Health Care Resource Use and Costs of Two-Year Survivors of Acute Lung Injury

An Observational Cohort Study

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Abstract

Rationale: Survivors of acute lung injury (ALI) require ongoing health care resources after hospital discharge. The extent of such resource use, and associated costs, are not fully understood.

Objectives: For patients surviving at least 2 years after ALI, we evaluated cumulative 2-year inpatient admissions and related costs, and the association of patient- and intensive care unit–related exposures with these costs.

Methods: Multisite observational cohort study in 13 intensive care units at four academic teaching hospitals evaluating 138 two-year survivors of ALI.

Measurements and Main Results: Two-year inpatient health care use data (i.e., admissions to hospitals, and skilled nursing and rehabilitation facilities) were collected for patients surviving at least 2 years, via (1) one-time retrospective structured interview with patient and/or proxy, (2) systematic medical record review for nonfederal study site hospitals, and (3) inpatient medical record review for non-study site hospitals, as needed for clarifying patient/proxy reports. Costs are reported in 2013 U.S. dollars. A total of 138 of

142 (97%) 2-year survivors completed the interview, with 111 (80%) reporting at least one inpatient admission during follow-up, for median (interquartile range [IQR]) estimated costs of \$35,259 (\$10,565–\$81,166). Hospital readmissions accounted for 76% of costs. Among 12 patient- and intensive care unit–related exposures evaluated, baseline comorbidity and intensive care unit length of stay were associated with increased odds of incurring any follow-up inpatient costs. Having Medicare or Medicaid (vs. private insurance) was associated with median estimated costs that were 85% higher (relative median, 1.85; 95% confidence interval, 1.01–3.45; $P = 0.045$).

Conclusions: In this multisite study of 138 two-year survivors of ALI, 80% had one or more inpatient admission, representing a median (IQR) estimated cost \$35,259 (\$10,565–\$81,166) per patient and \$6,598,766 for the entire cohort. Hospital readmissions represented 76% of total inpatient costs, and having Medicare or Medicaid before ALI was associated with increased costs. With the aging population and increasing comorbidity, these findings have important health policy implications for the care of critically ill patients.

Keywords: acute lung injury; critical care; long-term survivors; patient readmission; health care costs

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Survivors of acute lung injury (ALI) frequently experience long-lasting physical, cognitive, and mental health impairments (1–7). Such impairments may be associated with increased health care resource use and related costs after hospital discharge; however, these issues have not been fully evaluated (8, 9).

In the United States, critical care costs, including 1-year follow-up care, account for up to 11.2% of total health care spending or 2% of gross domestic product (GDP) (10). With the aging population, more patients are expected to require intensive care (11–14), increasing the need to understand factors associated with health care costs incurred by long-term survivors of critical illness. Moreover, with more patients being eligible for Medicare and Medicaid (15) and the introduction of accountable care organizations (16–18), there is heightened emphasis on understanding and minimizing hospital readmissions and postdischarge costs.

Our objectives are to evaluate inpatient admissions, associated costs, and patient- and intensive care unit (ICU)-related factors associated with such costs for 2-year survivors of ALI. Some results of this study have been previously reported as an abstract (19).

Methods

Study Cohort

This analysis was conducted as part of the Improving Care of Acute Lung Injury Patients (ICAP) Study (20), a prospective cohort study investigating long-term outcomes of survivors of ALI. The study enrolled consecutive, mechanically ventilated patients with ALI, diagnosed according to the American–European Consensus criteria (21), from 13 ICUs at 4 teaching hospitals in Baltimore, Maryland between 2004 and late 2007, with 2-year follow-up ending in 2010. Neurological subspecialty ICUs and patients with primary neurological disease or head trauma were not eligible. Moreover, on the basis of medical record review (with clarification from the patient's clinical team and surrogate decision maker), the ICAP Study excluded patients with (1) preexisting comorbid illness with a life expectancy not exceeding 6 months (e.g., metastatic cancer), (2) preexisting cognitive impairment or communication/language

barriers, (3) no fixed address for follow-up, (4) preexisting ALI of more than 24 hours' duration on hospital transfer, (5) mechanically ventilated for more than 5 days before ALI onset, (6) previous lung resection, (7) and a physician order for no escalation of care (e.g., no vasopressors) at ALI onset. We obtained written informed consent for prospective follow-up after decision-making capacity was regained (or via proxies if the patient was incapacitated). Given our focus on health care resource use and costs of long-term survivors of ALI, this analysis only included patients surviving at least 2 years after ALI; data were not available for those who died before 2 years. The institutional review boards of all participating study sites approved this research.

Collection of Inpatient Admissions Data

Inpatient admissions data, from index ALI hospitalization discharge until 2 years after ALI, were collected via a one-time, retrospective structured interview with patients and/or proxies. The data collection instrument was adapted from a prior ALI study (22) and collected data on admissions to (1) hospitals, (2) skilled nursing facilities, and (3) rehabilitation facilities. We verified these admissions via systematic medical record review for all enrolled patients at the three nonfederal study site hospitals and via medical records review for non-study site hospitals whenever there was uncertainty in the patient/proxy report.

Costing Methods

This study evaluated direct medical costs for inpatient admissions, using the perspective of the health care payer. Hospital charges for patients' index ALI hospitalization were obtained from study site financial databases. Costs of follow-up care were estimated as patient-level charges were not available. All Patient Refined Diagnosis Related Groups (APR-DRG)-based (23) charge data from the Maryland Health Services Cost Review Commission (HSCRC) (24, 25) were used to estimate costs for hospital readmissions. The HSCRC is a rate-setting body for hospital services for the state of Maryland, which sets hospital billing rates equally regardless of payer (18). We implemented an established costing methodology (26) using hospital charges per day based on hospital site, admission reason, and fiscal year.

We multiplied the length of stay for each hospitalization by the HSCRC hospital charge per day. These hospital charges were adjusted to estimated health care costs using hospital-specific Centers for Medicare and Medicaid Services (CMS) 2012 cost-to-charge ratios (25). To account for physician charges, excluded from HSCRC hospital data, we added 17% to hospital charges as in prior research (10, 27). To estimate costs, all reported hospital readmissions were attributed to the index ALI hospitalization study site hospital as charge data for non-study site hospitals are proprietary. For one 2-year survivor enrolled from a Veterans Affairs medical center, the hospital readmission costs were based on the affiliated nonfederal study site hospital.

Provider-reported charges from the MetLife Mature Market Institute Survey of Long-Term Care Costs were used for skilled nursing and rehabilitation facility admissions (28). These charges were adjusted to costs using a cost-to-charge ratio derived from CMS data (29).

All inpatient costs were inflated to 2013 U.S. dollars (30) using the Consumer Price Index (31). To compare costs with previously published literature reported in Canadian dollars, we inflated prior study costs, in the original currency, to 2013 costs using a currency-specific inflation calculator (32) and then converted to 2013 U.S. dollars using purchasing power parity (33).

Patient- and ICU-Related Exposures

Patient- and ICU-related exposure variables evaluated for association with inpatient follow-up health care costs were selected *a priori* on the basis of existing literature. The following patient baseline characteristics, before ALI, were considered: age, sex, race, location of residence (home vs. other), estimated income (median income by ZIP code reported by Nielsen Claritas, Inc.) (34, 35), medical insurance (Medicare or Medicaid, private, or no insurance), and having an informal caregiver residing with the patient and providing assistance before ALI. Patients' pre-ALI comorbidity burden was measured by the Functional Comorbidity Index (36) and the Charlson Comorbidity Index (37).

The following ICU-related exposures were evaluated: Acute Physiology and Chronic Health Evaluation (APACHE) II severity of illness score at ICU admission

(38), mean daily Sequential Organ Failure Assessment (SOFA) score (39) in the ICU, and ICU length of stay.

Statistical Methods

Standard descriptive statistics summarized patient baseline and ICU exposures. Reported admissions with missing length of stay data (15 of 357 [4%] admissions) had length of stay imputed using the cohort median for each admission type (hospital, skilled nursing, or rehabilitation) and reason (for hospital admissions). A sensitivity analysis using only admissions with fully reported length of stay ($n = 342$ of 357 admissions) was performed.

The distribution of 2-year inpatient follow-up costs has subjects with no costs (i.e., no inpatient admissions) and for those with any cost, a positively skewed distribution given a small number of patients with extremely high costs (Figure 1). To account for this distribution, a Hurdle two-part regression model (40–42) was constructed to evaluate exposures associated with inpatient follow-up costs. The Hurdle two-part regression model partitions the cost information for an individual into two independent parts: (1) any versus no cost and (2) the magnitude of

the cost. The first part was a logistic regression model, evaluating whether patients had any versus no inpatient costs, with results reported as odds ratios. The second part was a linear regression of the log-transformed total 2-year inpatient follow-up cost among patients with any cost. The linear regression results of the log-transformed cost data were reported as relative median costs. Selection of exposure variables for the multivariable two-part regression model was performed by evaluating the model fit for all combinations of predictors (2^{12} models) for the logistic and linear models, with selection of variables based on minimizing Akaike's information criterion for the joint model (43, 44). Variance inflation factors confirmed no multicollinearity (45). For the logistic model, the Hosmer–Lemeshow test (46) confirmed model fit. Model fit for the linear regression was confirmed using standardized residuals versus predicted value and predictor plots, Cook's distance, and the normal quantile plot for the residuals. Linearity of continuous variables was assessed via evaluation of scatter plots of residuals versus continuous variables with locally weighted regression smoothers. A two-sided P value less than 0.05 was considered statistically significant.

Figure 1. Distribution of 2-year inpatient cost data by patient. This figure demonstrates the distribution of the total 2-year cost of inpatient resource use (depicted here on a log base 2 scale). The distribution had subjects with no costs ($n = 27$), as they had no inpatient admissions during follow-up. For those with any inpatient follow-up cost ($n = 111$), there was a skewed distribution given a small number of patients with extremely high costs, which was normalized on a log scale. To account for this distribution, a two-part regression model (40, 41) was constructed to evaluate exposures associated with inpatient follow-up costs, with the first part being a logistic regression model for having any inpatient follow-up cost and the second a linear regression on the log-transformed costs for those with any positive costs. ALI = acute lung injury.

To aid interpretation of the two-part regression model, we combined the odds of having any inpatient admission with median expected costs if a patient was ever admitted. We then calculated estimated median 2-year inpatient follow-up costs for a prototypical patient (defined as a male without an informal caregiver before ALI, Charlson Comorbidity Index of 1, ICU length of stay of 2 wk, with Medicare or Medicaid insurance) and evaluated differences in estimated costs varying values for these exposures. We obtained estimated median costs by multiplying the estimated probability of any cost from the logistic regression model by the estimated median cost from the linear regression model, with 95% confidence intervals calculated from 1,000 bootstrap samples (47). Statistical analyses performed with R statistical software (version 2.15.2; Vienna, Austria).

Results

Baseline Patient Characteristics

A total of 138 of 142 (97%) 2-year survivors completed the structured interview of health care resource use and were included in this analysis (Figure 2). Of these 2-year survivors, the mean (SD) age was 47 (14) years, 64 (46%) were female, and 78 (56%) were white (Table 1). The mean (SD) estimated household income was \$51,820 (\$20,971), with no significant difference between patients with versus without inpatient follow-up admissions ($P = 0.452$). The vast majority of patients (129 of 138; 93%) reported having medical insurance before their ALI hospitalization (Table 1). For the ALI hospitalization, the mean (SD) ICU and hospital lengths of stay were 19 (18) and 30 (22) days, respectively.

Follow-Up Inpatient Admissions

Overall, 111 of 138 (80%) 2-year survivors reported one or more inpatient admissions to a hospital, skilled nursing facility, or rehabilitation facility during 2-year follow-up. A total of 92 (67%) 2-year survivors were readmitted to a hospital, with mean (SD) of 2.7 (2.4) hospitalizations and a mean (SD) hospital length of stay of 6 (8) days (Table 2). Of patients ever readmitted to the hospital, 32% (29 of 92) had their first hospital readmission occur within 30 days of discharge from the index hospitalization. Of the 250 hospital readmissions, the most common admission categories were infection

Figure 2. Flow diagram of 2-year survivors of acute lung injury. ALI = acute lung injury; ARDS = acute respiratory distress syndrome.

(26%), cardiovascular (13%), gastrointestinal (11%), endocrine (7%), orthopedics (7%), and psychiatry (7%), with hospital readmissions occurring more frequently during the first year after ALI (Table 2).

The majority (61 of 72; 85%) of patients admitted to a skilled nursing or

rehabilitation facility reported at least one such admission directly related to their ALI hospitalization. Such admissions were more common during the first year after ALI (Table 2). The mean (SD) length of stay for patients admitted to a skilled nursing facility and a rehabilitation facility,

respectively, was 142 (221) and 32 (37) days.

Estimated Costs of Inpatient Admissions

The median (interquartile range [IQR]) estimated cost of hospital readmission

Table 1. Baseline patient and intensive care unit variables for 2-year survivors of acute lung injury

Variable	All Patients (n = 138)	Patients with Any Inpatient Admissions over 2 Years (n = 111)	Patients with No Inpatient Admissions over 2 Years (n = 27)	P Value*
Age (yr), mean (SD)	47 (14)	47 (14)	46 (14)	0.916
Female, no. (%)	64 (46)	48 (43)	16 (59)	0.138
White, no. (%)	78 (57)	66 (59)	12 (44)	0.161
Charlson Comorbidity Index, mean (SD)	1.9 (2.3)	2.1 (2.5)	0.8 (1.4)	0.017
Functional Comorbidity Index, mean (SD)	1.5 (1.4)	1.6 (1.5)	1.2 (1.0)	0.200
Living at home before ALI, no. (%)	131 (96)	105 (95)	26 (96)	0.719
Informal caregiver before ALI, no. (%)	63 (46)	46 (41)	17 (63)	0.048
Estimated income (\$), mean (SD)	51,820 (20,971)	52,486 (20,959)	49,102 (21,194)	0.452
Medically insured, no. (%) [†]	129 (95)	103 (93)	26 (96)	0.516
Private insurance	41 (30)	28 (25)	13 (48)	REF
Medicare or Medicaid	88 (64)	75 (68)	13 (48)	0.029
No insurance	9 (7)	8 (7)	1 (4)	0.767
APACHE II score, mean (SD)	23 (8)	24 (8)	21 (8)	0.149
Mean daily SOFA score, mean (SD)	5 (2)	6 (3)	5 (2)	0.341
ICU length of stay (d), mean (SD)	19 (18)	20 (19)	14 (8)	0.081

Definition of abbreviations: ALI = acute lung injury; APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; REF = reference group; SOFA = Sequential Organ Failure Assessment.

*P values were calculated on the basis of simple logistic regression analysis of patients with any versus no inpatient resource use.

[†]Within the categorical variable representing the type of medical insurance, the column percentages may not add to 100% because of rounding.

Table 2. Inpatient admissions and associated costs

Inpatient Facility Hospital Readmissions	Year 1	Year 2	Overall for 2 Years	Total Cost* [\$ (%)]	Cost (\$) for Patients Using Service† [median (IQR)]	Cost (\$) for Patients Using Service† [mean (SD)]
Patients ever using service, no. (%)	71 (51)	55 (40)	92 (67)	5,025,910 (76)	29,864 (13,625–66,288)	54,629 (71,156)
No. of admissions,‡ median (IQR)	2 (1–2)	1 (1–2)	2 (1–2)			
No. of admissions,‡ mean (SD)	2 (1.4)	2 (1.7)	2.7 (2.4)			
Length of stay (d), median (IQR)	4 (2–7)	4 (2–7)	4 (2–7)			
Length of stay (d), mean (SD)	6 (8)	6 (9)	6 (8)			
Skilled nursing facility admissions						
Patients ever using service, no. (%)	23 (17)	3 (2)	24 (17)	774,372 (12)	11,239 (4,355–26,693)	14,464 (19,096)
No. of admissions,‡ median (IQR)	1 (1–1)	1 (1–1.5)	1 (1–1)			
No. of admissions,‡ mean (SD)	1.1 (0.3)	1.3 (0.6)	1.2 (0.5)			
Length of stay (d), median (IQR)	56 (14–99)	79 (55–194)	60 (16–104)			
Length of stay (d), mean (SD)	137 (227)	171 (211)	142 (221)			
Rehabilitation facility admissions						
Patients ever using service, no. (%)	48 (35)	11 (8)	55 (40)	798,484 (12)	7,912 (4,286–16,319)	32,266 (46,047)
No. of admissions,‡ median (IQR)	1 (1–1)	1 (1–1)	1 (1–1)			
No. of admissions,‡ mean (SD)	1.4 (1.1)	1.0 NA‡	1.4 (1.1)			
Length of stay (d), median (IQR)	24 (9–32)	32 (26–46)	21 (9–30)			
Length of stay (d), mean (SD)	31 (39)	37 (25)	32 (37)			
Summary costs						
Two-year follow-up inpatient cost, \$				6,598,766 (100)	35,259 (10,565–81,166)	59,422 (77,678)
Cost of index ALI hospitalization				18,545,323	98,822 (56,690–165,933)	138,005 (98,822)
Total cost, \$				25,144,089	124,316 (82,463–240,743)	182,182 (174,200)

Definition of abbreviations: ALI = acute lung injury; IQR = interquartile range; NA = not applicable.

*All costs reported in 2013 U.S. dollars.

†For patients using each inpatient service during follow-up time frame.

‡Of 11 patients admitted to a rehabilitation facility in Year 2, each had only one readmission; therefore, no standard deviation is reported.

during 2-year follow-up, for all 92 two-year survivors of ALI with hospital readmissions, was \$29,864 (\$13,625–\$66,288; 90th percentile, \$107,482; mean [SD], \$54,629 [\$71,156] Table 2). Costs of hospital readmissions accounted for 76% of inpatient follow-up costs, with 64% of follow-up costs incurred during the first year. The median (IQR) estimated cost of the index ALI hospitalization was \$98,822 (\$56,690–\$165,933; 90th percentile, \$258,090; mean [SD], \$138,005 [\$98,822]), with the estimated cost for the cohort (n = 138) totaling \$18,545,323. The median (IQR) estimated cost of 2-year follow-up inpatient admissions for all 111 patients with any inpatient care was \$35,259 (\$10,565–\$81,166; 90th percentile, \$143,364; mean [SD], \$59,422 [\$77,6878]) and the estimated cohort cost was \$6,598,766, approximating one-third of the index ALI hospitalization costs. The median (IQR) estimated cost of inpatient care for the cohort (n = 138), combining the index hospitalizations with follow-up inpatient care, was \$124,316 (\$82,463–\$240,743; 90th percentile, \$335,457; mean [SD], \$182,182 [\$174,200]) with a total estimated cost for the cohort of \$25,144,089.

Patient and ICU Exposures Associated with Follow-Up Inpatient Costs

In multivariable logistic regression analysis, patient and ICU exposures significantly associated (odds ratio, 95% confidence interval [CI], *P* value) with incurring any inpatient costs during 2-year follow-up were (Table 3) as follows: Charlson Comorbidity Index (1.51, 1.10–2.78; *P* = 0.025) and ICU length of stay (1.51, 1.09–2.34 per week; *P* = 0.038), while having an informal caregiver pre-ALI was associated with decreased odds of any follow-up costs (0.34, 0.12–0.90; *P* = 0.034). In multivariable linear regression of cumulative 2-year inpatient costs among those incurring any cost, median estimated costs were 85% higher (relative median, 1.85; 95% CI, 1.01–3.45; *P* = 0.045) for patients with Medicare or Medicaid (vs. private insurance) (Table 4). In sensitivity analysis, there was no material change in results when patients with imputed length of stay values were excluded.

Table 3. Baseline patient and intensive care unit variables associated with having any inpatient admissions

Variable	Bivariable Analysis		Multivariable Analysis*	
	OR [†] (95% CI)	P Value [‡]	OR [†] (95% CI)	P Value [‡]
Age, per decade	1.02 (0.74–1.39)	0.916		
Female	0.52 (0.22–1.23)	0.138	0.40 (0.15–1.02)	0.061
White	1.83 (0.78–4.28)	0.161		
Charlson Comorbidity Index	1.49 (1.07–2.07)	0.017	1.51 (1.10–2.78)	0.025
Functional Comorbidity Index	1.25 (0.89–1.77)	0.200		
Living at home before ALI	0.67 (0.08–5.84)	0.719		
Informal caregiver before ALI	0.42 (0.17–0.99)	0.048	0.34 (0.12–0.90)	0.034
Estimated income, per \$10,000	1.09 (0.88–1.35)	0.452		
Medically insured (%)	0.50 (0.06–4.14)	0.516		
Private insurance	REF		REF	
Medicare or Medicaid	2.70 (1.11–6.67)	0.029	2.70 (0.97–7.70)	0.592
No insurance	3.71 (0.42–32.90)	0.767	3.85 (0.37–40.12)	0.763
APACHE II score	1.24 (0.93–1.65)	0.149		
Mean daily SOFA score	1.61 (0.61–4.27)	0.341		
ICU length of stay, per week	1.35 (0.96–1.89)	0.081	1.51 (1.09–2.34)	0.038

Definition of abbreviations: ALI = acute lung injury; APACHE = Acute Physiology and Chronic Health Evaluation; CI = confidence interval; ICU = intensive care unit; OR = odds ratio; REF = reference group; SOFA = Sequential Organ Failure Assessment.

*Variables in this column were included in the multivariable model and were selected on the basis of minimization of Akaike's information criterion.

[†]The odds ratios represent the relative odds of a patient having any versus no follow-up inpatient costs as a function of the exposures. An odds ratio less than 1 indicates that as the exposure increases in magnitude, the odds of having any inpatient admission decreases.

[‡]P values were calculated using simple and multivariable logistic regression analysis of patients with any versus no inpatient resource use.

Estimated Median Costs for Inpatient Admissions

In our two-part regression model, the prototypical patient (male without an

informal caregiver before ALI, Charlson Comorbidity Index of 1, ICU length of stay of 2 wk with Medicare or Medicaid) had an estimated median (95% CI) cost of

\$27,445 (\$16,233–45,096) (Figure 3). The highest estimated median costs were for a male patient with an informal caregiver, a Charlson Comorbidity Index of 2, ICU length of stay of 3 weeks and Medicare or Medicaid, with a median (95% CI) cost of \$36,767 (\$24,601–\$57,958). Median (95% CI) estimated 2-year costs for patients with Medicare or Medicaid were higher than for patients with private insurance, holding other exposures constant (Figure 3).

Discussion

In this multisite prospective cohort study of 138 two-year survivors of ALI, we evaluated inpatient admissions, estimated costs, and patient and ICU exposures associated with these costs. We found that 80% of survivors required one or more inpatient admissions to a hospital, skilled nursing facility, or rehabilitation facility during 2-year follow-up. The median (IQR) costs of follow-up inpatient care were \$35,259 (\$10,565–\$81,166), with 64% of these costs incurred during the first year of follow-up, and 76% of these costs incurred due to hospital readmission, rather than skilled nursing or rehabilitation facility admission. Of patients ever readmitted to the hospital, one-third were first readmitted within 30 days. Charlson Comorbidity Index and ICU

Table 4. Variables associated with total inpatient admissions costs*

Variable	Bivariable Analysis		Multivariable Analysis [†]	
	Relative Median [‡] (95% CI)	P Value [§]	Relative Median [‡] (95% CI)	P Value [§]
Age, per decade	0.98 (0.82–1.19)	0.870		
Female	0.81 (0.49–1.34)	0.407	0.79 (0.48–1.32)	0.364
White	0.73 (0.44–1.21)	0.224		
Charlson Comorbidity Index	1.10 (0.99–1.21)	0.078	1.08 (0.97–1.21)	0.140
Functional Comorbidity Index	1.03 (0.87–1.23)	0.736		
Living at home before ALI	0.36 (0.12–1.09)	0.074		
Informal caregiver before ALI	1.21 (0.73–2.01)	0.466	1.20 (0.71–2.02)	0.492
Estimated income, per \$10,000	0.98 (0.87–1.11)	0.763		
Medically insured (%)	1.03 (0.39–2.75)	0.950		
Private insurance	REF		REF	
Medicare or Medicaid	2.04 (1.15–3.70)	0.016	1.85 (1.01–3.45)	0.045
No insurance	1.63 (0.18–14.5)	0.647	1.69 (0.19–14.98)	0.856
APACHE II score	1.01 (0.86–1.18)	0.923		
Mean daily SOFA score	1.21 (0.73–2.03)	0.461		
ICU length of stay, per week	1.02 (0.93–1.12)	0.635	1.05 (0.96–1.16)	0.284

Definition of abbreviations: ALI = acute lung injury; APACHE = Acute Physiology and Chronic Health Evaluation; CI = confidence interval; ICU = intensive care unit; REF = reference group; SOFA = Sequential Organ Failure Assessment.

*This analysis includes only patients incurring any follow-up inpatient costs (n = 111).

[†]Variables in this column were included in the multivariable model and were selected on the basis of minimization of Akaike's information criterion.

[‡]The relative median represents the ratio of estimated median costs, comparing incremental values of the exposure variable, and is obtained from a linear regression model fit for log-transformed total 2-year costs.

[§]P values were calculated on the basis of simple and multivariable linear regression analysis of log-transformed total 2-year inpatient costs.

Figure 3. Estimated median costs for inpatient admissions during 2-year follow-up. This figure represents the estimated median costs of 2-year follow-up inpatient admissions (y axis) at the 25th and 75th percentiles of baseline Charlson Comorbidity Index (0 and 2, respectively) (x axis) for insurance type (Medicare or Medicaid vs. private insurance). The mode sex of male and the mode status for informal caregiver status pre-ALI (none) were used in the model shown. The plotted points depict the estimated median cost at the 25th and 75th percentiles for ICU LOS (1 and 3 wk, respectively). The vertical line going through each point represents the 95% confidence interval for each median expected cost, calculated by the percentile method based on 1,000 bootstrap samples. ALI = acute lung injury; ICU = intensive care unit; LOS = length of stay.

length of stay were positively associated with incurring any cost during 2-year follow-up, and having an informal caregiver before ALI was negatively associated. For those incurring any cost, the median total 2-year follow-up inpatient costs were increased for patients with Medicare or Medicaid (vs. private insurance).

The proportion of patients readmitted to the hospital in our study was similar to a national multicenter study of survivors of ALI in the United States (48) (Table 5). Compared with a single-center cohort of Canadian survivors of acute respiratory disease syndrome (ARDS), our study had a markedly higher rate of readmissions over the 2-year follow-up period (Table 5), with a twofold increase in the mean number of readmissions (1.8 vs. 0.9 per patient). However, this increase might be explained by the Canadian study enrolling all patients with ARDS surviving their index hospitalization versus our focus on 2-year survivors. Our study's hospital readmission

length of stay also was longer than in the Canadian study (Table 5). However, determinants of cost and health care resource use may vary between Canada and the United States given the differences in the two health care systems. The proportion of survivors of ALI admitted to a rehabilitation facility was similar to that in prior studies (22, 48), although the length of stay was longer in prior studies (Table 5).

In terms of cost, the estimated 1-year mean cost of hospitalization readmissions was higher for our cohort versus the U.S. multicenter study of survivors of ALI, despite our mean hospital readmission length of stay being approximately threefold shorter (Table 5). This difference may partially be attributable to regulated hospital costs being relatively higher in Maryland versus other states (18). Compared with the Canadian ARDS study, we found that both the mean cost of hospital readmissions over 2 years of follow-up, and the total cost of all inpatient

follow-up resource use, were approximately twofold greater (Table 5).

Regarding exposures associated with inpatient costs, we found that an increase in pre-ALI comorbidity was significantly associated with higher odds of incurring any follow-up inpatient costs, but not in higher costs among those who were admitted. Higher follow-up costs with baseline comorbidity have been reported for survivors of sepsis (49, 50). Our finding is important given the aging population and increasing comorbidity of ICU patients (12, 51–53). We also found that an informal caregiver residing with the patient pre-ALI was independently associated with lower odds of any follow-up inpatient costs (Table 3). Having an informal caregiver before ALI may reflect continued access to a caregiver post-ALI and reduce inpatient care through several potential mechanisms, including assistance with ongoing medical problems, greater social support, and provision of logistical support (e.g., income or transportation). Future research should further evaluate the impact of caregiving on patient readmissions and the health effects of being a caregiver for ICU survivors (54).

Whereas uninsured patients in the United States undergo fewer ICU procedures and receive fewer critical care services (55, 56), the impact of insurance status for ICU survivors is less well understood. We found no significant relationship in ensured versus uninsured patients, although patients with Medicare or Medicaid (vs. private insurance) had higher odds of incurring any inpatient admission (Table 3) and higher costs (Table 4). Differences in patient age may be an explanation; however, a *post hoc* analysis adding age to the multivariable model did not produce any material change in results. Other possible explanations for this finding include decreased access to outpatient follow-up care (57, 58) or different comorbidity patterns, although we did adjust for patients' comorbidity. Given the association of baseline comorbidity, but not severity of illness, with inpatient admissions, future research focused on postdischarge outcomes should include robust evaluation of baseline illness.

The frequency of readmissions and high costs of care for survivors of critical illness highlight these patients as a potential target population for follow-up care after hospital discharge. The study could have important policy implications in the setting

Table 5. Comparison of findings with prior follow-up admission cost studies*

Inpatient Facility	Current Study U.S. ALI (ICAP) (n = 138)	U.S. ALI (48) (n = 429)	Canadian ARDS (22) (n = 109)	U.S. Prolonged Mechanical Ventilation (27) (n = 103)
Hospital readmissions, Year 1				
Patients ever using service, %	51	45	NR	67
Length of stay (d), mean	6.3	19.0	4.2	NR
Hospital readmissions, total, 2-yr				
Patients ever using service, %	67	NR	39	NR
Length of stay (d), mean	6.2	NR	3.5 [†]	NR
Hospital costs, mean				
Year 1	\$20,804	\$16,266 [‡]	NR	\$61,396
Total, 2-yr	\$36,420	NR	\$14,368	NR
Rehabilitation admissions, Year 1				
Patients ever using service, %	35	32	NR	NR
Length of stay (d), mean	31	64	NR	NR
Rehabilitation admissions, total, 2-yr				
Patients ever using service, %	40	NR	33	NR
Length of stay (d), mean	32	NR	52	NR
Rehabilitation costs, mean				
Year 1	\$4,878	\$15,750 [‡]	NR	\$23,581
Total, 2-yr	\$5,786	NR	\$8,580	NR
Year 1 follow-up inpatient costs, mean	\$30,366	\$32,252	NR	\$118,584
Two-year follow-up inpatient costs, mean	\$47,817	NR	\$25,099	NR

Definition of abbreviations: ALI = acute lung injury; ARDS = acute respiratory distress syndrome; ICAP = Improving Care of Acute Lung Injury Patients Study; NR = not reported.

*All costs reported in 2013 U.S. dollars.

[†]Value calculated on the basis of mean values from Year 1 and Year 2, weighted by the number of admissions reported each year (22).

[‡]Values estimated from Figure 4 in Reference 48.

of accountable care organizations, as they incentivize inpatient hospital systems to communicate with outpatient providers and reduce hospital readmissions under a model of shared accountability (59, 60).

Our study has important strengths, including the 2-year duration and high cohort retention rate. Moreover, the study met quality criteria for reporting post-ICU health care resource use (8) and criteria from the Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) (61) statement and the Consolidated Health Economic Evaluations Reporting Standards (CHEERS) (62). However, this study has potential limitations. First, the study population included only 2-year survivors after ALI and, consequently, may underestimate total costs for all hospital survivors of ALI given potentially increased health care costs occurring in the last year of life (63). However, the Canadian 2-year follow-up study found similar determinants of health care costs in a survivors-only analysis versus their primary analysis of all subjects (22). Nonetheless, because of a potential association of baseline comorbidity with post-ICU mortality, it is possible that

patients with higher comorbidity who suffer early mortality (and were excluded from this study) may indeed have lower follow-up health care costs because of their early mortality. Second, as in prior research (64), outpatient resource use was not evaluated; hence, underestimating total costs of care. However, prior ICU follow-up studies reported that inpatient care clearly represented the largest proportion of all follow-up costs (8), with 77% of follow-up costs attributable to inpatient costs in a U.S. ALI study (48), 95–98% in studies of follow-up of prolonged mechanical ventilation (27, 65), and 59–85% in Canadian survivors of ALI and sepsis (22, 49). Third, we did not evaluate post-ICU exposure variables for association with follow-up costs. This issue has not been explored in prior studies and is an important area for future investigation. Fourth, similar to other longitudinal long-term follow-up studies, there may be diagnostic surveillance bias. Specifically, by being in the follow-up study, patients may be more attuned to their health status, potentially resulting in increased inpatient admissions. Fifth, given the small sample size, there is the risk of a type II error;

hence, findings of a lack of association should be interpreted with caution. Finally, there may be limitations in the generalizability of these findings outside of teaching hospitals or in other geographic locations within the United States (18, 66, 67). However, our results, during the first year of follow-up, are comparable to a national, multicenter study of patients with ALI previously conducted in the United States (48), which potentially supports generalizability of our study's findings.

In conclusion, in this evaluation of 138 patients surviving at least 2 years after ALI, inpatient health care resource use was substantial, with 80% of 2-year survivors reporting one or more admissions to a hospital, skilled nursing facility, or rehabilitation facility, representing a median cost of more than \$30,000 per patient. Patients with higher baseline comorbidity or longer ICU length of stay were more likely to incur such costs, whereas patients with an informal caregiver before ALI were less likely to incur such costs. Patients with Medicare or Medicaid (vs. private insurance) before ALI had higher inpatient follow-up costs. With the aging population, increasing comorbidity, and projected

increase in patients covered by Medicare and Medicaid, these findings have important implications for health policy for the care of ICU survivors. ■

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References

- Herridge MS, Tansey CM, Matte A, Tomlinson G, Diaz-Granados N, Cooper A, Guest CB, Mazer CD, Mehta S, Stewart TE, *et al.* Functional disability 5 years after acute respiratory distress syndrome. *N Engl J Med* 2011;364:1293–1304.
- Desai SV, Law TJ, Needham DM. Long-term complications of critical care. *Crit Care Med* 2011;39:371–379.
- Bienvenu OJ, Colantuoni E, Mendez-Tellez PA, Dinglas VD, Shanholtz C, Husain N, Dennison CR, Herridge MS, Pronovost PJ, Needham DM. Depressive symptoms and impaired physical function after acute lung injury: a 2-year longitudinal study. *Am J Respir Crit Care Med* 2012;185:517–524.
- Barnato AE, Albert SM, Angus DC, Lave JR, Degenholtz HB. Disability among elderly survivors of mechanical ventilation. *Am J Respir Crit Care Med* 2011;183:1037–1042.
- Bienvenu OJ, Gellar J, Althouse BM, Colantuoni E, Sricharoenchai T, Mendez-Tellez PA, Shanholtz C, Dennison CR, Pronovost PJ, Needham DM. Post-traumatic stress disorder symptoms after acute lung injury: a 2-year prospective longitudinal study. *Psychol Med* 2013;43:2657–2671.
- Iwashyna TJ, Ely EW, Smith DM, Langa KM. Long-term cognitive impairment and functional disability among survivors of severe sepsis. *JAMA* 2010;304:1787–1794.
- Needham DM, Davidson J, Cohen H, Hopkins RO, Weinert C, Wunsch H, Zawistowski C, Bemis-Dougherty A, Berney SC, Bienvenu OJ, *et al.* Improving long-term outcomes after discharge from intensive care unit: report from a stakeholders' conference. *Crit Care Med* 2012;40:502–509.
- Lone NI, Seretny M, Wild SH, Rowan KM, Murray GD, Walsh TS. Surviving intensive care: a systematic review of healthcare resource use after hospital discharge. *Crit Care Med* 2013;41:1832–1843.
- Iwashyna TJ, Netzer G. The burdens of survivorship: an approach to thinking about long-term outcomes after critical illness. *Semin Respir Crit Care Med* 2012;33:327–338.
- Coopersmith CM, Wunsch H, Fink MP, Linde-Zwirble WT, Olsen KM, Sommers MS, Anand KJ, Tchorz KM, Angus DC, Deutschman CS. A comparison of critical care research funding and the financial burden of critical illness in the United States. *Crit Care Med* 2012;40:1072–1079.
- Rubenfeld GD, Caldwell E, Peabody E, Weaver J, Martin DP, Neff M, Stern EJ, Hudson LD. Incidence and outcomes of acute lung injury. *N Engl J Med* 2005;353:1685–1693.
- Needham DM, Bronskill SE, Calinawan JR, Sibbald WJ, Pronovost PJ, Laupacis A. Projected incidence of mechanical ventilation in Ontario to 2026: preparing for the aging baby boomers. *Crit Care Med* 2005;33:574–579.
- Zilberberg MD, de Wit M, Pirone JR, Shorr AF. Growth in adult prolonged acute mechanical ventilation: implications for healthcare delivery. *Crit Care Med* 2008;36:1451–1455.
- Halpern NA, Pastores SM. Critical care medicine in the United States 2000–2005: an analysis of bed numbers, occupancy rates, payer mix, and costs. *Crit Care Med* 2010;38:65–71.
- Center for Medicare and Medicaid Services. National health expenditure projections 2012–2022: forecast summary [accessed 2014 Aug 15]. Available from: <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/downloads/proj2012.pdf>
- Fineberg HV. Shattuck Lecture: a successful and sustainable health system—how to get there from here. *N Engl J Med* 2012;366:1020–1027.
- Mechanic R. Post-acute care—the next frontier for controlling Medicare spending. *N Engl J Med* 2014;370:692–694.
- Rajkumar R, Patel A, Murphy K, Colmers JM, Blum JD, Conway PH, Sharfstein JM. Maryland's all-payer approach to delivery-system reform. *N Engl J Med* 2014;370:493–495.
- Ruhl AP, Steinwachs DM, Mendez-Tellez PA, Sevransky PA, Shanholtz CB, Pronovost PJ, Needham DM. Survivorship after acute lung injury: 2-year healthcare resource utilization and costs [abstract]. *Am J Respir Crit Care Med* 2012;185:A3887.
- Needham DM, Dennison CR, Dowdy DW, Mendez-Tellez PA, Ciesla N, Desai SV, Sevransky J, Shanholtz C, Scharfstein D, Herridge MS, *et al.* Study protocol: the Improving Care of Acute Lung Injury Patients (ICAP) Study. *Crit Care* 2006;10:R9.
- Bernard GR, Artigas A, Brigham KL, Carlet J, Falke K, Hudson L, Lamy M, Legall JR, Morris A, Spragg R. The American–European Consensus Conference on ARDS: definitions, mechanisms, relevant outcomes, and clinical trial coordination. *Am J Respir Crit Care Med* 1994;149:818–824.
- Cheung AM, Tansey CM, Tomlinson G, Diaz-Granados N, Matte A, Barr A, Mehta S, Mazer CD, Guest CB, Stewart TE, *et al.* Two-year outcomes, health care use, and costs of survivors of acute respiratory distress syndrome. *Am J Respir Crit Care Med* 2006;174:538–544.
- Averil RF, Goldfield N, Hughes JS, Bonazelli J, McCullough EC, Steinbeck BA, Mullin R, Tang AM, Muldoon J, Turner L, *et al.* All patient refined diagnosis related groups (APR-DRGs): methodology overview [version 20.0]. Wallingford, CT: 3M Health Information Systems; 2003.
- Maryland Health Services Cost Review Commission. HSCRC overview [accessed 2014 Jan 30]. Available from: <http://www.hsrc.state.md.us/aboutHSCRC.cfm>
- Cost-to-Charge Ratios Fiscal Year 2012 from Center for Medicare and Medicaid Services Cost Report: Johns Hopkins Hospital, Johns Hopkins Bayview Medical Center, and University of Maryland. Regulatory Compliance Johns Hopkins Health System, Baltimore, MD.
- Salkever DS, Steinwachs DM. Utilization and case-mix impacts of per case payment in Maryland. *Health Care Financ Rev* 1988;9:23–32.
- Unroe M, Kahn JM, Carson SS, Govert JA, Martinu T, Sathy SJ, Clay AS, Chia J, Gray A, Tulskey JA, *et al.* One-year trajectories of care and resource utilization for recipients of prolonged mechanical ventilation: a cohort study. *Ann Intern Med* 2010;153:167–175.
- Metlife Mature Market Institute. Market survey of long-term care costs [accessed 2013 June 30]. Available from: <https://www.metlife.com/assets/cao/mmi/publications/studies/2012/studies/mmi-2012-market-survey-long-term-care-costs.pdf>
- Liu K; Centers for Medicare and Medicaid Services. Final report to CMS: options for improving Medicare payment for skilled nursing facilities [accessed 2013 June 30]. Available from: http://www.urban.org/UploadedPDF/411526_nursing_facilities.pdf
- Bureau of Labor Statistics. CPI inflation calculator [accessed 2014 Jan 20]. Available from: http://www.bls.gov/data/inflation_calculator.htm
- Kahn JM, Benson NM, Appleby D, Carson SS, Iwashyna TJ. Long-term acute care hospital utilization after critical illness. *JAMA* 2010;303:2253–2259.
- Bank of Canada. Inflation calculator [accessed 2014 Jan 5]. Available from: <http://www.bankofcanada.ca/rates/related/inflation-calculator/>
- Organisation for Economic Co-Operation and Development (OECD). Purchasing power parity (PPP) statistics and exchange rates [accessed 2014 Feb 26]. Available from: http://stats.oecd.org/Index.aspx?datasetcode=SNA_TABLE4
- Muni S, Engelberg RA, Treece PD, Dotolo D, Curtis JR. The influence of race/ethnicity and socioeconomic status on end-of-life care in the ICU. *Chest* 2011;139:1025–1033.

- 35 Bradley EH, Herrin J, Curry L, Cherlin EJ, Wang Y, Webster TR, Drye EE, Normand SL, Krumholz HM. Variation in hospital mortality rates for patients with acute myocardial infarction. *Am J Cardiol* 2010;106:1108–1112.
- 36 Groll DL, To T, Bombardier C, Wright JG. The development of a comorbidity index with physical function as the outcome. *J Clin Epidemiol* 2005;58:595–602.
- 37 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–383.
- 38 Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985;13:818–829.
- 39 Vincent JL, Moreno R, Takala J, Willatts S, De Mendonça A, Bruining H, Reinhart CK, Suter PM, Thijs LG. The SOFA (Sepsis-Related Organ Failure Assessment) score to describe organ dysfunction/failure. *Intensive Care Med* 1996;22:707–710.
- 40 Duan N, Manning WG, Morris CN, Newhouse JP. A comparison of alternative models for the demand for medical care. *J Bus Econ Stat* 1983;1:115–126.
- 41 Mullahay J. Specification and testing of some modified count data models. *J Econom* 1986;3:341–365.
- 42 Diehr P, Yanez D, Ash A, Hombrook M, Lin DY. Methods for analyzing health care utilization and costs. *Annu Rev Public Health* 1999;20:125–144.
- 43 Akaike H. A new look at the statistical model identification. *IEEE Trans Automat Contr* 1974;19:716–723.
- 44 Steyerberg EW, Eijkemans MJ, Harrell FE Jr, Habbema JD. Prognostic modelling with logistic regression analysis: a comparison of selection and estimation methods in small data sets. *Stat Med* 2000;19:1059–1079.
- 45 Stine R. Graphical interpretation of variance inflation factors. *Am Stat* 1995;49:53–56.
- 46 Hosmer D, Lemeshow S. Applied logistic regression. New York: Wiley; 2000.
- 47 Efron B. Bootstrap methods: another look at the jackknife. *Ann Stat* 1979;7:1–26.
- 48 Clermont G, Kong L, Weissfeld LA, Lave JR, Rubenfeld GD, Roberts MS, Connors AF Jr, Bernard GR, Thompson BT, Wheeler AP, et al. The effect of pulmonary artery catheter use on costs and long-term outcomes of acute lung injury. *PLoS One* 2011;6:e22512.
- 49 Lee H, Doig CJ, Ghali WA, Donaldson C, Johnson D, Manns B. Detailed cost analysis of care for survivors of severe sepsis. *Crit Care Med* 2004;32:981–985.
- 50 Liu V, Lei X, Prescott HC, Kipnis P, Iwashyna TJ, Escobar GJ. Hospital readmission and healthcare utilization following sepsis in community settings. *J Hosp Med* 2014;9:502–507.
- 51 Kahn JM, Angus DC. Health policy and future planning for survivors of critical illness. *Curr Opin Crit Care* 2007;13:514–518.
- 52 Kaukonen KM, Bailey M, Suzuki S, Pilcher D, Bellomo R. Mortality related to severe sepsis and septic shock among critically ill patients in Australia and New Zealand, 2000–2012. *JAMA* 2014;311:1308–1316.
- 53 Zilberberg MD, de Wit M, Shorr AF. Accuracy of previous estimates for adult prolonged acute mechanical ventilation volume in 2020: update using 2000–2008 data. *Crit Care Med* 2012;40:18–20.
- 54 Schulz R, Beach SR. Caregiving as a risk factor for mortality: the Caregiver Health Effects Study. *JAMA* 1999;282:2215–2219.
- 55 Lyon SM, Benson NM, Cooke CR, Iwashyna TJ, Ratcliffe SJ, Kahn JM. The effect of insurance status on mortality and procedural use in critically ill patients. *Am J Respir Crit Care Med* 2011;184: 809–815.
- 56 Fowler RA, Noyahr LA, Thornton JD, Pinto R, Kahn JM, Adhikari NK, Dodek PM, Khan NA, Kalb T, Hill A, et al. American Thoracic Society Disparities in Healthcare Group. An official American Thoracic Society systematic review: the association between health insurance status and access, care delivery, and outcomes for patients who are critically ill. *Am J Respir Crit Care Med* 2010;181:1003–1011.
- 57 Blanchard J, Ogle K, Thomas O, Lung D, Asplin B, Lurie N. Access to appointments based on insurance status in Washington, D.C. *J Health Care Poor Underserved* 2008;19:687–696.
- 58 Levinson DR; Department of Health and Human Services, Office of Inspector General. Access to care: provider availability in Medicaid managed care [accessed 2014 Dec 9]. Available from: <http://oig.hhs.gov/oei/reports/oei-02-13-00670.pdf>
- 59 DeCamp M, Sugarman J, Berkowitz S. Shared savings in accountable care organizations: how to determine fair distributions. *JAMA* 2014; 311:1011–1012.
- 60 Chen C, Ackerly DC. Beyond ACOs and bundled payments: Medicare's shift toward accountability in fee-for-service. *JAMA* 2014;311: 673–674.
- 61 von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ* 2007;335:806–808.
- 62 Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, Augustovski F, Briggs AH, Mauskopf J, Loder E. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. *BMJ* 2013;346:f1049.
- 63 Riley GF, Lubitz JD. Long-term trends in Medicare payments in the last year of life. *Health Serv Res* 2010;45:565–576.
- 64 Prescott HC, Langa KM, Liu V, Escobar GJ, Iwashyna TJ. Increased 1-year healthcare use in survivors of severe sepsis. *Am J Respir Crit Care Med* 2014;190:62–69.
- 65 Douglas SL, Daly BJ, Gordon N, Brennan PF. Survival and quality of life: short-term versus long-term ventilator patients. *Crit Care Med* 2002;30:2655–2662.
- 66 Fisher ES, Wennberg DE, Stukel TA, Gottlieb DJ. Variations in the longitudinal efficiency of academic medical centers. *Health Aff* 2004; Suppl Variation:VAR19–32.
- 67 Friedman B, De La Mare J, Andrews R, McKenzie DH. Practical options for estimating cost of hospital inpatient stays. *J Health Care Finance* 2002;29:1–13.