Research article

Association between presence of pneumonia and pressure ulcer formation following traumatic spinal cord injury

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Objective: To determine if the presence of pneumonia and pressure ulcers are associated in individuals with an acute spinal cord injury during acute care and rehabilitation hospitalizations.

Design: Retrospective, secondary analyses of data obtained from the Spinal Cord Injury Model Systems enrolled from 1993 until 2006

Setting: Acute care hospitalization and inpatient rehabilitation facilities

Participants: A cohort of individuals hospitalized in acute care ($n = 3,098$) and inpatient rehabilitation ($n = 1,768$) was included in the analysis. Frequencies of pressure ulcer formation and episodes of pneumonia were noted in both settings.

Interventions: Not applicable.

Outcome Measures: Pressure ulcer formation and diagnosis of pneumonia

Results: The development of pressure ulcers, including stage I, was 20.3% acute care and 21.1% during inpatient rehabilitation. Multivariate logistic regression analyses revealed a significant association of pneumonia with occurrence of pressure ulcers ($P \leq 0.001$, OR = 2.3 and 2.2 respectively), the American Spinal Injury Association Impairment Scale grades ($P < 0.001$), and utilization of mechanical ventilation ($P < 0.01$) in both settings.

Conclusion: A higher presence of pressure ulcers was found in individuals with pneumonia, after adjusting for injury severity, age, sex, and utilization of mechanical ventilation. Impaired inflammatory response and decreased mobility in individuals with pneumonia may predispose these individuals to develop pressure ulcers. Surveillance and preventive measures for pressure ulcers should be rigorous in individuals with SCI and pneumonia.

Keywords: Acute hospitalization, Inpatient, Rehabilitation, Pressure ulcers, Pneumonia, Risk factors

Introduction

Spinal cord injury (SCI) is a devastating neurologic disorder and has a profound impact from physical and psychological perspectives. Increased age of patients and the severity of injury are associated with a rise in long-term complications after traumatic SCI.¹ The second leading cause of death in individuals with SCI is septicemia (88.6%), which is usually associated with pneumonia, and/or the presence of pressure ulcers (PUs).² Pressure ulcers are the most frequent secondary complication in individuals with SCI from the time of

acute hospitalization through community reintegration.³ They affect both the quality of life and the length of stay during hospitalization, which increase patient mortality and morbidity.^{4,5} Many risk factors are known to be associated with the formation of PUs in the traumatic SCI population such as males,⁶ history of smoking, alcohol or drug use⁷; with medical comorbidities, such as cardiac or renal or pulmonary disease⁸; diabetes mellitus⁹; decreased oxygenation or hypotension¹⁰; and on steroids.¹⁰

Pneumonia, an inflammatory condition of the lungs, specifically the alveoli, is the most common respiratory complication (66.9% cases) and one of the most frequent causes of mortality following SCI.¹¹ Around 30% of

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individuals with SCI develop pneumonia during their acute hospitalization, and 5–20% individuals are diagnosed with pneumonia during initial rehabilitation.¹² Prior anesthesia and progressively higher levels of SCI affect the muscles of respiration increases the incidence of pneumonia.¹³ The altered lung volumes and pattern of respiration decreases the lung compliance and increases the energy expenditure, predisposing the individual to respiratory fatigue.

A possible association exists between pneumonia and PUs. An increased incidence of pneumonia and PUs in the heel and sacral regions were observed in individuals who had been placed in a supine position, when compared to those in a semi-recumbent position.¹⁴ Supine position in patients with SCI is associated with increased incidence of pneumonia and PU as this position may predispose patients to aspiration and increased pressure on the sacrum and heel areas. Also, an increased inflammation is associated with individuals diagnosed with pneumonia¹⁵ and the presence of PUs.¹⁶ An intrinsic inflammatory response, and decreased oxygenation associated with the presence of pneumonia may result in immunocompromised individuals and predispose them to secondary complications following SCI, including skin breakdown. However, an association between these two secondary complications has not yet been explored. The SCI Quality Enhancement Research Initiative project highlighted the importance of identifying the respiratory factors involved with the risk in the occurrence of PUs following SCI.³

To explore the association between pneumonia and PU formation, a preliminary study in 86 individuals with traumatic SCI enrolled in the Rehabilitation Engineering Research Center on SCI research study was performed. The individuals were followed during acute care hospitalization through inpatient rehabilitation. The occurrence of pneumonia and incidence of first PU were studied retrospectively. The individuals diagnosed with pneumonia were twice as likely to have a PU formation within three weeks after being diagnosed, in comparison with those who did not develop pneumonia.¹⁷ The current study explores data from the SCI Model systems (SCIMS) program to evaluate if this association holds true in a larger population. The objective of the proposed study was to determine if the presence of pneumonia and PUs are associated in individuals with SCI during acute and rehabilitation phases. Since there is no data on the timing of onset of pneumonia or pressure ulcer, this study will be able to determine an association between the two conditions and causality cannot be inferred. Individuals with pneumonia were hypothesized to have a higher presence of

PUs than individuals who did not have pneumonia in acute care hospitalization and inpatient rehabilitation in this population, regardless of injury level.

Methods

Study design

This is an observational study. The National SCI Statistical Center (NSCISC) database includes data from prospectively collected from individuals with SCI treated at federally funded SCI Care Model Systems (SCIMS) centers. Approximately 13% of new SCI occurring in the United States is captured by the NSCISC database. The Form 1 collects data on the individual's status at the time of SCI and documents events during initial hospitalization. To be eligible in the SCIMS program Form 1 data collection, there must be presence of external traumatic event, temporary or permanent loss of motor and sensory function, admission to the Model System within 1 year of the injury, no organized rehabilitation program completed before admission to the system, and provision of informed consent.¹⁸

Data collection

Form 1 data for 24,762 individuals enrolled from 1972 until 2006 by the Model SCI Care Systems centers were obtained from the NSCISC database. Data on PUs during acute care and rehabilitation were not collected in the 2006–2011 and 2011–2016 cycles; hence these time periods were not included in this analysis. Only individuals admitted within one day of injury (Day-1 admissions) had data collected on PUs and pneumonia. Hence the rest of the individuals were excluded from this study. The data during acute hospitalization and inpatient rehabilitation was recorded by interview, direct neurological examination and also supplemented by medical record review. The following data was retrieved from Form 1 of the NSCISC database: age at injury, sex, traumatic etiology, American Spinal Injury Association impairment scale (AIS) at initial System examination, number of episodes of pneumonia during acute care and inpatient rehabilitation, number of PUs, location of PUs, and grade of PUs during acute care and inpatient rehabilitation, utilization of mechanical ventilation during rehabilitation admit and discharge from the system.

The American Spinal Injury Association impairment scale (AIS) attempts to quantitate the degree of impairment. It is classified as A – complete (no motor or sensory function is preserved in the sacral segments), B – incomplete (sensory but not motor function is preserved below the neurological level and includes the sacral segments), C – incomplete (motor function is

preserved below the neurological level and at least half the key muscles below the neurological level have a grade less than 3), D – incomplete (motor function is preserved below the neurological level and at least half the key muscles below the neurological level have a grade more than 3).¹⁹ At the time of measurement and collection of data in the SCIMS, the severity of injury was changed from the Frankel Scale to the AIS impairment scale. The international standards for neurological classification of SCI discusses the comparison between the two scales.²⁰ The AIS follows the Frankel scale with the exception of definition in the sacral sparing.¹⁹ For this study the individual's grade on Frankel was converted to AIS (n = 5 in acute care and n = 6 in inpatient rehabilitation) to allow comparison of injury severity between the groups.

The occurrence of PUs along with grade and location was documented during acute (or subacute) medical/surgical care and during inpatient acute (or subacute) rehabilitation. Each ulcer was documented only once, at onset. No major changes in definitions and reporting procedures for occurrence of PUs occurred over the time of study that affected the outcome of this study. Pneumonia was defined as a state of lung tissue inflammation of infectious etiology with radiographic demonstration of parenchymal disease. Pneumonia is documented with onset in acute (or subacute) medical/surgical care and during inpatient (or subacute) rehabilitation. From October 2000 the data

collection changed from episodes of atelectasis and/or pneumonia to episodes of pneumonia. The utilization of mechanical ventilation was documented if any kind of mechanical ventilator was used to sustain respiration. For additional details on the data collection procedures see the Model Systems syllabus.¹⁸

The individuals who had missing data on the presence of pneumonia or occurrence of PU, AIS at initial admission for acute care and AIS at rehabilitation admission for inpatient rehabilitation, and utilization of mechanical ventilation for rehabilitation admission were excluded. Since new PUs were recorded during acute care and rehabilitation, data pertaining to PU incidence during acute care versus rehabilitation were analyzed separately using the same analysis procedure for each time period to study the association between the presence of pneumonia and occurrence of PUs. After eliminating the missing data, we retained data on 3,098 subjects during acute care hospitalization and on 1,768 individuals during inpatient rehabilitation from 1993 to 2006 (Fig. 1).

Statistical analyses

All statistical analyses were performed using SPSS (version 23.0, IBM Corp., Armonk, NY, USA). The significance level was set at $\alpha = 0.05$. A two-tailed, Mann Whitney *U* test was performed to test significant differences in ages, and a χ^2 test was performed to test significant differences in sex, use of mechanical ventilation,

Figure 1. Eligible individuals with traumatic spinal cord injury enrolled in Model Systems Centers

severity of injury (AIS), and episodes of pneumonia between individuals with and without PUs, in both settings.

To test the association between occurrence of PUs in individuals with pneumonia as compared to no pneumonia during acute care hospitalization, a multivariate logistic regression was performed. AIS at initial admission, age at injury, sex and use of mechanical ventilation at rehabilitation admission (as a proxy to utilization of mechanical ventilation during acute care), were added in the multivariate model. To test the association between occurrence of PUs in individuals with pneumonia as compared to no pneumonia during inpatient rehabilitation, a multivariate logistic regression was performed. AIS at rehabilitation admission, age at injury, sex and use of mechanical ventilation at rehabilitation admission, were added in the multivariate model. The Hosmer-Lemeshow and global chi-square test was used to evaluate the goodness of fit for the multivariate models. Odds ratios (ORs) with 95% confidence intervals (CIs) were computed.

Results

Demographics

The demographics and characteristics of individuals in the groups in acute care and inpatient rehabilitation are listed in Table 1. Mann Whitney U test revealed no significant difference in ages between the two groups in the acute care setting and inpatient rehabilitation. The chi-square test detected significant differences in sex, the severity of injury and utilization of mechanical ventilation for formation of PUs in both settings ($P < 0.001$). Of the individuals in acute care around 66% and 64% of individuals in inpatient rehabilitation with PUs were classified as AIS A. Of individuals with PUs, 46% and 27% were on mechanical ventilation in acute care and inpatient rehabilitation, respectively. Of individuals on mechanical ventilation, 39% and 33% developed at least one PU in acute care and inpatient rehabilitation, respectively.

Pressure ulcer and pneumonia in acute care

Approximately 20% (n = 629) of individuals in acute care hospitalization developed at least one PU. Most PUs were in the sacral region (15%), followed by the heel, occiput and the ischium (Table 3). Univariate analysis produced by the χ^2 test showed significant differences for the presence of pneumonia and formation of PUs, χ^2 (1, n = 3,098) = 216.5, $P < 0.001$ (Table 1). A significant prediction of PU outcome was found by the variables included in the multivariate model, χ^2 (7, n = 3,098) = 346.5, $P < 0.001$.

Table 1 Demographic and clinical characteristics of individuals with SCI during acute care hospitalization and inpatient rehabilitation.

Demographics	Acute				Inpatient			
	Total n = 3098	Individuals with PU n = 629	Individuals with no PU n = 2469	P value	Total n = 1768	Individuals with PU n = 373	Individuals with no PU n = 1395	P value
Age (years) mean ± SD	36.7 ± 16.2	37.63 ± 16.9	36.47 ± 16	0.22	37.3 ± 16.41	36.01 ± 16.1	37.7 ± 16.3	0.05
Sex								
AIS at initial admission	M = 2479(80%) F = 619(20%)	M = 515 (82%) F = 114(18%)	M = 1964 (79.5%) F = 505(20.5%)	0.19	M = 1403(79.4%) F = 365(20.6%)	M = 312(83.6%) F = 61(16.4%)	M = 1091(78.2%) F = 304 (21.8%)	0.21
	A = 1529(49.4%)	A = 417 (66.3%)	A = 1112 (45%)	< 0.001	A = 765 (44.4%)	A = 237 (63.5%)	A = 548 (39.3%)	
	B = 489(15.8%)	B = 100 (15.9%)	B = 389 (15.8%)		B = 257(15.5%)	B = 61 (16.4%)	B = 196(14.1%)	
	C = 569(18.4%)	C = 79 (12.6%)	C = 490 (19.8%)		C = 319(18%)	C = 48 (12.9%)	C = 271(19.4%)	
	D = 511(16.5%)	D = 33 (5.2%)	D = 478(19.4%)		D = 407(23%)	D = 27 (7.2%)	D = 380(27.2%)	
Mechanical Ventilation at rehab admit	Y = 749(24.2%)	Y = 292(46.4%)	Y = 457(18.5%)	< 0.001	Y = 306(17.3%)	Y = 100(26.8%)	Y = 206(14.8%)	< 0.001
	N = 2349(75.8%)	N = 337(53.6%)	N = 2012(81.5%)		N = 1462(82.7%)	N = 273(73.2%)	N = 1189(85.2%)	
Episodes of pneumonia	Y = 883(28.5%)	Y = 328(52.1%)	Y = 555(22.5%)	< 0.001	Y = 76(4.3%)	Y = 33(8.8%)	Y = 43(3.1%)	< 0.001
	N = 2215(71.5%)	N = 301(47.9%)	N = 1914 (77.5%)		N = 1692(95.7%)	N = 340(91.2%)	N = 1352(96.9%)	

Table 2 Logistic regression analysis for individuals in acute care hospitalization and inpatient rehabilitation

Variable	Acute					Inpatient				
	B	Standard error	Wald	P value	Exp B (95% CI)	B	Standard error	Wald	P value	Exp B (95% CI)
Age (years)	0.11	0.003	13.29	< 0.001	1.01 (1.01–1.02)	0.005	0.004	1.23	0.26	1.005 (0.99–1.01)
Sex	0.15	0.12	1.59	0.21	0.86 (0.67–1.09)	–0.29	0.16	3.51	0.06	0.74 (0.54–1.01)
AIS A to AIS B	–0.25	0.13	3.62	0.06	0.78 (0.6–1.01)	–0.28	0.17	2.7	0.1	0.76 (0.55–1.06)
AIS A to AIS C	–0.67	0.15	21.13	< 0.001	0.51 (0.39–0.68)	–0.9	0.18	24.3	< 0.001	0.41 (0.29–0.58)
AIS A to AIS D	–1.35	0.2	45.78	< 0.001	0.26 (0.18–0.39)	–1.7	0.22	58.7	< 0.001	0.18 (0.12–0.28)
Mechanical Ventilation at rehab admit	0.78	0.11	52.09	< 0.001	2.18 (1.76–2.69)	0.44	0.15	8.96	< 0.01	1.54 (1.16–2.05)
Episodes of pneumonia	0.83	0.11	63.20	< 0.001	2.3 (1.87–2.82)	0.79	0.25	10.33	0.001	2.23 (1.37–3.62)

Multivariate logistic regression revealed significant association of episodes of pneumonia ($P < 0.001$, OR = 2.3), utilization of mechanical ventilation ($P < 0.001$, OR = 2.2), age ($P < 0.001$, OR = 1.01), AIS C to AIS A ($P < 0.001$, OR = 0.51) and AIS D to AIS A ($P < 0.001$, OR = 0.26) with the development of PUs (Table 2). The Hosmer-Lemeshow statistic, measuring the fit of the model, was χ^2 (8, $n = 3,098$) = 5.62, $P > 0.05$, indicating adequate fit.

Pressure ulcers and pneumonia in inpatient rehabilitation

Approximately, 21% ($n = 373$) of individuals in inpatient rehabilitation developed at least one PU. Most of the PUs were in the sacral region (13%), followed by the heel, ischium and the occiput (Table 3). Univariate analysis produced by the χ^2 test produced significant results for the presence of pneumonia and formation of PUs, χ^2 (1, $n = 1,768$) = 23.77, $P < 0.001$ (Table 1). A significant

prediction of PU outcome was found by the variables included in the multivariate model, χ^2 (7, $n = 1,768$) = 136.4, $P < 0.001$. Multivariate logistic regression revealed significant association of episodes of pneumonia ($P < 0.01$, OR = 2.2), utilization of mechanical ventilation at rehabilitation admission ($P < 0.01$, OR = 1.5), AIS C to AIS A ($P < 0.001$, OR = 0.4) and AIS D to AIS A ($P < 0.001$, OR = 0.2) with the development of pressure ulcers (Table 2). The Hosmer-Lemeshow statistic, measuring the fit of the model, was χ^2 (8, $n = 1,768$) = 7.59, $P = 0.5$, indicating adequate fit.

Discussion

The current study found a higher presence of PUs in individuals with pneumonia compared to those without pneumonia after controlling for injury severity, age, sex and utilization of mechanical ventilation. These results confirm the preliminary analyses conducted from data on 86 individuals with SCI population.¹⁷ In this

Table 3 Location of PUs in acute care and inpatient rehabilitation

PU Location	Acute Care ($n = 629$)	Inpatient Rehabilitation ($n = 373$)
Sacrum	461 (14.9%)	227 (12.8%)
Heel - left, right	74 (2.4%), 62 (2%)	65 (3.7%), 55 (3.1%)
Ischium - left, right	42 (1.4%), 39 (1.3%)	26 (1.5%), 24 (1.4%)
Occiput	58 (1.9%)	22 (1.2%)
Foot - left, right	25 (0.8%), 20 (0.6%)	15 (0.8%), 19 (1.1%)
Scapula - left, right	25 (0.8%), 21 (0.7%)	9 (0.5%), 5 (0.3%)
Unclassified - left, center, right	10 (0.3%), 15 (0.5%), 16 (0.5%)	11 (0.6%), 11 (0.6%), 9 (0.5%)
Elbow - left, right	6 (0.2%), 3 (0.1%)	5 (0.3%), 9 (0.5%)
Rib-left, right	2 (0.1%), 2 (0.1%)	1 (0.1%), 2 (0.1%)
Iliac Crest - left, right	3 (0.1%), 3 (0.1%)	3 (0.2%), 5 (0.3%)
Knee - left, right	9 (0.3%), 7 (0.2%)	4 (0.2%), 5 (0.3%)
Malleolus - left, right	5 (0.2%), 8 (0.3%)	7 (0.4%), 5 (0.3%)
Spinous process	10 (0.3%)	10 (0.6%)
Genitalia	10 (0.3%)	6 (0.3%)
Trochanter - left, right	8 (0.3%), 2 (0.1%)	8 (0.5%), 9 (0.5%)

study, the risk of developing PUs in individuals with SCI diagnosed with pneumonia was 2.3 times in the acute care population and 2.2 times in inpatient rehabilitation when compared to individuals who did not have pneumonia.

This study reported an association between increasing age and occurrence of PU during acute care, whereas no relationship in age and PU development was found in inpatient rehabilitation. Previous studies have reported age to be a risk factor for PU development.²¹ Although previous studies have reported association between sex and development of PUs in individuals with SCI,²² this study found no such association in both acute care hospitalization and inpatient rehabilitation. Individuals with AIS A were at increased risk to develop PUs than AIS C and AIS D, similar to previous studies.^{21,23} A complete motor and sensory lesion (AIS A) disrupts ability to perceive discomfort and severely limits mobility not allowing individuals to perform the activities of daily living and other activities that increases their risk to develop PUs.^{6,23–25}

Individuals with a higher level of SCI are prone to respiratory compromise with impaired airway secretion clearance predisposing them to respiratory infections such as pneumonia and/ or other pulmonary conditions. A majority of individuals in this study were on mechanical ventilation at rehabilitation admission and were at an increased risk to develop PUs. Previous studies have indicated an increase in the risk of developing PUs due to the use of mechanical ventilators during acute care.^{14,26} While not proven by this study, the use of ventilators in individuals with pneumonia may limit patient mobility, and the decreased oxygenation in these individuals may interfere with tissue healing and repair,²⁷ predisposing them to develop PUs.¹⁴

Literature that addresses risk factors for the development of PUs generally considers all the medical co-morbidities as one factor while assessing the potential risks. Pulmonary disease, deep vein thrombosis, and kidney stones are some of the clinical factors reported in previous studies to be associated with the formation of PUs.^{6,28} Although previous studies attributed pulmonary conditions as one of the clinical factors towards developing an ulcer,²⁹ pneumonia was not studied. The finding in this study is supported by previous studies that indicated an association of pulmonary disease with the formation of PUs.^{9,28} Although studies have identified pulmonary disease as a possible risk factor for developing PUs, their pathology is not fully understood. Presence of pneumonia may trigger an intrinsic inflammatory response and immunocompromise these individuals, predisposing them to

develop PUs. The impaired ventilation in individuals with pneumonia causes an imbalance in ventilation perfusion ratio that may cause decreased oxygen (hypoxia) and increased carbon dioxide (hypercapnia) in the blood.³⁰ Impaired circulation due to decreased oxygen in the blood may cause the tissues to starve. Oxygen is essential for healing and repair, and previous literature has indicated impaired oxygen exchange in the tissues to be one of the predictors for the formation of PUs.²⁷ Also, management of pneumonia in supine position may decrease the mobility and increase pressure and shear on the bony prominences thus forming PUs in this population. It is notable that most of the individuals in this study developed PUs on sacrum, heel, occiput and ischium.

Study limitations

This study was a retrospective secondary analysis with the associated limitations. The NSCISC database includes specialized programs of care in SCI, and this should also be taken into consideration for generalization and interpretation of the results. The data analyzed in this study was until 2006 since PU data were not collected beyond that time period. The longitudinal changes that may have taken place in patient care and improvement in health care technology cannot be ignored. In spite of this, the odds of developing a PU in individuals with pneumonia in the preliminary data in which the data was collected prospectively was similar to the current study. The association between the presence of pneumonia and PUs may be due to factors intrinsic to the person with SCI and his/her tissue tolerance to pressure, rather than external factors such as patterns of care provision. During the time from which the data was recorded in the NSCISC database the measurement of injury severity was changed from the Frankel grade scale to AIS scale score. For our analysis the Frankel grade was converted to AIS. The AIS uses “sacral sparing” to define the incomplete injury whereas the Frankel uses preservation of sensation at least 3 levels below the injury level. Thus, there could have been potential misclassification in AIS A and B. Also, a considerable amount of data was missing on the presence of pneumonia, PUs and injury severity hence these individuals were excluded from the analyses. The data for pneumonia and PUs were recorded in the SCIMS study only on individuals who were admitted from day 1 of injury. The SCIMS study also collected follow-up data on individuals with SCI, these individuals were not admitted in the specialized center for their acute care or rehabilitation and hence no data were collected on presence of pneumonia or

PU. Although these variables were primary focus of this study, individuals who were not Day-1 admissions had to be excluded. This may have potentially biased the results. In the preliminary study,¹⁷ the sequence and timing of pneumonia and PU were considered. Individuals who had formation of PUs within three weeks of diagnosis of pneumonia were considered in the interest group. In this study individuals who had pneumonia and PUs were considered, regardless of the timing. Although, the current study explores data from the NSCISC database to confirm the results in a larger population, the sequence and timing of the comorbidities were not collected in the SCIMS data. Future prospective studies are needed to assess the sequence and timing of pneumonia and pressure ulcer development so that causal links may be uncovered.

Conclusions

The findings suggest an association between the presence of pneumonia and formation of pressure ulcer. The results indicate that a higher proportion of PUs occur in individuals with SCI having pneumonia after controlling for their injury severity, use of mechanical ventilation, age and sex. The association between presence of pneumonia and presence of PU could be because of restriction of mobility after pneumonia, decreased oxygenation or imbalance in the inflammatory response due to the presence of pneumonia. Findings from this study suggest that presence of pneumonia may create conditions that reduce tissue's tolerance to pressure and increase the risk for the occurrence of a PU. Thus, surveillance and preventive measures for PUs should be even more rigorous in individuals with pneumonia. The intervention techniques in individuals with pneumonia should be monitored regularly. Clinicians and other health care professionals should assess the skin frequently and implement PU preventive strategies in individuals with pneumonia. Further evidence on the intrinsic changes in skin following presence of pneumonia may help understand the risk to develop PUs in individuals with SCI.

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