ORIGINAL ARTICLE

Factors Associated with Functional Recovery among Older Intensive Care Unit Survivors

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Abstract

Rationale: Most of the 1.4 million older adults who survive the intensive care unit (ICU) annually in the United States face increased disability, but little is known about those who achieve functional recovery.

Objectives: Our objectives were twofold: to evaluate the incidence and time to recovery of premorbid function within 6 months of a critical illness and to identify independent predictors of functional recovery among older ICU survivors.

Methods: Potential participants included 754 persons aged 70 years or older who were evaluated monthly in 13 functional activities (1998–2012). The analytic sample included 218 ICU admissions from 186 ICU survivors. Functional recovery was defined as returning to a disability count less than or equal to the pre-ICU disability count within 6 months. Twenty-one potential predictors were evaluated for their associations with recovery.

Measurements and Main Results: Functional recovery was observed for 114 (52.3%) of the 218 admissions. In multivariable analysis, higher body mass index (hazard ratio [HR], 1.07; 95% confidence interval [CI], 1.03–1.12) and greater functional self-efficacy (HR, 1.05; 95% CI, 1.02–1.08), a measure of confidence in performing various activities, were associated with recovery, whereas pre-ICU impairment in hearing (HR, 0.38; 95% CI, 0.22–0.66) and vision (HR, 0.59; 95% CI, 0.37–0.95) were associated with a lack of recovery.

Conclusions: Among older adults who survived an ICU admission with increased disability, pre-ICU hearing and vision impairment were strongly associated with poor functional recovery within 6 months, whereas higher body mass index and functional self-efficacy were associated with recovery. Future research is needed to evaluate whether interventions targeting these factors improve functional outcomes among older ICU survivors.

Keywords: intensive care; functional status; quality of life; Medicare

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At a Glance Commentary

Scientific Knowledge on the Subject: Most of the 1.4 million older adults who survive the intensive care unit (ICU) annually in the United States face increased disability, but little is known about how many achieve recovery of pre-ICU function or what factors predict functional recovery after a critical illness.

What This Study Adds to the Field: Our longitudinal study found that approximately half of older ICU survivors achieve functional recovery in the 6 months after an ICU admission. Hearing and vision impairment were strongly associated with a lack of functional recovery, whereas functional self-efficacy and body mass index were positively associated with recovery. These factors represent potential new targets for interventions to improve functional outcomes among older adults who survive a critical illness.

Nearly 1.4 million older adults survive an episode of critical illness every year in the United States (1), and most will have increased levels of disability (2–4). This consequence of critical illness has significant implications for patients and society, as disability is associated with increased mortality, institutionalization, and greater use of formal and informal home services (5). Although many older ICU survivors suffer from persistent disability after a critical illness, others are able to achieve functional recovery in the months thereafter. However, little is known about the incidence of such recovery or what factors predict functional recovery in this older patient population.

To date, studies that have evaluated factors associated with persistent disability after ICU discharge have focused primarily on ICU-related factors, with relatively little attention to patient-related and geriatric conditions (6–9). In older adults, these conditions may be powerful risk factors for post-ICU disability. To avoid erroneous conclusions about the effect of the critical illness itself, these patient-related and geriatric factors should ideally be measured prospectively, before the patient's critical illness (10, 11). Given recent efforts to improve functional outcomes after ICU discharge (12–14), a careful evaluation of potential predictors of functional recovery may clarify additional targets for interventions.

The objectives of the current study were twofold: first, to evaluate the incidence and time to recovery of premorbid function within 6 months of a critical illness; and second, to identify independent predictors of functional recovery among older persons who survive a critical illness with increased disability. To accomplish our objectives, we used data from a unique longitudinal study that has followed a large cohort of older persons for more than 14 years with monthly assessments of functional status and repeated assessments of patient-related and geriatric factors.

Methods

Study Population

Participants were drawn from the Precipitating Events Project (PEP), an ongoing longitudinal study of 754 community-dwelling persons aged 70 years or older, who were initially nondisabled in four basic activities of daily living: bathing, dressing, walking across a room, and transferring from a chair (15). Potential participants were members of a large health plan in greater New Haven, Connecticut and were enrolled from March 1998 through October 1999. Persons were oversampled if they were physically frail, defined on the basis of slow gait speed (i.e., required >10 s to walk a 3-m course). Exclusion criteria included significant cognitive impairment with no available proxy, life expectancy less than 12 months, plans to leave the area, and non–English speaking. Eligibility was determined during a screening telephone interview and confirmed during an in-home assessment. Only 4.6% of persons contacted refused screening, and 75.2% of those eligible agreed to participate; those who refused did not differ significantly from those who enrolled. The Yale Human Investigation Committee approved the study. All participants provided informed consent.

Data Collection

Comprehensive home-based assessments were completed at baseline and at 18-month intervals for 180 months (with the exception of 126 mo). Telephone interviews were completed monthly through June 2013. For participants who had significant cognitive impairment or were unavailable, a proxy informant was interviewed (16). Deaths were ascertained by review of obituaries and/or from an informant during a telephone interview, with a completion rate of 100%. A total of 580 (76.9%) participants died after a median follow up of 93 months, and 42 (5.6%) dropped out of the study after a median follow up of 27 months. Data were otherwise available for 99.1% of 79,446 monthly interviews.

Potential patient-related and geriatric predictors. We considered potential predictors that have been linked to functional recovery in prior studies (17–21). At each 18-month comprehensive assessment, data were obtained on demographic characteristics (age, sex, race/ethnicity, education, and living situation), nine self-reported physician-diagnosed chronic conditions (hypertension; myocardial infarction; congestive heart failure; stroke; cancer, excluding minor skin cancers; diabetes; fractures; arthritis; and chronic lung disease), cognitive status, depressive symptoms, body mass index (BMI), frailty, hearing, vision, functional self-efficacy, social support, and physical capacity. Cognitive impairment was defined as a Mini-Mental State Examination score less than 24 (22), and depression was defined as a score of 20 or greater on the Center for Epidemiological Studies Depression scale (23). Frailty was defined as a score of 3 or greater on the Fried Frailty Index (24). Severe hearing impairment was defined as 4 out of 4 tones missed, based on 1,000- and 2,000-Hz measurements for the left and right ears, using a handheld AudioScope (25). Percent vision impairment was assessed with a Jaeger card, with the participant wearing their own reading glasses when applicable (26). Functional self-efficacy, a measure of confidence in performing various activities, was assessed with the Modified Self-Efficacy Scale (17, 27). Participants were asked, "how confident/sure are you that you can [ask activity]"? for each of 10 activities, where 0 = not at all, 1 = a little, 2 = fairly, 3 = very, and 4 = completely. Examples of activities include "get dressed or undressed" or "get in and out of a chair."

Scores range from 0 to 40, where higher scores indicate greater functional self-efficacy. Social support was assessed with a modified version of the Medical Outcomes Survey Social Support Scale (28). Physical capacity was evaluated with a modified version of the Short Physical Performance Battery (29) that included the standard balance maneuvers but substituted three timed chair stands (instead of five) and timed rapid gait (back and forth over a 10-ft course) instead of timed usual gait (over a 4-m course without a turn) (18).

Assessment of functional status. The monthly assessment of functional status included 13 activities. Participants were asked, "At the present time, do you need help from another person to (complete the task)"? for each of four basic activities (bathing, dressing, walking, and transferring), five instrumental activities (shopping, housework, meal preparation, taking medications, and managing finances), and three mobility activities (walk a quarter mile, climb a flight of stairs, and lift or carry 10 pounds). Disability was operationalized as the need for personal assistance or inability to perform the task. Participants were also asked about a fourth mobility activity, "Have you driven a car during the past month?" To maintain consistency with the other activities, participants who responded "no" were classified as being "disabled" in driving (30). To address the small amount (0.9%) of missing disability data, we used multiple imputation with 100 random draws per missing observation (31).

Ascertainment of ICU admissions. For the majority of the sample (80.4%), linked Medicare claims data were available to ascertain ICU admissions. We defined ICU admission as the presence of any critical care revenue code, including general, specialty, and coronary care units, while excluding psychiatric or intermediate critical care. For participants in managed Medicare, information on hospitalizations was obtained during the monthly interviews. Participants were asked whether they had stayed overnight in a hospital since the previous month's interview. The accuracy of these reports, based on an independent review of hospital records, was high, with a sensitivity of 93.3% (95% CI, 90.5–96.1%) and specificity of 99.3% (95% CI, 99.0–99.6%) (32). All self-reported hospitalizations were then evaluated for ICU admission through medical record review. For all hospitalizations within the Yale-New Haven Hospital system, the physical chart was obtained from Medical Records or the electronic medical record reviewed securely on the medical campus. For hospitalizations outside the system, the faxed or mailed medical records were reviewed at a secure site. For each hospitalization, all physician notes were reviewed from the date of admission through the date of discharge by either the first author (L.E.F.) or a trained research nurse to ascertain whether the patient had been admitted to the ICU.

Acquisition of ICU data and potential ICU-related predictors. For all ICU admissions, additional data were obtained, including duration of ICU stay, ICU service, presence of shock, and use of mechanical ventilation. When data were available from Medicare claims, ICU length of stay was based on number of days billed in a critical care unit. The remaining information was obtained from International Classification of Diseases, Ninth Revision codes.

For participants in managed Medicare, shock and mechanical ventilation were abstracted from the medical record. Mechanical ventilation was present if the patient was intubated for respiratory failure or airway protection. Intubations for surgical procedures were excluded, except when the patient was unable to be weaned from the ventilator within 12 hours.

Assembly of the analytic sample. The analytic sample included participants who had at least one ICU admission from their enrollment date through 2012. Participants could contribute more than one ICU admission over the 14 years of the study, but only the first ICU admission within an 18-month interval was eligible, because the potential predictors were measured during the comprehensive assessments. Therefore, to be included in the analysis, ICU admissions for the same participant had to occur in different nonoverlapping 18-month periods. To permit an evaluation of recovery, ICU admissions were included if the post-ICU disability count (from the first monthly interview after ICU discharge) was greater than the pre-ICU disability count (from the monthly interview immediately before ICU admission). The assembly of the analytic sample is described in Figure 1. The final sample included 218 ICU admissions contributed by 186 participants.

Statistical Analysis

The unit of analysis was an ICU admission. Descriptive characteristics were calculated for the admissions meeting eligibility criteria. Continuous variables were described with mean and SD or by median and interquartile range (IQR), and dichotomous variables were described with the number (%) of observations. Functional recovery was defined as the return, within 6 months of ICU admission, to a total disability count less than or equal to that of the month immediately before ICU admission. The median (IQR) number of disabilities before, immediately after, and at 6 months after ICU admission was determined, and the number (%) of ICU admissions where the participant recovered, did not recover, or died within 6 months of ICU admission were calculated.

Twenty-one explanatory variables, chosen *a priori* based on clinical relevance, were tested for their bivariate associations with recovery. The bivariate associations were calculated from a proportional hazards model that used a person-specific random intercept to account for the correlation of the multiple events of certain participants (33). All multivariable models included age, sex, race, and increase in disability, which was defined as the difference between the last pre-ICU disability count and the first post-ICU disability count. A backward selection approach was used for subsequent multivariable models with a retention criterion of $P \leqslant 0.10$ for the other 17 explanatory variables. For each explanatory variable retained in the model, both functional form and the proportional hazards assumption were checked with cumulative sums of martingale residuals (34). If functional form was poor for a chosen explanatory variable, that explanatory variable was removed and backward selection was repeated. BMI was tested in several forms, including a continuous form and a four-level categorical form with indicators for underweight (BMI $<$ 18.5), overweight (BMI, 25.0–29.9), and obese (BMI $\geqslant$ 30) relative to normal weight. Because the categorical form showed the same hazard ratio trend as the continuous form, but

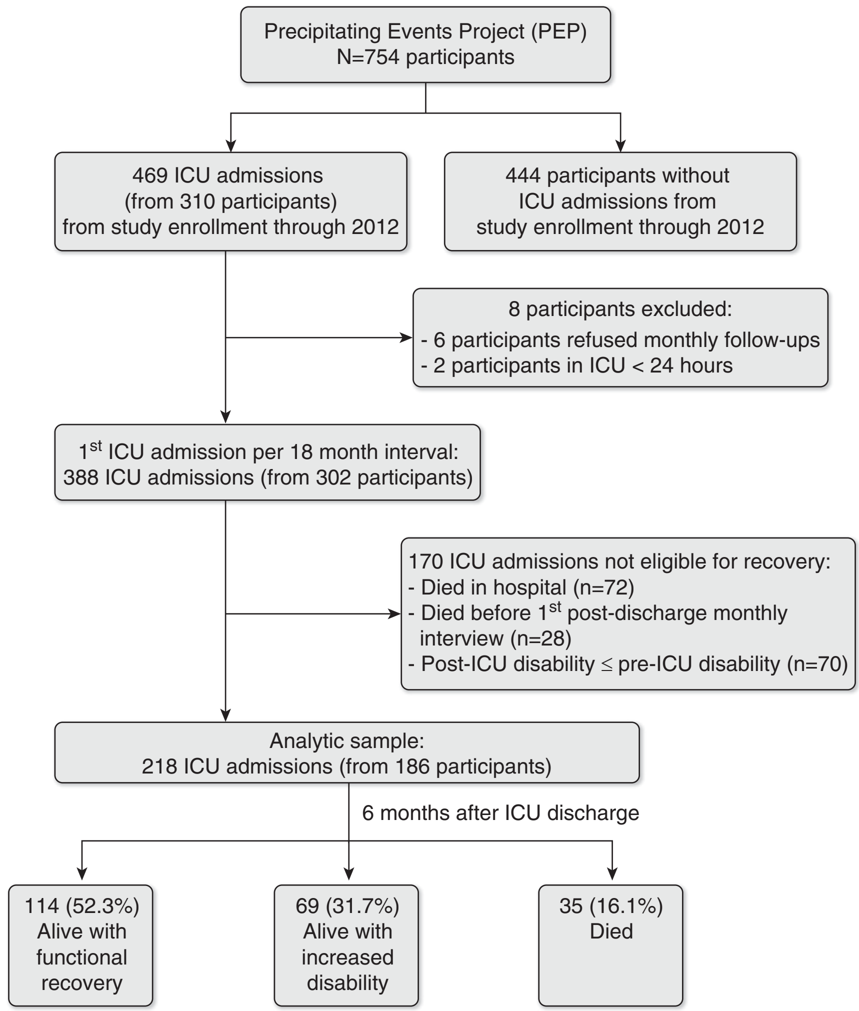

Figure 1. Assembly and outcomes of the analytic sample from the parent cohort. The analytic sample included participants who had at least one intensive care unit (ICU) admission from their enrollment date through 2012. Eight participants were excluded owing to refusal to continue in the parent study (n = 6) or an ICU admission lasting less than 24 hours (n = 2). Participants could contribute more than one ICU admission over the 14 years of the study, but only the first ICU admission within an 18-month interval was eligible. To permit an evaluation of recovery, ICU admissions were included if the post-ICU disability count (from the first monthly interview after ICU admission) was greater than the pre-ICU disability count (from the monthly interview immediately before ICU admission). Over the more than 14 years of the study, 302 participants contributed 388 qualifying ICU admissions (i.e., first within an 18-month interval). Of these, 170 ICU admissions were not eligible for recovery because of death in the hospital (n = 72), death occurring postdischarge but before the first monthly interview (n = 28), or because the post-ICU disability counts (measured at a median of 14.5 d [interquartile range, 9–24 d] after hospital discharge) were equal to (n = 46) or less than (n = 24) the pre-ICU disability counts. The remaining 186 participants contributed a total of 218 ICU admissions. Within the 6-month follow-up period, 114 (52.3%) achieved functional recovery, 69 (31.7%) were living with increased disability, and 35 (16.1%) had died. The percentages sum to 100.1% because of rounding.

overall model fit and functional form were better with the continuous form, we chose to use BMI in its continuous form in the analysis. After final selection of the explanatory variables, the multivariable model was rerun with the addition of a person-specific intercept to account for the repeated outcomes of certain patients. The multivariable model was run using SAS version 9.4 (35), where $P < 0.05$ (two-tailed) denoted statistical significance. The result for each explanatory variable is reported as a hazard ratio, which can be thought of as the average rate of the event per unit of time (day) among those with the variable, referenced against the average rate of those without that variable. We then tested for significance of the interaction between age and each of BMI, hearing impairment, self-efficacy, and visual impairment. We also tested for an interaction between increase in disability and self-efficacy.

Several sensitivity analyses were also run. First, type of ICU service was tested in the final model. Second, to check for potentially informative censoring from death, several hypothetical models were run. The first hypothetical assumed that decedents did not recover through the end of the study. The second hypothetical assumed the decedents did not die, and their time to recovery was imputed under two scenarios: the first scenario assumed missing at random and the second assumed missing not at random. Finally, the multivariable model was run on a sample restricted to the first ICU admission per participant. Some of the results of this study have been previously reported in the form of an abstract (36).

Results

Among the 218 ICU admissions contributed by older adults who survived to their first post-ICU functional assessment, more than half were in women (57.8%), most were in non-Hispanic white individuals (88.5%), and 8.3% were from a nursing home. Before ICU admission, the median number of disabilities was 4 (IQR, 2–7). The mean BMI was 26. One in five admissions were in obese participants (n = 44, 20.2%), whereas only 5.1% (n = 11) were in underweight participants (BMI < 18.5). The median number of months since the last comprehensive assessment was 9 (IQR, 4–14). Other patient characteristics that were evaluated as potential predictors of functional recovery can be found in Table 1.

Seventy-nine (36.2%) of the admissions were to a medical or general ICU; 46 (21.1%) to a surgical or cardiothoracic surgical ICU; 81 (37.2%) to a nonsurgical cardiac unit; and 12 (5.5%) to an "other" ICU, most often a neurosurgical ICU or burn unit. The median ICU length of stay was 2 days (IQR, 1–3), and the

Table 1. Characteristics and Bivariate Associations of Potential Predictors of Functional Recovery within 6 Months of Intensive Care Unit Admission, N = 218*

Potential Predictor	Operational Details	n (%) or Mean ± SD	HR	95% CI	*P* Value
Demographic					
Age	In years at time of ICU admission	83.6 ± 5.5	0.98	0.95–1.02	0.280
Female sex		126 (57.8)	0.93	0.64–1.35	0.703
Non-Hispanic white	Self-identified as white and non-Hispanic†	193 (88.5)	0.92	0.53–1.61	0.773
Lives alone		87 (39.9)	0.78	0.53–1.14	0.199
Education	In years	12.0 ± 2.9	1.02	0.96–1.09	0.516
Health related					
Chronic conditions	9 self-reported, physician-diagnosed‡	2.5 ± 1.3	0.93	0.81–1.07	0.293
Hearing impairment, severe	4 tones missed out of 4§	72 (33.0)	0.49	0.31–0.76	0.001
Vision impairment	Vision impairment of at least 5% (with use of corrective lenses, if applicable)	105 (48.2)	0.56	0.38–0.82	0.003
Weight loss	>10 pounds lost in the previous year	75 (34.4)	0.65	0.43–0.98	0.041
BMI	Self-reported height and weight, kg/m²	26.1 ± 5.4	1.05	1.02–1.09	0.002
Frailty	Fried Frailty index 0 = not frail, 1 = pre-frail (1–2), 2 = frail (3–5) (24)	1.4 ± 0.7	0.71	0.55–0.93	0.014
Cognitive-psychosocial					
Cognitive impairment	Score on Folstein MMSE < 24 (22)‖	37 (17.0)	0.78	0.46–1.32	0.352
Depression	Score of ⩾20 on the CES-D (23)¶	35 (16.1)	0.81	0.48–1.35	0.414
Functional self-efficacy	Score on the Modified Self-Efficacy Scale: 0 (low) to 40 (high) (27)**	26.3 ± 9.0	1.03	1.01–1.06	0.003
Social support	Score on the MOS: 0 (low) to 28 (high)††	21.9 ± 5.9	1.03	0.99–1.06	0.111
Physical					
Low physical capacity	Score of 0–3 on the SPPB, referent to high function (8–12) (28)‡‡	64 (29.4)	0.46	0.28–0.77	0.003
Intermediate physical capacity	Score of 4–7 on the SPPB, referent to high function (8–12) (29)	99 (45.4)	0.65	0.43–1.00	0.051
Increase in disability	Between the first post-ICU disability count and last pre-ICU disability count§§	5.1 ± 3.1	0.90	0.85–0.96	0.002
ICU variables					
Mechanical ventilation		39 (17.9)	0.62	0.37–1.07	0.086
Shock‖‖		11 (5.0)	0.55	0.20–1.48	0.237
Days in the ICU		3.1 ± 4.5	0.97	0.93–1.02	0.298

Definition of abbreviations: BMI = body mass index; CES-D = Center for Epidemiological Studies Depression Scale; CI = confidence interval; HR = hazard ratio; ICU = intensive care unit; MMSE = Folstein Mini-Mental State Examination; MOS = Medical Outcomes Survey; SPPB = Short Physical Performance Battery.
*The 218 ICU admissions were contributed by 186 participants.
†Compared with African American race (n = 21, 9.6%), Hispanic ethnicity (n = 3, 1.4%), and unknown race/ethnicity (n = 1, 0.5%) combined into one group, owing to the low prevalence of these individual groups.
‡Hypertension, myocardial infarction, heart failure, stroke, diabetes mellitus, arthritis, hip fracture, chronic lung disease, and cancer (other than minor skin cancers).
§Based on 1,000- and 2,000-Hz measurements for the right and left ears.
‖Scores range from 0 to 30, with higher scores representing better cognitive function.
¶CES-D 11-item version: scores range from 0 to 60, with higher scores representing a greater number of depressive symptoms.
**Assesses confidence in performing 10 activities, scored 0 to 4: cleaning the house, getting dressed or undressed, preparing simple meals, taking a bath or shower, simple shopping, getting in and out of a chair, going up and down stairs, walking around the neighborhood, reaching into cabinets or closets, and hurrying to answer the telephone.
††MOS Social Support Scale: scores range from 0 to 28, with higher scores representing greater social support.
‡‡Scores range from 0–12, with higher scores indicating better performance on three objectively measured tasks: gait speed, chair stands, and balance, as described in the text.
§§Disability was assessed monthly in each of 13 functional activities, as described in the text.
‖‖Ascertained from International Classification of Disease, Ninth Revision codes for participants with fee-for-service Medicare and from the attending ICU physician's assessment in the medical record for participants with Medicare Managed Care.

median hospital length of stay was 7 days (IQR, 5–11). Shock was present during 11 of the 218 admissions (5.1%), and mechanical ventilation was present during nearly 1 in 5 admissions (17.9%). The median number of disabilities after a critical illness was 11 (IQR, 7–13), assessed at a median of 15 days (IQR, 7–21) after ICU discharge.

Among the 218 observations who survived to the first post-ICU functional assessment, death occurred in 35 (16.1%) during the 6-month follow-up period, with a median time to death of 83 days (IQR, 55–108). Recovery of pre-ICU function was observed for 114 (52.3%) of the 218 ICU admissions, with a median time to recovery of 3 months (IQR, 2–4). Six months after a critical illness, the median number of disabilities was five (IQR, 2–10).

The bivariate associations of potential predictors of recovery are presented in Table 1. Higher BMI and higher functional self-efficacy were associated with an increased likelihood of functional recovery within 6 months of ICU admission. Severe hearing impairment, vision impairment, greater than 10-pound weight loss, frailty, low physical capacity, and increase in disability were each associated with a reduced likelihood of recovery.

All predictors included in the final multivariable model are presented in Table 2. Hearing impairment and vision impairment were each associated with a markedly reduced likelihood of functional recovery (62 and 41%, respectively). A greater increase in disability between the last pre-ICU functional assessment and the first post-ICU functional assessment was also associated with a reduced likelihood of functional recovery. Higher BMI and greater functional self-efficacy were associated with an increased likelihood of functional recovery within 6 months of a critical illness. For each unit increase in BMI and self-efficacy, the likelihood of recovery increased by 7 and 5%, respectively.

In the additional analyses, neither type of ICU nor any of the interactions tested were significant. Several hypothetical models, where time to death of decedents was multiply imputed under missing-at-random and missing not-at-random assumptions, showed the results to be robust under a comprehensive range of clinical scenarios (*see* Table E1 in the online supplement). Finally, the results were comparable when the analyses were restricted to the first ICU admission per participant (Table E2).

Discussion

In this prospective study of older adults who survived an ICU admission with increased disability, we found that approximately half recovered to their pre-ICU level of function within 6 months, with a median time to recovery of 3 months. In a multivariable analysis that accounted for the decline in function due to a critical illness and then evaluated a large array of demographic, health-related, cognitive-psychosocial, physical, and ICU factors, hearing impairment and vision impairment were associated with a lack of functional recovery, whereas higher BMI and greater functional self-efficacy were positively associated with functional recovery. Importantly, each of these independent predictors is potentially modifiable.

We identified hearing and vision impairment as two significant factors that impede functional recovery after a critical illness. A possible mechanism by which these sensory impairments may adversely affect recovery is through delirium, which is now recognized to be a common, morbid, and costly condition among older hospitalized patients, both in the ICU and on the hospital floor (37–39). Prior work in older non-ICU hospitalized patients has shown that hearing and vision impairment are predictive of delirium occurrence (40), and vision and hearing aids, when indicated, reduce the incidence of delirium (41). Future ICU studies may find comparable associations between sensory impairment and ICU delirium as well as benefits of intervening on these sensory deficits. Because International Classification of Diseases, Ninth Revision coding for delirium is insensitive, we were unable to evaluate delirium in this study. Even without delirium, the presence of hearing and/or vision impairment would make it more difficult for an older adult to function at home after a critical illness, particularly if living alone.

Based on our findings that hearing and vision impairment were each associated with a markedly reduced likelihood of functional recovery, future studies should evaluate whether the provision of hearing and vision aids for older ICU patients increases the likelihood of functional recovery after a critical illness. Vision aids, such as glasses and magnifying glasses kept on the unit, and adaptive equipment, such as large-print materials and fluorescent tape on call bells, have been used in prior hospital interventions, such as the Hospital Elder Life Program (HELP) (42). The HELP program and others have also demonstrated the effectiveness of portable amplifying devices, which are inexpensive and easy to use. When feasible, patients in the ICU could be screened for vision and hearing impairment so that these simple and inexpensive interventions could be implemented, maintained throughout the patient's hospital stay, and factored into discharge planning.

Functional self-efficacy, a measure of confidence in one's ability to complete functional tasks, was also an independent

Table 2. Multivariable Associations of Potential Predictors of Functional Recovery within 6 Months of Intensive Care Unit Admission in Older Adults, N = 218*

	Cause-Specific Proportional Hazards Model‡	
Potential Predictor†	**HR (95% CI)**	***P* Value**
Age, yr	1.02 (0.97–1.07)	0.454
Female sex	0.59 (0.35–1.00)	0.049
Non-Hispanic white	1.24 (0.59–2.63)	0.571
Increase in disability§	0.80 (0.74–0.88)	<0.001
Severe hearing impairment‖	0.38 (0.22–0.66)	<0.001
Vision impairment¶	0.59 (0.37–0.95)	0.031
BMI, per unit increase	1.07 (1.03–1.12)	0.003
Functional self-efficacy, per point**	1.05 (1.02–1.08)	0.002

Definition of abbreviations: BMI = body mass index; CI = confidence interval; HR = hazard ratio; ICU = intensive care unit.
*The 218 ICU admissions were contributed by 186 participants.
†All predictors included in the final multivariable model are presented.
‡Proportional hazards model includes person-specific random intercepts.
§Operationalized as the difference between the first post-ICU disability count and last pre-ICU disability count. Disability was assessed monthly in each of 13 functional activities, as described in the text.
‖Four tones missed out of 4 (1,000 Hz and 2,000 Hz in each ear) measured with a handheld AudioScope.
¶Vision impairment of at least 5% as assessed with a Jaeger card (with use of corrective lenses, when applicable).
**On the Modified Self-Efficacy Scale (17, 27): 0 (low) to 40 (high), where higher scores indicate greater confidence performing various activities.

predictor of functional recovery. A change from being "fairly" to "completely" confident on three routine tasks was associated with a 34% increase in functional recovery within 6 months of a critical illness. Prior work has shown self-efficacy to be a predictor of longer duration of recovery (i.e., more sustained recovery) after recurrent disability (17) in community-dwelling older adults and to have a "buffering effect" against functional decline in this population (43). Moreover, evidence from clinical trials indicates that functional self-efficacy is modifiable and can mediate improvements in functional status among physically frail older persons (44). Our results complement these findings and suggest that functional self-efficacy should serve as a target of interventions (both in the ICU and on discharge) to improve functional outcomes after a critical illness.

We also found that every unit increase in BMI is associated with a 7% increase in the likelihood of functional recovery. To illustrate the magnitude of this effect, an older woman with a height of 5 feet 6 inches who weighs 186 pounds (a BMI of 30.0) would have a 40% greater likelihood of functional recovery after a critical illness than an older woman of the same height who weighs 155 pounds (a BMI of 25.0). Our finding complements the existing critical care literature that has evaluated the prognostic effect of BMI on mortality. Most studies have demonstrated that a higher BMI is associated with decreased mortality in critically ill adults (45–47), with the exception of a few results demonstrating worse outcomes in the morbidly obese (48, 49). Likewise, higher BMI in the entire older adult population is paradoxically associated with lower, not higher, mortality risk (50). Our study provides further support for this "obesity paradox," with greater BMI increasing the likelihood of functional recovery among older adults after a critical illness. Notably, a recent study found that when muscle area was accounted for, BMI was no longer associated with mortality, whereas low skeletal muscle mass was a strong independent predictor of mortality (51). This suggests that skeletal muscle mass may be the factor that is truly responsible for functional recovery after a critical illness. If this is the case, then assessing muscle mass in clinical practice and whether it can be modified with therapeutic interventions (such as feeding, early mobilization, and rehabilitation) would be important. Low skeletal muscle mass may be a marker of chronic disease, frailty, or malnutrition; thus, whether or not BMI and/or skeletal muscle mass are modifiable is a complex issue, particularly in the setting of a critical illness.

A key strength of our study is its prospective, longitudinal design, with monthly assessments of functional status and regular comprehensive assessments of patient-related and geriatric factors over more than 14 years. This allowed us to evaluate multiple potential predictors of recovery from several different domains: demographic, health-related, cognitive-psychosocial, physical, and ICU. To our knowledge, no prior study of functional recovery after critical illness has evaluated such a broad array of potential predictors, although a recent study investigated a modest number of patient-level factors (9). Our findings build on this study, which found that frailty (measured with an accumulation-of-deficits index) was the strongest predictor of poor recovery at 1 year. Additionally, our study design allowed us to accurately identify a study sample of patients who experienced functional decline in the setting of a critical illness, rather than relying on self or proxy report at the onset of critical illness. Furthermore, the availability of monthly data on 13 basic, instrumental, and mobility activities allowed us to precisely identify the occurrence and time to recovery during the follow-up period. Additional strengths include minimal attrition and the ascertainment of ICU admissions through the use of medical records in addition to claims data, which enabled the inclusion of patients with managed Medicare, a population that has been excluded from some prior studies due to the lack of claims data (1–3). Finally, because admissions to the cardiac care unit were not omitted, as they sometimes are in studies of critical illness (1), our results should be applicable across different ICU settings.

Our study has several limitations. First, we did not have a scale such as Acute Physiology and Chronic Health Evaluation II to account for severity of illness. However, we evaluated other factors reflecting ICU severity of illness, including ICU length of stay. Second, our sample size was relatively small, which limited our power to detect statistically significant effects for factors that had a low prevalence, such as shock and mechanical ventilation. Participants with shock or mechanical ventilation were more likely to die in the ICU and were therefore less likely to be included in this study of ICU survivors, thereby explaining the low prevalence of these factors. Third, a small number of ICU admissions under managed Medicare may have been missed, because ascertainment of these hospitalizations was based on self-report; however, the accuracy of self-reported hospitalizations was high. Fourth, information was not available on the receipt of restorative interventions that could have altered the course of recovery after a critical illness. Finally, because study participants were drawn from a single urban area, our results may not be generalizable to older persons in other settings. However, the demographics of our cohort reflect those of older persons in New Haven County, Connecticut, which are similar to the demographics of the U.S. population, with the exception of race and ethnicity.

To date, therapeutic interventions to improve functional outcomes after a critical illness have focused largely on physical rehabilitation and factors relating to ICU management, without much consideration of patient-level and geriatric factors. Our results highlight several potentially modifiable factors that may strongly influence functional recovery after a critical illness in older adults. Interventions targeting hearing impairment, vision impairment, and functional self-efficacy can be easily incorporated into critical care and postdischarge planning, and further exploration of the factors contributing to BMI may identify additional targets for intervention. Future research should focus on these and other potentially modifiable factors that may help promote functional recovery after a critical illness. ■

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