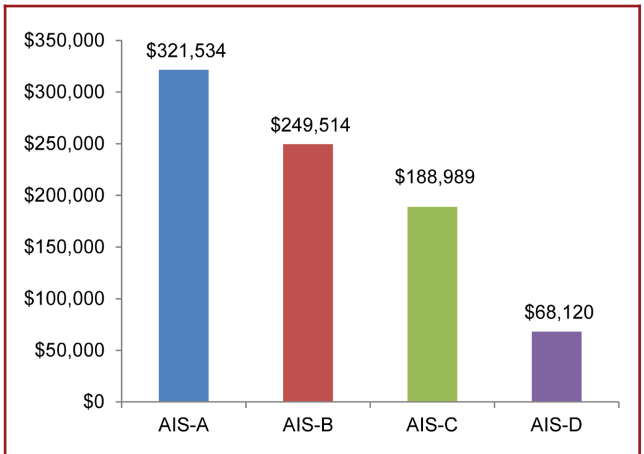

FIGURE 4. *Projected lifetime costs (2015$) of hospitalization for persons with thoracic SCI occurring at age 35 yr, by AIS grade (discounted at 3%).*

of hospitalization among persons who experience AIS-A thoracic injuries at age 35 yr would be $321 534 (Figure 4); comparable estimates for those with AIS-B, AIS-C, and AIS-D injuries at the same age were $249 514, $188 989, and $68 120, respectively (2015 US$). Estimated lifetime costs of hospitalization were approximately $253 000 lower among persons with AIS-D injuries compared with those with AIS-A thoracic SCI.

DISCUSSION

Our research represents an initial attempt to estimate the lifetime economic burden of hospitalization among persons with thoracic SCI by AIS grade. Our findings suggest that differences in relative neural involvement and functional impairment are associated with substantial differences in expected future costs of inpatient care. Our findings are potentially important for multiple stakeholders, including persons with SCI, healthcare systems, and budget holders responsible for their care.

Hospitalization exacts both a physical and mental toll on persons with SCI.[22] Typically, successful rehabilitation supports reconceptualization of life as a healthy—albeit disabled—person that nonetheless retains meaning. Achieving this involves reclaiming roles that may have been vacated during acute recovery, and developing new roles as rehabilitation and optimal recovery occur.[23] Any illness that results in hospitalization poses an affront to the integrity of the adult self-concept, most notably competence and independence.[24] It is reasonable to deduce that hospitalization, via interruption in regular life, strains attainment of benefits that are hard-won in the months and years following SCI. It is equally reasonable to deduce that lessening the burden of hospitalization, as seen with the differences we observed by AIS grade, would benefit persons with thoracic SCI.

Neurological recovery for baseline complete (AIS-A) thoracic injuries tends to be limited. Several studies using large, well-established databases report that only 14% to 16% of persons who are AIS-A 6 to 12 mo post-SCI ever convert to AIS-B, AIS-C, or AIS-D status.[17,25-26] We believe that our estimates of differences in the expected economic burden of hospitalization by AIS grade may be of value in future evaluations of the potential clinical and economic benefits of novel therapeutics and treatment strategies intended to improve AIS conversion in thoracic injuries.[27-28]

Hospitalization in persons with SCI is difficult to study because of relatively low event rates. There are approximately 17 000 new cases of SCI in the USA annually.[29-30] On a prevalent basis, there are approximately 282 000 persons with SCI, of whom 58% sustained injuries resulting in tetraplegia, and 41% who sustained injuries resulting in paraplegia.[30] Ideally, persons with SCI receive acute care and rehabilitation in centers of excellence, but they eventually return to their lives and receive care closer to home. All of these factors coalesce to make it difficult to amass large groups of persons to study over time. The NSCISC is a well-organized and standardized registry that allows for follow-up of persons with SCI.[12,13] We needed a sizable population for our analysis. It was also important that our stratification of persons by AIS grade be based on a standardized-neurological assessment. Designation of AIS grade 1 yr post-injury was conducted within the SCI Model Systems, based on published assessment guidelines.[1] Use of SCI Model Systems data afforded us a sufficient sample size to stratify persons with SCI by AIS grade.

Previous efforts to quantify healthcare costs following SCI have used ICD-9 or ICD-10 diagnosis codes in various health insurance databases. Although these large databases allow for more precise estimation of costs, they do not permit patients to be stratified by AIS grade, which is not captured by ICD-9 or ICD-10 diagnosis coding methodology. To the best of our knowledge, the NSCISC database is unique in capturing both AIS status and healthcare utilization among persons with SCI at various points in time post-injury. We therefore believe that it was ideally suited for our study, though we were necessarily limited as a result to focus on hospitalization, as NSCISC does not capture all components of healthcare utilization (eg, medication use, all-cause physician visits).

Limitations

Our study has several limitations. For one, we limited our attention to persons with thoracic SCI to reduce confounding by NLI and to enable us to better discern differences in economic burden in relation to AIS grade. We do not know whether a similar relationship would be found among persons with cervical or lumbar injuries. The clinical and functional significance of NLI is greater when moving from level to level in the cervical region.

Our sample size was also not sufficient to permit examination of the influence of AIS grade by NLI in the 12 thoracic regions. While we explored the influence of AIS grade among persons with high (T1-T6) vs low (T7-L1) thoracic injuries, a similar pattern in rates of rehospitalization was noted in the 2 groups, and we therefore decided to aggregate all thoracic patients in our initial analyses.

We did not address the reasons for hospitalization. Diseases of the urinary tract, skin, and respiratory problems are prominent reasons for postacute hospitalization.[1,4] Future research could explore rates and costs of hospitalization by reason for admission. SCI Model Systems data are not population based, and care in SCI Model Systems likely represents a high level of excellence for both acute and rehabilitation phases of recovery. Initial care can impact downstream likelihood of developing certain medical complications (eg, pressure ulcers).[31] Our results may underestimate the burden of hospitalization among persons who do not receive this level of care initially. Post-rehabilitation, however, many persons who receive care in SCI Model Systems return to geographically diverse community-based settings as the locus of their care. Future research could build on our findings and yield more refined and robust estimates as the amount of NSCISC data increases over time. More comprehensive sources of hospital costs also could be developed to refine estimates of economic burden, and other components of direct medical care costs also could be evaluated. That being said, we believe that our research constitutes an important first step in understanding the relationship between AIS grade and economic burden in persons with thoracic SCI. While improvement in NLI often may be viewed as the only relevant metric by which the efficacy of interventions in SCI should be gauged, we believe that AIS grade is also an important predictor of future patient functioning and well-being.

CONCLUSION

While the impact of having a complete vs incomplete lesion on functional status is well known, the relationship between discrete AIS grades and economic burden is not well understood. Our study revealed that in persons with thoracic SCI, risk of rehospitalization 1, 5, and 10 yr following acute injury is lower among those with greater preservation of motor and/or sensory function below the NLI. Our findings suggest that new interventions enhancing neurological recovery potentially may reduce the economic burden of SCI in addition to improving the quality of patients' lives.

Disclosures

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COMMENTS

The authors utilize NSCISC data to estimate lifetime hospitalization costs for 35-year-old victims of thoracic SCI of different ASIA grades. As expected, the gradient of costs parallels that of neurological disability. These data permit a determination of whether new approaches can be introduced cost-effectively. Most importantly, the calculations can be done transparently and openly. If not for research such as this, decisions on cost-effectiveness will likely be made by insurance companies, often without transparency or accountability.

The model is well-constructed and described with clarity. However, a serious limitation of the study, acknowledged by the authors, is its restriction to hospital costs, omitting other major cost elements related to SCI. These costs include outpatient rehab and other treatment, medications, medical appliances, adaptations to homes and vehicles, lost wages, etc. The latter are often considerably greater than hospitalization costs. Nevertheless, this is a valuable first step in the economic analysis of spinal injury.

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Spinal cord injury (SCI) is a devastating disease with nearly 20 000 new cases in the United States each year. On an individual basis, per-patient costs for high cervical SCI in 2016 were over $1 million in the first year and $185 111 in each subsequent year. However, there is scant literature on the costs associated with thoracic SCI. In this manuscript, data from 2 national databases - the National Inpatient Sample and the National Spinal Cord Injury Statistical Center - are utilized in order to calculate the lifetime costs associated with thoracic SCI. In the current era of value-based health care, deciphering the economic burden associated with SCI is of paramount importance and the authors should be commended for carrying out this important work. There are several limitations in the present study, including the limited sample size and the utilization of aggregate cost data which may differ based on the individual patient's insurance. A future study may consider the primary reason for hospitalization of these patients as well as delineate the cost associated with outpatient services, such as rehabilitation.

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