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PREDICTORS OF CARDIOPULMONARY HOSPITALIZATION IN CHRONIC SPINAL CORD INJURY

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Abstract

Objective—We investigated longitudinal risk factors of hospitalization for circulatory and pulmonary diseases among veterans with chronic spinal cord injury (SCI). Circulatory and respiratory system illnesses are leading causes of death in chronic SCI patients, yet risk factors for related hospitalizations have not been characterized.

Design—Prospective cohort study.

Setting—Veterans Affairs (VA) Boston Healthcare System, Boston, Massachusetts.

Participants / Data Source(s)—309 veterans ≥ 1 year post-SCI from the VA-Boston Chronic SCI cohort who completed a health questionnaire and underwent spirometry at study entry. Baseline data was linked to 1996–2003 hospitalization records from the VA National Patient Care Database.

Interventions—Not applicable.

Main Outcome Measure(s)—Cardiopulmonary hospital admissions, the predictors of which were assessed by Multivariate Cox regression.

Results—Of 1,478 admissions observed, 143 were due to cardiopulmonary (77 circulatory and 66 respiratory) illnesses. Independent predictors were greater age (3% increase /year), hypertension, and if in the lowest BMI quintile (<22.4 kg/m²). A greater %-predicted FEV₁ was associated with reduced risk. SCI level and completeness of injury was not statistically significant after adjusting for these risk factors.

Conclusion—Cardiopulmonary hospitalization risk in persons with chronic SCI is related to greater age and medical factors that, if recognized, may result in strategies for reducing future hospitalizations.

Keywords

Spinal Cord Injury; Hospitalization; Circulatory; Respiratory; Proportional Hazards Regression

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The annual incidence of spinal cord injury (SCI) in the United States is an estimated 40 cases per million population or 11,000 new cases a year, and there are approximately 253,000 Americans living with chronic SCI [1]. Following rehabilitation, persons with SCI return to the community. Despite improvements in medical care, persons with chronic SCI require frequent hospitalization [2] [3]. As compared to the development of a medical condition, hospitalization is a widely accepted measure of morbidity associated with a specific illness. Annual hospitalization rates of 25%–40% were previously reported at 10 to 15 years post-injury in Department of Veterans Affairs (VA) hospitals in the 1970's and 1980's [4]. Annual hospitalization rates for SCI patients in non-VA systems are less certain due to incomplete data, but were approximately 25% among persons 5 to 20 years after injury in US SCI Model Systems hospitals [5]. Despite the high rates of hospitalization, there has been little research conducted assessing risk factors for specific causes of hospitalization in this population. Circulatory and respiratory system illnesses are leading causes of death in persons with SCI [6] [4], but risk factors for hospitalizations related these illnesses have not been described.

Since 1994, as part of the VA Boston SCI Cohort Study, we have regularly assessed the health of cohort of persons with chronic SCI [7]. Comprehensive data on personal characteristics, including respiratory health and comorbid illness were collected by questionnaire, spirometry was obtained, and a neurological exam at study entry was conducted. Previous studies of hospitalization risk have relied only on administrative data and have lacked information on personal risk factors. In this report, we link baseline personal and clinical information on the study cohort with hospitalization records to assess prospective risk factors for circulatory and respiratory system related hospitalizations at VA Medical Centers. Our findings suggest ways of reducing these admissions so as to decrease health service utilization as well as disruptions to community reintegration and functional independence arising from frequent hospital stays.

METHODS

STUDY POPULATION

Between October 1994 and December 2002, as part of a longitudinal health study conducted at VA Boston, we enrolled 328 veterans with SCI who had received treatment at VA Boston. Persons who had other neurological conditions or who had recovered from the SCI were ineligible. Since the study was designed to assess pulmonary function in chronic SCI, persons with a tracheostomy or requiring mechanical ventilation were also excluded. As pulmonary function steadily improves in the first year following acute injury participants were recruited at one or more years post-SCI. Recruitment and baseline assessment methodology have been previously presented [7]. Of the 328 enrollees, 3 died before 10/01/1996, 8 had recovered or did not undergo examination, 2 had no data on all baseline variables, and 6 did not complete pulmonary function testing. We included 309 veterans (94%) with complete data on key variables. Approval was granted by our Institutional Review Boards and informed consent obtained.

HOSPITALIZATION AND SERVICE ELIGIBILITY DATA

Hospitalization in an acute-care VA Medical Center was determined using VA electronic databases from 10/1/1996 through 12/31/2003 to allow at least one year of follow-up. It was not possible to include hospitalization data before 10/1996 due to non-uniform reporting standards. We extracted hospitalization data from the VA National Patient Care Database located in Austin, Texas. Each medical record includes an admitting diagnosis (DXPRIME), up to nine secondary diagnoses, and a length-of-stay diagnosis (DXLSF) the condition responsible for the length of hospital stay. Diagnosis codes follow the clinically modified ninth edition of the International Classification of Diseases (ICD-9-CM). Information regarding

eligibility for VA benefits [8] and Medicare was extracted from VA records in 2006. Given chronic disability, it was assumed that the entitlement status of participants remained stable.

MAIN OUTCOME

Starting in 10/1/1996, we calculated the number of days to hospital admission for any cause and from discharge to the next admission. Outcomes based on DXPRIME were circulatory (ICD 390–459) or respiratory system (ICD 460–519) admissions (defined here as cardiopulmonary). There was little difference between DXPRIME and DXLSF with 96% concordance overall when considered in ICD-9 categories, and 87% concordance for cardiopulmonary hospitalization. Admissions for other causes were considered censored events. The hospital discharge summaries from a random sample of cardiopulmonary admissions (30%) were reviewed and DXPRIME validated in 97%.

PREDICTORS

Factors considered at study entry included sociodemographics, comorbid illnesses, respiratory symptoms, personal behaviors, measures of pulmonary function, and BMI. (Table 1). Age and injury duration were updated at the start of each observation period (i.e. at the end of each hospitalization). Based on the American Thoracic Society adult respiratory questionnaire [7], chronic cough was defined as cough occurring on most days for ≥ 3 consecutive months of the year and chronic phlegm was described similarly. ‘Any wheeze’ was defined as wheezing with a cold, or occasionally apart from colds, or wheezing on most days or nights. ‘Persistent wheeze’ was wheezing on most days or nights, or with a cold and occasionally apart from colds. Pneumonia was defined as a history of pneumonia since hospital discharge after SCI. Heart disease was defined as any heart condition requiring treatment in the past 10 years. Participants were asked if a physician had ever diagnosed asthma, emphysema or chronic bronchitis, diabetes, or hypertension. Chronic obstructive pulmonary disease (COPD) included emphysema or chronic bronchitis. Self-reports of these illnesses were previously validated by examining their electronic medical records [6].

Smoking intensity and duration and beverage-specific alcoholic consumption were reported. Smokers had smoked greater than ≥ 20 cigarette packs in a lifetime or ≥ 1 cigarette(s) per day for ≥ 1 year. Current smokers reported cigarette use within one month of testing. Quantity of wine, beer, or liquor consumed was expressed as grams of alcohol [9]. Participants were weighed using a wheelchair scale (subtracting wheelchair weight if required) and transferred to a thin mat where supine length (stature) was measured. If measurement was declined or there were joint contractures that precluded accurate assessment ($n=66$ [21.4%]) self-reported height was used. Weight was measured in 280 (90.6%) study participants, obtained from self report in 24 (7.8%) and from the medical record of a recent clinic visit in 5 (1.6%). Height (stature) and weight were used to compute the body mass index (BMI), which was classified into underweight (BMI <18.5) normal weight (BMI ≥ 18.5 - <25), overweight (BMI ≥ 25 - <30), and obese (BMI ≥ 30 kg/m²) and was also considered in quintiles. Spirometry was based on American Thoracic Society standards modified for use in SCI as described previously [10]. The best FEV₁ and FVC were reported, and 93% of the cohort had at least 3 acceptable expiratory efforts with the best FEV₁ and FVC within 200 ml. Predicted FEV₁ and FVC were calculated using Hankinson’s equations as we previously described [7]. We assessed SCI severity / level by the American Spinal Injury Association (ASIA) criteria as previously described. Motor incomplete SCI included ASIA C (most key muscles below the neurological level grade $< 3/5$) or ASIA D (most muscles grade $\geq 3/5$). SCI severity / level was grouped into severe quadriplegia (cervical motor complete and cervical grade C); severe paraplegia (other thoracic or lower motor complete and grade C); and others (all ASIA grade D).

STATISTICAL ANALYSIS

Proportional hazards methods for repeated outcomes (TPHREG procedure in SAS software version 9.1 [SAS Inc, Cary, NC]) were used. Secular trends were tested by analyzing calendar year effect in a time-dependent manner. Proportional hazards assumption was examined using survival plots and testing the interaction between covariates and the time variable, and confirmed that modeling was appropriate.

RESULTS

DESCRIPTIVE CHARACTERISTICS

Participants with cardiopulmonary admissions were more likely to be older, have a lower BMI, a history of pneumonia following SCI, hypertension, heart disease, chronic respiratory symptoms, reduced lung function, and have a greater mortality (35%) compared to persons without cardiopulmonary admissions (15%, $p<0.001$) (Table 1). Total time at risk was 1,619 person-years, or an average of 5.24 person-years per participant and 17% of all hospitalizations occurred ≤ 30 days after a prior admission. There were 1,478 all-cause hospitalizations among 251 participants for an admission rate of 0.91/person-year, and 143 cardiopulmonary hospitalizations among 75 persons for a rate of 0.09/person-year. There were 77 admissions for circulatory system diseases (5.2%), and 66 admissions for respiratory system diseases (4.5%). The median (q1, q3) hospital stay for cardiopulmonary admissions was 9 (4, 19) days, and 5 (2, 15) days for non-cardiopulmonary admissions.

UNIVARIATE MODELS

Predictors of cardiopulmonary admissions were assessed with and without adjustment for age and hospital readmission within 30 days (Table 2). Adjusted for age and hospital readmission, persons with severe quadriplegia had a risk of cardiopulmonary hospitalization that was of borderline significance [$p=0.06$; hazard ratio (HR) =1.89 (95% CI=0.99–3.63)] compared to persons with ASIA D SCI, and for persons with severe paraplegia the risk was not significantly elevated [$p=0.17$; HR=1.60 (95% CI=0.82–3.14)]. VA service connected disability $\geq 50\%$, if in the lowest BMI quintile (compared to other quintiles), and each chronic respiratory symptom, pneumonia, and hypertension were risk factors for cardiopulmonary admission, while persons with greater pulmonary function were significantly less likely to be admitted. Adjusting for age and hospital readmission, current smokers were significantly more likely to be admitted for cardiopulmonary causes, and persons enrolled in Medicare were less likely to be admitted. Wheelchair use, lifetime alcohol consumption or alcohol consumption in the year before study entry, history of diabetes, asthma, COPD, employment status, educational or marital status, and calendar year of admission were not significant risk factors.

MULTIVARIABLE MODEL

In a multivariate model, significant predictors of cardiopulmonary hospitalization risk were greater age (3% increase per year), a history of hypertension, and BMI in the lowest quintile ($<22.4 \text{ kg/m}^2$), whereas a greater %-predicted FEV₁ was associated with reduced risk (3% reduction/%-predicted FEV₁) (Table 3A). When SCI level was added to this model, there was no significant increase in hazard among persons with cervical motor complete and ASIA C SCI ($p=0.14$; HR=1.62; 95% CI=0.85–3.10) nor among those with thoracic or lower motor complete and ASIA C SCI ($p=0.36$; HR=1.32; 95% CI=0.73–2.39) compared to ASIA D SCI. The reduced risk attributable to greater pulmonary function was similar when FVC was included. Separate models of circulatory and respiratory system hospitalizations were also considered. The predictors for circulatory and respiratory system hospitalizations considered separately were similar. The only exception was the greater effect of hypertension on respiratory admissions (HR=2.69; 95% CI=1.47–4.90) in contrast to the effect of hypertension

on circulatory admission risk (HR=1.18; 95% CI=0.73–1.90). The effects of age, hypertension, %-predicted FEV₁, or if in the lowest BMI quintile on cardiopulmonary admission risk were similar and remained significant whether or not VA service connected disability $\geq 50\%$ (p=0.06; HR=1.52, 95% CI=0.98–2.38) or Medicare enrollment (p=0.04; HR=0.60, 95% CI=0.37–0.97) were added to the final regression model.

RESPIRATORY SYMPTOMS AND PNEUMONIA

When added separately (Table 3B) to the multivariate model, any wheeze, persistent wheeze and cigarette smoking, were not significant predictors of circulatory, respiratory, or cardiopulmonary hospitalization. Chronic cough and chronic phlegm were stronger predictors of respiratory than circulatory hospitalizations but were not statistically significant in either model, and overall were of borderline significance in models including all cardiopulmonary hospitalizations. Effects of respiratory symptoms and of pneumonia were greater when measures of pulmonary function (FEV₁ %-predicted) were excluded from the multivariate models, particularly for respiratory admissions (Table 3C).

HEART DISEASE

When added to the multivariate model, a history of heart disease was a significant predictor of hospitalization for circulatory system causes, but not of respiratory diseases (Table 4). Hypertension remained a stronger predictor of respiratory admissions than of circulatory system diseases.

DISCUSSION

Our study is important because persons with SCI have very high hospitalization rates, and our study is the first to assess risk factors for cardiopulmonary hospital admissions prospectively using merged administrative and baseline assessment data. Our results demonstrate that cardiopulmonary admissions in SCI are strongly related to modifiable risk factors as in the able-bodied population and includes factors that are not unique to SCI. Pulmonary dysfunction is a common outcome of respiratory muscle paralysis, and both respiratory and cardiovascular diseases have previously been identified [6] as leading causes of death in chronic SCI. Circulatory and respiratory system illnesses frequently present with similar symptoms and signs, and mortality risk factors often double as determinants of hospitalization [11], providing the basis for jointly examining risk factors for cardiopulmonary hospitalizations. We expected to find that persons with a greater degree of neurologic impairment would have a significantly greater risk of hospital admissions for cardiopulmonary disease since these persons are likely to have greater degrees of respiratory impairment [7] and potentially have more cardiovascular disease risk factors such as a greater BMI. However, persons with cervical motor complete and ASIA C SCI (severe quadriplegia) had a risk of cardiopulmonary hospitalization that was of borderline significance after adjusting for age and readmission, and the risk was reduced further after accounting for other risk factors in a multivariate model. In this multivariate model, the risk for cardiopulmonary hospitalization was greater with increasing age, a history of hypertension, BMI in the lowest quintile, and with lower pulmonary function, adjusting for re-hospitalization within ≤ 30 days. Although there were some differences when circulatory and respiratory system admissions were considered separately, overall risk models were similar, and we were able to increase the power of the study and the precision of the risk estimates by considering both causes together.

Rather than restrict ourselves merely to investigating risk factors for the development of cardiopulmonary disease, we studied predictors of hospitalization since it is a more broadly acceptable measure of attributable morbidity. Frequent or avoidable admissions are costly to the health care system and disruptive to the rehabilitating patient's functional independence

and community reintegration. Understanding the causes of hospitalization provides insight into the potential for its reduction. Our selection of predictor variables was based on a conceptual model of healthcare utilization suggested by Andersen and coworkers [12] [13] and on known relationships between these variables and cardiopulmonary diseases. Cardiopulmonary hospitalization may occur for a variety of risk factors both related and unrelated to the specific development of cardiopulmonary diseases. The Andersen model [12] [13] considers determinants of health service utilization to include various predisposing and enabling factors unrelated to a specific medical condition as well as medical reasons for admission. In older adults, medical conditions have been found to be an important determinant of utilization [14], and risk factors for the development of cardiopulmonary disease may also serve as risk factors for worsening of the disease leading to hospital admission. In this cohort we were able to consider specific medical conditions and personal risk factors related to cardiopulmonary disease well as pulmonary function and respiratory symptoms. Predisposing factors include various socio-demographic characteristics and enabling factors relate to the logistical aspects of obtaining care including access to healthcare, income, and health insurance status. In this study all participants were eligible for VA care, but there was variation in priority and access based on service-connected status and Medicare enrollment.

Findings regarding SCI level and completeness of injury have been mixed in previous studies, and individuals with tetraplegia are reported to have a greater risk when assessed within 10 years since injury [4] [15] [16] [17] [18] [19] [20]. In contrast, our study included many persons assessed 10 or more years since injury when factors related to secondary medical conditions were important but SCI level and completeness of injury was not. All-cause hospitalization rate in our study (0.91 / person-year) was also higher than in the Model Systems (0.38 / person-year) 20 years post-SCI [5] and greater than that previously reported in VA hospitals in the 1970's and 1980's (0.55 / person-year) [4]. The causes of hospitalization, by organ system, in our study resembled those of Middleton et al [20] who found that 4.5% of readmissions were due to respiratory illness and 4.8% due to cardiovascular diseases among younger (mean age = 37.8 ± 17.4 years), predominantly (78%) male Australians with SCI. A previous study from the SCI Model System only examined 1-year risk for admission for any cause [15]. There was a lesser risk associated with greater education, functional independence, and ability to ambulate independently.

Our results suggest that cardiopulmonary admission risk was greater if the participant had a VA service connected disability of $\geq 50\%$ and was less likely if a participant was enrolled in Medicare. Veterans with service-connected disabilities rated by VA $\geq 50\%$ belong to the highest priority group [8] and are most eligible for hospitalization benefits [21]. These results indicate that although all persons with SCI in this cohort are veterans who were recruited at VA Boston and eligible for care, including hospitalization, the extent they are hospitalized for cardiopulmonary diseases in VA medical centers varied based on whether they had a VA service connected disability $\geq 50\%$ and had Medicare benefits. However, adjustment for these factors did not change the contribution of the risk factors identified in our multivariate model, and further suggest that our results are generalizable to persons with SCI hospitalized elsewhere regardless of the degree of VA service disability or Medicare enrollment. Previous studies in persons with SCI suggest that social factors such as education [15] are significant predictors, but our results highlight personal and medical variables as more important risk factors than most sociodemographics.

We assessed motorized and hand-propelled wheelchair use compared to others who walk as a risk factor for cardiopulmonary admission since persons who use these locomotive modes are likely to be less active compared to persons who walk. The *activity level hypothesis* in the literature suggests that hospitalization rates among persons with SCI are lower among persons with greater degrees of functional independence [15] [22]. Immobility is a risk factor for

pressure ulcers, and unemployed persons with SCI are reported to be at greatest risk for hospitalization partly because of a greater risk of developing pressure sores [15]. We found no evidence for the *activity level theory* in this study, since employment status and mode of locomotion were not significant risk factors.

A greater level of pulmonary function was a significant protective factor against cardiopulmonary hospitalization in this study. This is consistent with observations in the able-bodied that reduced pulmonary function is a risk factor for respiratory, cardiovascular, and all-cause mortality [23]. In our SCI cohort, previous analysis of deaths up to the year 2000 showed that greater levels of FEV₁ was also a protective factor for mortality [6]. Although respiratory symptoms were associated with pulmonary and overall cardiopulmonary hospitalization risk, with FEV₁ included in the model, the effects of respiratory symptoms and previous pneumonia were reduced. Although respiratory symptoms have been related to cardiovascular and pulmonary mortality in the general population independent of lung function [24], and for any-cause hospitalization independent of lung function in the general population [25], our data suggest that the assessment of pulmonary function in SCI is more important.

Reduced pulmonary function is a well described independent risk factor for cardiovascular mortality [26], and a lower FEV₁ may increase a person's vulnerability to a cardiac or pulmonary illness. However, reduced pulmonary function is associated with greater values of circulating markers of systemic inflammation (C-reactive protein) in the able-bodied [27], and therefore may also be a marker for greater cardiovascular disease risk on this basis.

Not surprisingly, we found that a history of heart disease was a significant predictor of circulatory disease admissions. We unexpectedly found a history of hypertension to be a strong predictor of hospitalization with respiratory illness. An independent association between hypertension and *Chlamydia pneumoniae* infection has been suggested in some studies [28]. Among the elderly population, hypertension has also been associated with reduced pulmonary function [29]. We know of no prior report of hypertension as an independent risk factor for respiratory illness in chronic SCI [30].

Although SCI is characterized by an increase in BMI and increase in adiposity, persons in the lowest BMI quintile at study entry had a significantly increased risk of cardiopulmonary hospitalization than persons with a greater BMI. We found that this increased risk was limited to those persons who had BMI near the lower normal range or who were underweight, and including persons who were only underweight provided similar results. Persons who were obese or overweight did not have an increased risk of cardiopulmonary hospitalization. Such an "obesity risk factor paradox" is also reported for morbidity and mortality outcomes in illnesses that may be associated with cachexia [31] including heart failure [32], end-stage renal disease [33], malignancies [34], and AIDS [35]. The cause of a greater cardiopulmonary hospitalization risk in persons with the lowest BMI in chronic SCI is uncertain, particularly since BMI was assessed at study entry often years before hospital admission.

STRENGTHS AND LIMITATIONS

A strength of this report is its prospective design and the identification of factors at study entry that were not considered in previous studies assessing hospitalization risk in chronic SCI. Although history of heart disease and hypertension were based on self-report, we previously validated the accuracy of self-reports of heart disease in 93% and those of hypertension in 80% of our cohort, which were concordant with clinical diagnoses in electronic charts [6]. Another limitation is that data on hospitalizations outside VA medical centers was not available, and that non-veterans were not included. As noted previously, adjustment for degree of VA service connected disability and Medicare enrollment did not change the results, suggesting that their relevance is not restricted to veterans with SCI. Employment status and locomotive mode might

not accurately reflect the full spectrum of activity level and it is possible that variables assessed at baseline changed over time. Random misclassification in baseline variables would decrease our ability to detect an effect on hospitalization risk, and a decrease in FEV₁ over time as compared to the baseline or further reduction in BMI could lead to underestimation of their true effect on hospitalization. We also acknowledge that BMI underestimates true adiposity in SCI, and it was not possible to measure stature and weight in all participants. Although our results indicate that the factors included in the final multivariate model are stronger predictors of cardiopulmonary admission than level and completeness of injury, it is possible that in a larger sample, a small residual effect of SCI level and completeness could be detected. When added to the final model, the hazard ratio for the effects of level and completeness of SCI decreased and its significance decreased, yet its point estimate remained positive.

IMPLICATIONS

Our findings have long-term implications for the medical care and follow-up of persons with chronic spinal cord injury, particularly as survival following SCI increases and medical conditions unrelated to the original injury occur. Previous studies have focused primarily on assessing hospitalization risk based on SCI level and completeness of injury, but our study suggests that cardiopulmonary admissions in chronic SCI are more strongly related to potentially modifiable risk factors. In addition, the strongest risk factors identified in our study are not unique to chronic SCI, but are conditions commonly addressed in the care of the able-bodied. In addition to SCI-related conditions that are more commonly addressed, we suggest that generalist and specialist physicians caring for these patients direct increased efforts at prevention of secondary medical conditions. The training of SCI-specialized physicians might need to reemphasize skills in managing chronic medical illnesses that have, until now, been viewed as necessary mostly for family physicians and general internists. Early identification and aggressive treatment of hypertension, heart disease, excessive weight loss and reduced pulmonary function among persons with SCI might reduce circulatory and respiratory system related hospitalizations.

CONCLUSIONS

In a multivariate model, independent predictors of cardiopulmonary hospitalization risk were greater age (3% increase per year), a history of hypertension, being in the lowest BMI quintile (<22.4 kg/m²), and lower pulmonary function (3% increase/unit decrease in %-predicted FEV₁). Cardiopulmonary hospitalization risk in chronic SCI was more significantly associated with modifiable factors than with SCI level and severity at an average of 20 years post-injury.

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Abbreviations

AIDS, Acquired Immune Deficiency Syndrome
 ASIA, American Spinal Injury Association
 BMI, Body Mass Index
 COPD, Chronic Obstructive Pulmonary Disease
 DXLSF, Length of Stay Diagnosis
 DXPRIME, Primary Admitting Diagnosis
 FEV₁, Forced Expiratory Volume in one second
 FVC, Forced Vital Capacity
 HR, Hazard Ratio
 ICD-9-CM, International Classification of Diseases, Ninth Edition, Clinically Modified
 SCI, Spinal Cord Injury
 VA, Veterans Affairs.

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Table 1

Baseline Characteristics

Variables	Cardiopulmonary Admission [N=75]	No Cardiopulmonary Admission [N=234]	Total [N=309]
n (%) Died 1996-2003	26 (35%)	36 (15%)	62 (20%)
Sociodemographics			
Age [Mean $\pm$ SD] yrs	60.1 $\pm$ 13.2	52.4 $\pm$ 14.0	54.3 $\pm$ 14.2
Male %	100.0	98.3	98.7
White %	96.0	94.0	94.5
Married %	61.3	47.4	50.8
Employed or Student %	17.3	26.5	24.3
Educated Beyond High School %	48.0	58.6	56.0
Enrolled in Medicare %	25.3	31.6	30.1
50-100% VA Service Eligibility %	41.3	39.7	40.1
Health Behaviors			
BMI [Mean $\pm$ SD] kg/m ²	25.9 $\pm$ 5.0	27.3 $\pm$ 5.4	27.0 $\pm$ 5.3
▪ % Underweight (< 18.5)	5.3	2.6	3.2
▪ % Normal ($\geq$ 18.5 - < 25)	38.7	32.1	33.7
▪ % Overweight ($\geq$ 25 - < 30)	33.3	38.5	37.2
▪ % Obese ($\geq$ 30)	22.7	26.9	25.9
Smoking Status (%)			
▪ Never Smoked	25.3	27.8	27.2
▪ Ex-Smoker	50.7	42.7	44.7
▪ Current Smoker	24.0	29.5	28.1
Alcohol use (%)	85.3	90.2	89.0
Alcohol (kg) consumed in preceding year	2.23 $\pm$ 5.49	4.88 $\pm$ 19.20	4.24 $\pm$ 16.95
Lifetime Alcohol Consumption (kg-yrs [*])	257 (69, 840)	223 (63, 578)	224 (64, 647)
Injury Characteristics			
Severity / Level (%)			
▪ Cervical motor complete and ASIA C	40.0	24.3	28.2
▪ Thoracic motor complete and ASIA C	42.7	43.2	43.0
▪ ALL Asia D	17.3	32.5	28.8
Duration of SCI [Mean $\pm$ SD] yrs	27.6 $\pm$ 15.2	18.3 $\pm$ 13.1	20.0 $\pm$ 13.9
Traumatic (%)	89.3	89.3	89.3
Locomotive Mode > 50% of time (%)			
Motorized Wheelchair	21.3	15.4	16.8
Hand-propelled Wheelchair	65.3	57.3	59.2

Variables	Cardiopulmonary Admission [N=75]	No Cardiopulmonary Admission [N=234]	Total [N=309]
Walks with or without aid	13.3	27.4	24.0
Respiratory Symptoms (%)			
Any Wheeze	52.0	50.0	50.5
Persistent Wheeze	25.3	20.9	22.0
Chronic Phlegm	24.0	23.5	23.6
Chronic Cough	26.7	18.0	20.1
Dyspnea	14.7	9.0	10.4
Pulmonary Function [Mean $\pm$ SD]			
FVC-%Predicted	68.0 $\pm$ 18.5	78.1 $\pm$ 17.5	75.7 $\pm$ 18.3
FEV ₁ -%Predicted	67.2 $\pm$ 19.7	78.0 $\pm$ 18.4	75.4 $\pm$ 19.3
Comorbid Illnesses (%)			
COPD	10.7	9.0	9.4
Asthma	5.3	9.4	8.4
Pneumonia	26.7	17.1	19.4
Hypertension	44.0	29.9	33.3
Diabetes Mellitus	12.0	15.0	14.2
Heart Disease	16.0	10.7	12.0

* 1 kilogram-year = 1½ beers or 1¾ wine glasses or 1¼ shots of liquor per week for a year.

Table 2
Hazard Ratios for Cardiopulmonary Hospitalization[§]

Variable	Unadjusted (95% CI)	Adjusted [‡] (95% CI)
Age	1.03 (1.01 – 1.06)	1.03 (1.00 – 1.05)
Married	1.39 (0.77 – 2.52)	1.02 (0.65 – 1.62)
Currently Employed or Student	0.66 (0.36 – 1.22)	1.04 (0.51 – 2.11)
Education Level: Beyond High School	0.85 (0.49 – 1.47)	0.85 (0.52 – 1.37)
Enrolled in Medicare	0.67 (0.37 – 1.21)	0.58 (0.35 – 0.94)
VA Service Eligibility: ≥50% Service Connected	1.77 (1.06 – 2.96)	1.72 (1.10 – 2.67)
Calendar Year		
▪ 2002 – 2003	1.48 (0.77 – 2.82)	0.99 (0.52 – 1.90)
▪ 2000 – 2001	0.95 (0.55 – 1.65)	0.75 (0.43 – 1.31)
▪ 1998 – 1999	1.47 (0.88 – 2.47)	1.18 (0.73 – 1.91)
▪ 1996 – 1997	1.00	1.00
Body Mass Index		
Lowest BMI quintile (BMI < 22.43 kg/m ²)	2.21 (1.17 – 4.18)	2.23 (1.32 – 3.77)
Quintiles 2 – 5	1.0	1.0
Cigarette Smoking		
Cigarette Smoker Category		
▪ Current Smoker	1.39 (0.63 – 3.04)	1.92 (1.04 – 3.56)
▪ Ex-smoker	1.48 (0.83 – 2.65)	1.42 (0.86 – 2.36)
▪ Never smoker	1.0	1.0
Alcohol Consumption		
Alcohol (kg) consumed in preceding year	0.98 (0.95 – 1.02)	0.99 (0.97 – 1.01)
Lifetime Alcohol Consumption (kg-yrs [*])	1.00 (1.00 – 1.00)	1.00 (1.00 – 1.00)
SCI Level/Severity		
Cervical motor complete and ASIA C	1.88 (0.96 – 3.69)	1.89 (0.99 – 3.63)
Thoracic motor complete and ASIA C	1.69 (0.81 – 3.54)	1.60 (0.82 – 3.14)
All ASIA D	1.0	1.0
Duration of SCI	1.04 (1.02 – 1.05)	1.02 (1.01 – 1.04)
Locomotive Mode >50% of time		
Motorized Wheelchair	1.37 (0.59 – 3.14)	1.33 (0.59 – 2.99)
Hand-propelled Wheelchair	1.79 (0.85 – 3.79)	1.63 (0.80 – 3.30)
Walks with or without aid	1.00	1.00

Variable	Unadjusted (95% CI)	Adjusted ⁷ (95% CI)
Respiratory Symptoms		
Any Wheeze	1.40 (0.83 – 2.39)	1.55 (1.01 – 2.39)
Persistent Wheeze	2.20 (1.17 – 4.15)	1.84 (1.04 – 3.25)
Chronic Cough	2.44 (1.34 – 4.43)	2.17 (1.31 – 3.60)
Chronic Phlegm	2.10 (1.14 – 3.87)	1.76 (1.00 – 3.08)
Pulmonary Function		
FEV ₁ -%Predicted	0.97 (0.95 – 0.99)	0.97 (0.96 – 0.99)
FVC-%Predicted	0.97 (0.96 – 0.99)	0.97 (0.96 – 0.98)
Comorbid Illnesses		
COPD	0.66 (0.34 – 1.28)	0.62 (0.35 – 1.12)
Asthma	1.15 (0.35 – 3.81)	1.23 (0.48 – 3.15)
Pneumonia	2.22 (1.14 – 4.30)	1.94 (1.09 – 3.47)
Hypertension	2.17 (1.27 – 3.72)	1.86 (1.08 – 3.20)
Diabetes	0.98 (0.47 – 2.05)	0.81 (0.41 – 1.58)
Heart Disease	2.19 (1.14 – 4.20)	1.52 (0.90 – 2.56)

⁷Adjusted for age, & readmission in ≤30 Days.

* 1 kilogram-year = 1½ beers or 1¾ wine glasses or 1¼ shots of liquor per week for a year.

[§]**Bolded numbers** represent statistical significance, i.e. $p < 0.05$

Table 3
Multivariable Models ^ζ of Cardiopulmonary Hospitalizations[§]

Model	Cardiopulmonary HR (95% CI) (n=143)	Circulatory System HR (95% CI) (n=77)	Respiratory System HR (95% CI) (n=66)
A. Multivariate Model			
Age	1.03 (1.01–1.05)	1.05 (1.03–1.07)	1.01 (1.00–1.03)
Hypertension	1.74 (1.12–2.75)	1.18 (0.73–1.90)	2.69 (1.47–4.90)
FEV ₁ -%predicted	0.97 (0.96–0.98)	0.99 (0.98–1.00)	0.96 (0.94–0.97)
Lowest BMI quintile	1.79 (1.19–2.68)	1.46 (0.83–2.54)	1.99 (1.13–3.51)
B. Each variable added:			
Any Wheeze	1.02 (0.70–1.49)	1.01 (0.63–1.64)	1.13 (0.62–2.06)
Persistent Wheeze	1.08 (0.71–1.65)	0.86 (0.50–1.49)	1.32 (0.70–2.49)
Chronic Phlegm	1.48 (0.93–2.38)	1.07 (0.62–1.84)	1.88 (0.94–3.73)
Chronic Cough	1.54 (1.02–2.33)	1.23 (0.76–1.99)	1.91 (0.98–3.72)
Pneumonia	1.53 (0.99–2.38)	1.25 (0.69–2.28)	1.52 (0.89–2.61)
C. Each variable added in place of FEV₁:			
Any Wheeze	1.28 (0.85–1.93)	1.12 (0.69–1.83)	1.59 (0.83–3.04)
Persistent Wheeze	1.44 (0.91–2.30)	0.98 (0.57–1.67)	2.07 (1.10–3.91)
Chronic Phlegm	1.62 (0.99–2.66)	1.10 (0.64–1.90)	2.24 (1.15–4.37)
Chronic Cough	1.70 (1.09–2.65)	1.28 (0.78–2.10)	2.23 (1.14–4.36)
Pneumonia	1.89 (1.18–3.01)	1.31 (0.73–2.33)	2.47 (1.37–4.47)

^ζAdjusted for any-cause readmission within ≤ 30 days

[§]**Bolded numbers** represent statistical significance, i.e. $p < 0.05$

Table 4Assessment of Effects of Heart Disease on Cardiopulmonary Hospitalization ^ζ §

Model	Cardiopulmonary HR (95% CI) (n=143)	Circulatory HR (95%CI) (n=77)	Respiratory HR (95%CI) (n=66)
Age	1.03 (1.01–1.05)	1.05 (1.03–1.07)	1.01 (0.99–1.03)
Hypertension	1.66 (1.04–2.65)	1.03 (0.64–1.66)	2.70 (1.47–4.94)
FEV ₁ -%predicted	0.97 (0.96–0.98)	0.99 (0.98–1.00)	0.96 (0.94–1.00)
Lowest BMI quintile	1.77 (1.19–2.62)	1.42 (0.85–2.38)	1.99 (1.13–3.52)
Heart Disease	1.40 (0.84–2.32)	1.92 (1.13–3.24)	0.97 (0.38–2.51)
Heart Disease (excluding hypertension)	1.66 (1.00–2.74)	1.93 (1.14–3.27)	1.35 (0.53–3.47)

^ζ Adjusted for any-cause readmission within ≤ 30 days[§] **Bolded numbers** represent statistical significance, i.e. p < 0.05