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ORIGINAL

Premorbid functional status as a predictor of 1-year mortality and functional status in intensive care patients aged 80 years or older

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Abstract

Purpose: We assessed the association between the premorbid functional status (PFS) and 1-year mortality and functional status of very old intensive care patients.

Methods: Using a nationwide quality registry, we retrieved data on patients treated in Finnish intensive care units (ICUs) during the period May 2012–April 2013. Of 16,389 patients, 1827 (11.1%) were very old (aged 80 years or older). We defined a person with good functional status as someone independent in activities of daily living (ADL) and able to climb stairs without assistance; a person with poor functional status was defined as needing assistance for ADL or being unable to climb stairs. We adjusted for severity of illness and calculated the impact of PFS.

Results: Overall, hospital mortality was 21.3% and 1-year mortality was 38.2%. For emergency patients (73.5% of all), hospital mortality was 28% and 1-year mortality was 48%. The functional status at 1 year was comparable to the PFS in 78% of the survivors. PFS was poor for 43.3% of the patients. A poor PFS predicted an increased risk of in-hospital death, adjusted odds ratio (OR) 1.50 (95% confidence interval, 1.07–2.10), and of 1-year mortality, OR 2.18 (1.67–2.85). PFS data significantly improved the prediction of 1-year mortality.

Conclusions: Of very old ICU patients, 62% were alive 1 year after ICU admission and 78% of the survivors had a functional status comparable to the premorbid situation. A poor PFS doubled the odds of death within a year. Knowledge of PFS improved the prediction of 1-year mortality.

Keywords: Very old, Intensive care, ICU, Mortality, Functional status, Frailty

Introduction

The number of elderly people will increase markedly in the near future [1]. Old patients have poorer outcomes after intensive care than younger patients [2, 3]. Chronological age is not itself a decisive factor for prognosis, but old age is frequently accompanied by frailty, which impairs the capacity to recover from a critical illness [4–9].

Previously, many researchers considered patients aged over 65 years to be elderly [10–12]. Many recent studies have categorised patients aged 80 years or over as 'elderly' [3], 'very elderly' [13–15] or 'very old' [9, 16, 17]. In the terminology used by the European Union (EU), 'very old' refers to people aged 80 years and over [18]. In fact, the age of 65 years, which was regarded as 'elderly' in studies

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of decades past, is near the median age of all the intensive care patients in more recent studies [3, 19].

Age is included in scoring systems used for predicting the hospital mortality of intensive care patients [20, 21]. In these scoring systems, all patients aged 80 years or older receive equal points based on their age, regardless of their functional status, which can be highly variable [9, 19]. A recent study demonstrated that the pre-admission functional status alone predicts long-term mortality better than the Acute Physiology and Chronic Health Evaluation (APACHE) IV score [19].

The aim of this study was to explore to what extent the premorbid functional status (PFS) predicts the 1-year mortality of very old intensive care patients (those aged over 80 years). We hypothesised that a poor PFS would be associated with a poor 1-year outcome.

Methods

The Research Ethics Committee of the Northern Savo Hospital District approved the protocol of this observational cohort study (225/13.02.00/2016). Authorisation for the research was obtained from the National Institute for Health and Welfare (THL/1585/5.05.00/2016).

We defined patients aged 80 years and over as 'very old', in accordance with recent literature [9, 16, 17] and the EU definition [18]. We retrieved data on patients who had been treated in Finnish intensive care units (ICUs) during the period from May 2012 to April 2013, using the Finnish Intensive Care Consortium's (FICC's) database. The FICC database includes information on admissions to all general ICUs [22].

We gathered data on the age, gender, length of stay in the ICU, type of ICU admission (scheduled surgical, emergency surgical or medical), diagnosis and PFS of the patients. On the basis of the primary diagnosis that necessitated intensive care, we classified the patients into ten categories: cardiac or vascular surgery, gastrointestinal surgery, neurological or neurosurgical diseases, trauma, other surgery, cardiovascular diseases, respiratory diseases, metabolic disturbances, intoxication and miscellaneous. We measured the severity of the illness using the Simplified Acute Physiology Score II (SAPS II) [21] and the presence and severity of organ dysfunctions during the first 24 h using the Sequential Organ Failure Assessment (SOFA) [23, 24]. We assessed the treatment intensity with the Therapeutic Intervention Scoring System (TISS) [25].

The patients' premorbid capacity is routinely recorded in the FICC database using the WHO/ECOG performance status classification [26]. We used these data to assess independence in activities of daily living (ADL). Since May 2012, FICC data collection has included more detailed information about the PFS of patients older than 80 years. Their functional status, based on five physical activities (getting out of bed, moving indoors, dressing themselves, climbing stairs and walking 400 m) is documented. For each of these activities, data concerning whether or not the patient has been able to manage without assistance are recorded. Additionally, their accommodation type (lives at home or in institutional care) is documented. PFS is assessed preferably on admission, but in all cases during the ICU stay. The information is obtained by interviewing the patient or his/her next of kin. If the patient is unable to answer the questions because of his/her critical condition, the family are interviewed as soon as they visit the ICU or are in telephone contact with the ICU staff. The functional status 1 year after ICU treatment is assessed using a questionnaire that is sent to the patient.

Take-home message

In Finnish ICU patients aged 80 years or over, 6 out of 10 were still alive 1 year after ICU admission and 5 out of 10 were alive and had a functional status comparable to the premorbid situation. A poor premorbid functional status (defined as need for assistance in activities of daily living or inability to climb stairs) doubled the odds of death within a year.

We determined the discriminative ability of each of the five physical activities to be a prognostic factor, using vital status 1 year after ICU admission as the endpoint. The ability to climb stairs turned out to have the best predictive ability (Supplementary Table S1). Thus, we classified a person who is independent in ADL and able to climb stairs without assistance as one with a good PFS. Conversely, a person who is either dependent on assistance for ADL or unable to climb stairs without assistance was classified as having a poor PFS.

We also created a 'functional status score' that calculates the total number of the five physical activities manageable without assistance. We then compared the PFS score (maximum five points) with the survivors' scores 1 year later.

We used hospital mortality, 1-year mortality and functional status 1 year after intensive care as the primary endpoints. We defined the intensity of treatment and orders to restrict treatment activity as secondary endpoints. We assessed the associations of the PFS with each endpoint.

We conducted our statistical analyses with SPSS version 24 (IBM Corp, Armonk, NY, USA). We used a chi-square test to compare categorical variables, a *t* test to compare continuous variables with normal distributions and a Mann–Whitney *U* test for continuous variables with skewed distributions.

We performed univariate logistic regression analyses to assess the association of baseline variables with hospital and 1-year mortalities. The variables that were significant in the univariate analyses (significance criterion for variable exclusion set at $p > 0.10$) were included in the multivariate regression analysis in order to test their independent association with hospital and 1-year mortalities. Because of interaction between the admission type and diagnostic categories, we included only the admission type in the multivariate analyses. A multivariate regression analysis was first performed without parameters reflecting the PFS, following which these parameters were added to the analysis one at a time. We present the results as odds ratios (OR) with 95% confidence intervals (CI).

We calculated the predicted probabilities of hospital mortality and 1-year mortality with two prognostic models. First, we created a model with the following predictor variables: age, gender, admission type and SAPS II score without admission type points. Second, we added the PFS. To evaluate whether adding PFS data to the prognostic model improved its predictive ability, we assessed the area under the receiver operating characteristic curve (AUROC) for each model. We tested the statistical significance of the difference between the AUROC values with R statistical software using the roc.test function in the ROC package with the paired samples option and the bootstrap method. p values less than 0.05 were considered statistically significant.

Results

During the 1-year study period (May 2012–April 2013), there were 17,451 admissions of patients aged 15 years or older to 25 Finnish ICUs. We excluded readmissions (1062, 6.1%), leaving 16,389 patients, of whom 1827 (11.1%) were very old (≥ 80 years). Data on the 1-year vital status were available for 1791 (98%) very old patients. The baseline characteristics of the study population are presented in Table 1. The characteristics of the very old patients, stratified according to mortality outcomes, are presented in Table 2.

The results of the univariate and multivariate analyses are presented in Table 3. The baseline characteristics are presented separately for scheduled patients and for emergency surgical and emergency medical patients in the Supplementary Table S3, and outcome data for the emergency patients are presented in Supplementary Tables S4 and S5. A poor PFS predicted an increased risk for in-hospital death (adjusted OR 1.50, 95% CI 1.07–2.10). Its independent association with 1-year mortality was even stronger (adjusted OR 2.18, 95% CI 1.67–2.85).

PFS was poor for 43.3% of the very old patients. Hospital mortality was 13.7% (107/779) for the patients with a good PFS, but 23.5% (140/595) for those with a poor PFS ($p < 0.001$). The 1-year mortality was 25.5% (199/779) for patients with a good PFS and 47.1% (280/595) for those with a poor PFS ($p < 0.001$). The hospital and 1-year mortalities for very old patients with good and for those with poor PFS, stratified by admission type, are presented in Fig. 1. A poor PFS was associated with an increased risk of death within 1 year among medical patients (adjusted OR 1.82, 95% CI 1.30–2.54) and an even greater risk increase in surgical patients (adjusted OR 3.55, 95% CI 2.31–5.45). Figure 2 depicts hospital and 1-year mortalities of patients according to each PFS component.

Table 1 Baseline characteristics of the study population

	< 80 years old	80 years and older
Number of admissions	14,562	1827
Age, years	61 (49–70)	83 (81–85)
Male gender, *n* (%)	9478 (65.1)	920 (50.4)
Type of admission, %		
Scheduled surgical	27.5	26.5
Emergency surgical	18	21.8
Medical	54.2	51.6
Diagnostic categories, %		
Cardiac or vascular surgery	23.2	30.0
Gastrointestinal surgery	7.3	11.2
Neurological or neurosurgical diseases	18.8	10.2
Trauma	6.4	3.2
Other surgery	3.5	1.7
Cardiovascular diseases	12.3	20.2
Respiratory diseases	9.3	11.9
Metabolic disturbances	11.4	9.2
Intoxication	4.0	0.2
Miscellaneous	3.7	2.2
SAPS II	29 (21–42)	39 (31–50)
SAPS II without age points	19 (12–31)	21 (13–32)
SAPS II without admission type	25 (17–36)	34 (27–44)
SAPS II without admission type and age points	15 (8–25)	16 (9–26)
SOFA24	5 (3–8)	6 (4–8)
TISS	29.3 (22.0–37.4)	30.7 (24.5–38.5)
LOS ICU	1.36 (0.88-3.11)	1.48 (0.90-2.92)
Independent in ADL, %	88.3[a]	66.3[b]
Hospital mortality	10.6%	21.3%
1-year mortality	20.9%	38.2%

Data for continuous variables are presented as median values (interquartile ranges)

SAPS II Simplified Acute Physiology Score, *SOFA24* Sequential Organ Failure Assessment score based on the first 24 h, *TISS* mean daily Therapeutic Intervention Scoring System 76 score, *LOS ICU* length of stay (days) in intensive care unit, *ADL* activities of daily living

$p = 0.001$ for "SAPS II without admission type and age points"; $p < 0.001$ for all other variables. Data available for [a]98.4%, [b]98.2%

Table 2 Characteristics of the very old (80 years and over) study population by outcome

	Hospital outcome			1-year outcome		
	Survivors	Non-survivors	*p*	Survivors	Non-survivors	*p*
Number of admissions	1410 (78.7%)	381 (21.3%)		1107 (61.8%)	684 (38.2%)	
Age, years	83 (81–85)	83 (81–86)	0.030	83 (81–85)	83 (81–86)	< 0.001
Male gender, *n* (%)	675 (47.9)	230 (60.4)	< 0.001	524 (47.3)	381 (55.7)	0.001
Type of admission, %			< 0.001			< 0.001
Scheduled surgical	32.6	4.2		37.6	8.6	
Emergency surgical	21.9	21.5		20.3	24.3	
Medical	45.5	74.3		42.1	67.1	
Diagnostic categories, %			< 0.001			< 0.001
Cardiac or vascular surgery	35.1	10.2		40.7	12.3	
Gastrointestinal surgery	11.0	12.1		10.3	12.7	
Neurological or neurosurgical diseases	10.6	8.9		9.5	11.5	
Trauma	3.4	2.4		3.5	2.6	
Other surgery	1.8	1.0		1.3	2.3	
Cardiovascular diseases	15.9	37.5		13.8	31.3	
Respiratory diseases	10.6	16.3		9.9	14.9	
Metabolic disturbances	8.9	10.0		8.5	10.1	
Intoxication	0.2	0.3		0.3	0.1	
Miscellaneous	2.4	1.3		2.3	2.0	
SAPS II	36 (31–45)	56 (45–71)	< 0.001	35 (30–43)	48 (39–63)	< 0.001
SAPS II without age points	18 (13–27)	38 (27–53)	< 0.001	17 (12–25)	30 (21–45)	< 0.001
SAPS II without admission type	32 (26–39)	50 (38–65)	< 0.001	31 (25–37)	42 (33–56)	< 0.001
SAPS II without admission type and age points	14 (8–21)	32 (20–47)	< 0.001	13 (7–19)	24 (15–38)	< 0.001
SOFA24	6 (4–8)	9 (7–11.5)	< 0.001	6 (4–8)	8 (5–10)	< 0.001
TISSavg	30.3 (24.0–38.7)	32.0 (27.0–37.6)	0.039	31.0 (24.0–40.0)	30.5 (25.5–36.3)	0.104
LOS ICU	1.24 (0.90–2.78)	1.89 (0.90–4.32)	< 0.001	1.14 (0.90–2.67)	1.80 (0.91–3.92)	< 0.001
Non-independent in ADL, %[a]	31.3	42.4	< 0.001	26.4	45.2	< 0.001
Unable to live at home, %[b]	10.9	12.9	0.351	9.0	15.3	< 0.001
Unable to move indoors, %[c]	4.2	8.3	0.006	3.2	8.1	< 0.001
Unable to walk 400 m, %[d]	26.9	35.7	0.005	23.2	38.6	< 0.001
Unable to climb stairs, %[e]	25.8	32.5	0.004	19.4	36.7	< 0.001
Unable to dress themselves, %[f]	8.0	10.7	0.171	5.7	13.7	< 0.001
Unable to get out of bed, %[g]	3.8	7.9	0.004	2.4	4.5	< 0.001
Poor premorbid functional status, %[h]	40.4	56.7	< 0.001	35.2	58.5	< 0.001

Data for continuous variables are presented as median values (interquartile ranges)

Poor premorbid functional status, a person dependent on assistance for ADL or unable to climb stairs without assistance

SAPS II Simplified Acute Physiology Score, *SOFA24* Sequential Organ Failure Assessment score based on the first 24 h, *TISSavg* mean daily Therapeutic Intervention Scoring System score, *LOS ICU* length of stay (days) in intensive care unit, *ADL* activities of daily living

Data available for [a]98.2%, [b]81.4%, [c]79.6%, [d]78.7%, [e]77.7%, [f]78.8%, [g]78.8%, [h]76.7%

Adding data on the PFS did not result in a statistically significant improvement in the discriminative ability to predict hospital mortality [AUROC 0.833 (95% CI 0.807–0.859) vs. 0.830 (0.803–0.857), $p = 0.169$]. However, PFS data improved discrimination regarding 1-year mortality prediction [AUROC 0.789 (0.764–0.813) vs. 0.772 (0.747–0.798), $p = 0.002$].

Orders to restrict treatment intensity (including orders to withhold treatments or withdraw ongoing treatments) were documented for 3.0% of scheduled surgical, 25.4% of emergency surgical and 33.0% of medical admissions. Treatment restrictions were set for 32.3% (192/595) of patients with a poor PFS, as compared to 13.5% (105/779) of those with a good PFS ($p < 0.001$). In multivariate analysis (Table S2), a poor PFS predicted treatment restrictions (adjusted OR 2.18, 95% CI 1.60–2.97). Hospital mortality was 55.6% (233/419) for patients with treatment restrictions and 10.8% (148/1372) for those

Table 3 Predictors of hospital and 1-year mortality in the very old (80 years and over) study population

Predictors of hospital mortality	Univariate analysis			Multivariate analysis		
	OR	95% CI	*p*	Adjusted OR	95% CI	*p*
Age[a]	1.040	1.004–1.077	0.030			NS
Male gender	1.659	1.317–2.088	< 0.001	1.663	1.264–2.188	< 0.001
Type of admission						
Scheduled surgical	Reference			Reference		
Emergency surgical	7.613	4.371–13.258	< 0.001	4.565	2.563–8.131	< 0.001
Medical	12.646	7.535–21.222	< 0.001	5.449	3.175–9.354	< 0.001
SAPS II without admission type[b]	1.092	1.081–1.102	< 0.001	1.081	1.070–1.092	< 0.001
Non-independent in ADL	1.617	1.278–2.045	< 0.001			NS
Unable to live at home	1.209	0.811–1.802	0.352			NS
Unable to move indoors	2.064	1.214–3.507	0.007	1.846	1.001–3.405	0.050
Unable to walk 400 m	1.506	1.129–2.010	0.005	1.456	1.035–2.049	0.031
Unable to climb stairs	1.542	1.145–2.078	0.004	1.386	0.970–1.979	0.073
Unable to dress themselves	1.369	0.872–2.152	0.173			NS
Unable to get out of bed	2.173	1.257–3.756	0.005	1.823	0.979–3.392	0.058
Poor premorbid functional status	1.932	1.463–2.553	< 0.001	1.501	1.074–2.098	0.017
Predictors of 1-year mortality	**Univariate analysis**			**Multivariate analysis**		
	OR	**95% CI**	***p***	**Adjusted OR**	**95% CI**	***p***
Age[a]	1.086	1.054–1.121	< 0.001	1.081	1.044–1.120	< 0.001
Male gender	1.399	1.155–1.694	0.001	1.428	1.145–1.780	0.002
Type of admission						
Scheduled surgical	Reference			Reference		
Emergency surgical	5.202	3.708–7.297	< 0.001	3.501	2.453–4.998	< 0.001
Medical	6.945	5.137–9.390	< 0.001	3.983	2.898–5.474	< 0.001
SAPS II without admission type[b]	1.073	1.064–1.083	< 0.001	1.064	1.054–1.073	< 0.001
Non-independent in ADL	2.276	1.858–2.789	< 0.001	1.755	1.383–2.227	< 0.001
Unable to live at home	1.827	1.317–2.534	< 0.001	1.640	1.134–2.372	0.009
Unable to move indoors	2.655	1.632–4.319	< 0.001	2.269	1.338–3.848	0.002
Unable to walk 400 m	2.084	1.643–2.644	< 0.001	2.048	1.561–2.687	< 0.001
Unable to climb stairs	2.417	1.887–3.096	< 0.001	2.287	1.719–3.044	< 0.001
Unable to dress themselves	2.606	1.785–3.806	< 0.001	2.302	1.520–3.484	< 0.001
Unable to get out of bed	3.844	2.267–6.518	< 0.001	3.094	1.757–5.450	< 0.001
Poor premorbid functional status	2.591	2.063–3.253	< 0.001	2.181	1.670–2.848	< 0.001

Poor premorbid functional status, a person dependent on assistance for ADL or unable to climb stairs without assistance

Multivariate analysis includes variables that were significant (with the significance criterion for variable exclusion set at 0.10) in univariate analyses. The first phase of binary multivariate logistic regression analysis was performed without premorbid functional status variables and then the variables were tested individually

OR odds ratio, *CI* confidence interval, *SAPS II* Simplified Acute Physiology Score, *ADL* activities of daily living

[a] For each additional year of age

[b] For each additional point

without restrictions ($p < 0.001$). The 1-year mortality was 77.8% (326/419) for patients with treatment restrictions and 26.1% (358/1372) for those without restrictions ($p < 0.001$). The mean daily TISS score, reflecting intensity of treatment, was 32.0 (interquartile range 25.0–40.0) for patients with a good PFS and 29.2 (24.0–35.0) for those with a poor PFS ($p < 0.001$).

For 1-year survivors ($n = 1107$), data on the PFS was available for 903 (81.6%), data on functional status at 1 year for 822 (74.3%) and data on both of these for 676 (61.1%) patients. The PFS score was at least 4 out of 5 in 84.4%, and the score was at least 4 out of 5 in 79.6% 1 year after intensive care. The functional status score at 1 year after intensive care was the same or better than the premorbid score for 77.8% of the survivors in the overall

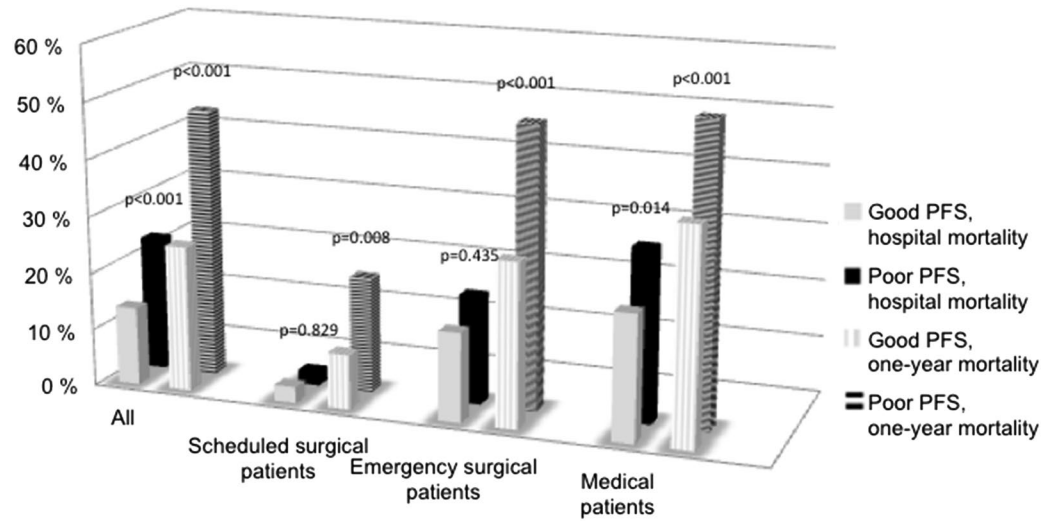

Fig. 1 Hospital mortality and 1-year mortality for patients in different admission categories, according to PFS. *p* values refer to comparisons between patients with good PFS and those with poor PFS. *PFS* premorbid functional status

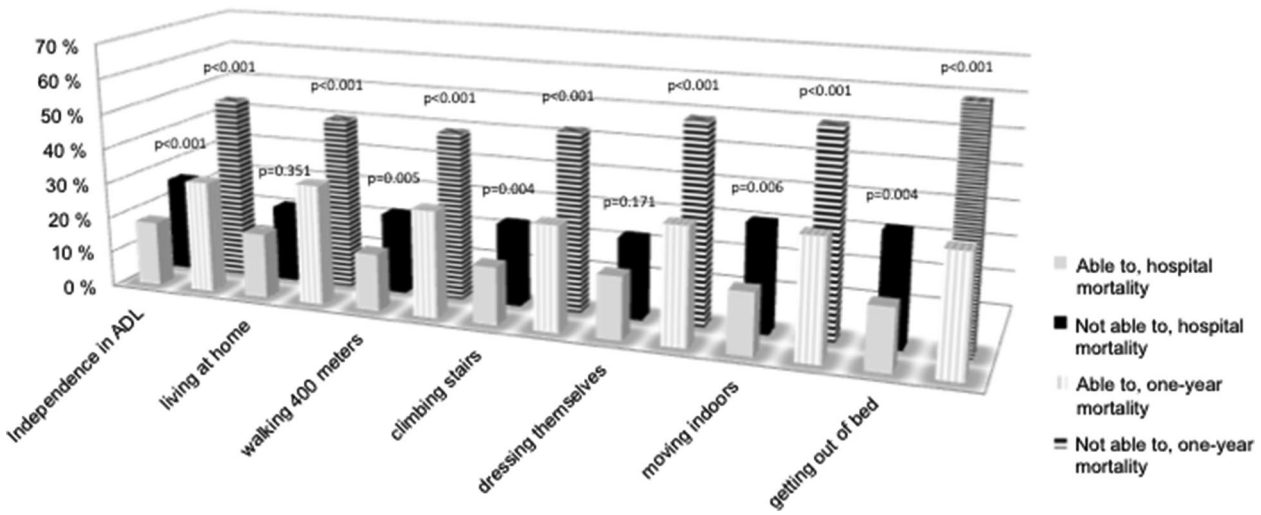

Fig. 2 Hospital mortality and 1-year mortality, according to the ability to perform physical activities *p* values refer to comparisons between patients who were able and those who were unable to manage the activity

patient population, and for 84.9% in scheduled surgical patients, for 79.3% in emergency surgical patients and for 70.0% in medical patients (Supplementary Tables S6–8). Of all the 1-year survivors, 84.2% lived at home 1 year after ICU admission, and 88.3% of the survivors who had lived at home before the ICU admission were still living at home.

Discussion

In this nationwide, multicentre, observational registry study on 1827 very old ICU patients (those aged 80 years or over), 79% of the patients were discharged alive from the hospital, and 62% were alive 1 year after ICU admission. Of 1-year survivors, 78% had a functional status comparable to the premorbid situation, and 84% of them lived at home 1 year after ICU admission.

A key finding of our study is that the PFS was independently associated with 1-year mortality in very old patients. A poor PFS doubled the odds of death within 1 year. This association was particularly strong for surgical patients; the odds of death within a year were 3.5-fold higher for surgical patients with a poor PFS than for those with a good PFS.

Some previous studies have also found that the pre-admission functional status affects the probability of death in critically ill old patients. Heyland et al. [16, 27]

studied very old (≥ 80 years) ICU patients in Canada. They found that a good baseline functional performance was predictive of 1-year survival and better performance. The 1-year survival was 50%, and only about 50% of the survivors recovered to their premorbid level of physical functioning [16, 27]. Only one-third of the survivors who had lived at home before ICU admission returned home [16]. Heyland et al. did not include scheduled surgical admissions and admissions that lasted under 24 h in their study, which may explain the somewhat poorer outcomes than those found in our study.

The number of scheduled surgical patients was rather high (26.5%) in our study. Most of these patients were admitted after cardiovascular surgery. For emergency patients, hospital mortality was 28%, and 1-year mortality was 48%, which is comparable to the mortality outcomes in the study by Heyland et al. [27]. For the majority of 1-year survivors in our study, regardless of the type of admission, the functional status at 1 year was comparable to that of the premorbid situation.

Krinsley et al. [19] found that the functional status before ICU admission is an independent predictor of hospital mortality. They also noticed that comorbidities, which may be used as indicators of chronic health status, do not necessarily correlate with a patient's functional capacity. Recently, Flaatten et al. [15] studied frailty and outcomes in very old (≥ 80 years) ICU patients. They found that the presence of frailty is independently associated with 30-day mortality with an OR of 1.5. Interestingly, we found that a poor PFS predicted an increased risk for in-hospital death with an adjusted OR of 1.5. Flaatten et al. [15] defined frailty as a value of 5 or higher on the Clinical Frailty Scale (CFS) [28]. CFS values below 5 describe people who are not dependent on help for daily activities, whereas the value 5 describes mild frailty, typically associated with evident slowing of physical activities, and values higher than 5 mean more severe frailty. It is plausible that our simple definition of poor PFS (need for help in ADLs or inability to climb stairs) may be nearly comparable to the definition of frailty used by Flaatten et al.

The relevance of assessing frailty in association with intensive care has received considerable attention recently. In their systematic review, Pugh et al. [29] evaluated the available evidence concerning the feasibility and reliability of frailty assessment in the critically ill. They stated that using conventional frailty assessment tools may be problematic in critical illness. Frailty assessment of critically ill patients often relies on proxies, and the reliability of assessment tools should be evaluated.

We found that a medical reason for ICU admission, as opposed to surgical admission, was a strong risk factor for adverse outcomes. This accords with findings from other studies; elderly patients admitted after surgical treatment, especially scheduled operative care, have better survival rates than those admitted for a medical reason [16, 27]. However, we found that a poor PFS worsened the 1-year prognosis of surgical patients even more strongly than that of medical patients. Among patients with a poor PFS, the 1-year mortality of emergency surgical patients was not remarkably different from that of medical patients.

Living at home was only weakly associated with survival in our study population. This is probably explained by the fact that even people with poor physical health can live at home with the help of their families or outpatient healthcare systems. Thus, although living in institutional care is a known risk factor for a poor long-term outcome [30], living at home does not necessarily mean a good long-term prognosis.

We tested the prognostic value of different physical activities and, on the basis of these analyses, defined a good PFS as independence in ADL and the ability to climb stairs without assistance. In the multivariate analyses, the abilities to get dressed and to get out of bed were strongly associated with survival. However, there were few patients who were unable to perform these functions. We presume that a majority of patients with limitations in these activities have not been referred or admitted to intensive care.

Currently, no clinical prediction tool exists that is validated specifically for the very old. Commonly used severity-of-disease scoring systems include age [9, 21]. However, the capacity to recover from a critical illness cannot be estimated on the basis of chronological age alone. In our study, each of the five functional status parameters correlated with mortality more strongly than age. Adding information about the PFS to our prediction model significantly improved its predictive ability for 1-year mortality. This result, in addition to the results of other studies [4, 15, 31], suggests that prediction models could be improved by incorporating factors reflecting physiological age in addition to chronological age.

The results of our study may have clinical implications. We have demonstrated that a simple measure of functional status, the combination of independence in ADL and ability to climb stairs, is a useful indicator of a patient's physiological reserves that affect the ability to recover from a critical illness. Asking simple questions about the PFS gives important information in addition to the physical examination of very old patients. Our study is based on data collected prospectively to a nationwide high-quality database, which means that the study population is well representative of very old general ICU patients.

There are limitations to our study. The study population is prone to selection bias. For example, only 5% of the very old patients were unable to move indoors, only 5% were unable to get out of bed without assistance, and only 9% were unable to dress themselves (Fig. S1). It is likely that many old patients with a poor functional status, very old age or a do-not-resuscitate order were never referred to or admitted to the ICUs. Therefore, our study population can be assumed to represent the very old who were initially considered to have reasonable chances to recover from their critical illness. Nevertheless, the PFS had a significant impact on the prognosis even in this selected population, which actually strengthens the reasoning that PFS strongly affects the outcome.

In addition to admission policies, decisions to limit treatment intensity in the ICU may have affected our study population and their outcomes. A poor PFS was associated with a lower treatment intensity and with more treatment restrictions. Several other studies have documented more restrictions on life-sustaining treatment modalities in the elderly or very old as compared to younger patients [32, 33]. The treatment intensity for the very old has been previously documented to be lower, and the length of stay shorter, compared to younger patients [2, 33]. However, in our study, the treatment intensity, as measured with TISS points, was actually higher in the very old than in younger patients. The median length of ICU stay was also longer in the very old than in younger patients.

In summary, six out of 10 very old intensive care patients were still alive 1 year after ICU admission, and five out of 10 were alive and had a functional status comparable to the premorbid situation. However, a poor PFS doubled the odds of death within a year, highlighting the importance of information on functional performance. Knowledge of PFS improved significantly the prediction of 1-year mortality.

Electronic supplementary material
The online version of this article (https://doi.org/10.1007/s00134-018-5273-y) contains supplementary material, which is available to authorized users.

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Compliance with ethical standards

Conflicts of interest
Dr Hästbacka has received reimbursement for research meeting travel expenses from LaJolla Pharmaceutical and compensation for consulting from Pfizer. The other authors have no conflicts of interests.

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References

1. World Health Organization (2017) Ageing and life course. http://www.who.int/topics/ageing/en/Accessed 5 June 2018
2. Reinikainen M, Uusaro A, Niskanen M, Ruokonen E (2007) Intensive care of the elderly in Finland. Acta Anaesthesiol Scand 51:522–529
3. Nielsson MS, Christiansen CF, Johansen MB, Rasmussen BS, Tonnesen E, Norgaard M (2013) Mortality in elderly ICU patients: a cohort study. Acta Anaesthesiol Scand 58:19–26
4. Montgomery C, Bagshaw SM (2017) Frailty in the age of VIPs (very old intensive care patients). Intensive Care Med 43:1887–1888
5. Bagshaw SM, Mc Dermid RC (2013) The role of frailty in outcomes from critical illness. Curr Opin Crit Care 19:496–503
6. Bagshaw SM, Stelfox HT, McDermid RC et al (2014) Association between frailty and short- and long-term outcomes among critically ill patients: a multicentre prospective cohort study. CMAJ 186:E95–E102
7. Bagshaw SM, Stelfox HT, Johnson JA et al (2015) Long-term association between frailty and health-related quality of life among survivors of critical illness: a prospective multicenter cohort study. Crit Care Med 43:973–982
8. Muscedere J, Waters B, Varambally A et al (2017) The impact of frailty on intensive care unit outcomes: a systematic review and meta-analysis. Intensive Care Med 43:1105–1122
9. Flaatten H, de Lange DW, Artigas A et al (2017) The status of intensive care medicine research and future agenda for very old patients in the ICU. Intensive Care Med 43:1319–1328
10. Chelluri L, Pinsky MR, Donahoe MP, Grenvik A (1993) Long-term outcome of critically ill elderly patients requiring intensive care. JAMA 269:3119–3123
11. Wood KA, Ely EW (2003) What does it mean to be critically ill and elderly? Curr Opin Crit Care 9:316–320
12. Kaarlola A, Tallgren M, Pettilä V (2006) Long-term survival, quality of life, and quality-adjusted life-years among critically ill elderly patients. Crit Care Med 34:2120–2126

13. Zampieri FG, Colombari F (2014) The impact of performance status and comorbidities on the short-term prognosis of very elderly patients admitted to the ICU. BMC Anesthesiol 14:59–67
14. Heyland D, Cook D, Bagshaw SM et al (2015) The very elderly admitted to ICU: a quality finish? Crit Care Med 43:1352–1360
15. Flaatten H, De Lange DW, Morandi A et al (2017) The impact of frailty on ICU and 30-day mortality and the level of care in very elderly patients (≥ 80 years). Intensive Care Med 43:1820–1828
16. Heyland DK, Garland A, Bagshaw SM et al (2015) Recovery after critical illness in patients aged 80 years or older: a multi-center prospective observational cohort study. Intensive Care Med 41:191–1920
17. Ihra GC, Lehberger J, Hochrieser H et al (2012) Development of demographics and outcome of very old critically ill patients to intensive care units. Intensive Care Med 38:620–626
18. European Commission (2012) eHealth Action Plan 2012–2020—Innovative healthcare for the 21st century. https://ec.europa.eu/digital-single-market/en/news/ehealth-action-plan-2012-2020-innovative-healthcare-21st-century. Accessed 5 June 2018
19. Krinsley JS, Wasser T, Kang G, Bagshaw SM (2017) Pre-admission functional status impacts the performance of the APACHE IV model of mortality prediction in critically ill patients. Crit Care 21:110
20. Knaus WA, Draper EA, Wagner DP (1985) APACHE II: a severity of disease classification system. Crit Care Med 13:818–829
21. Le Gall JRJ, Lemeshow SS, Saulnier FF (1993) A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicenter study. JAMA 270:2957–2963
22. Reinikainen M, Mussalo P, Hovilehto S, Uusaro A, Varpula T, Kari A, Pettilä V, Finnish Intensive Care Consortium (2012) Association of automated data collection and data completeness with outcome of intensive care. A new customised model for outcome prediction. Acta Anaesthesiol Scand 56:1114–1122
23. Vincent JL, Moreno R, Takala J et al (1996) The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. On behalf of the Working Group on Sepsis-Related Problems of the European Society of Intensive Care Medicine. Intensive Care Med 22:707–710
24. Vincent JL, de Mendonça A, Cantraine F et al (1998) Use of the SOFA score to assess the incidence of organ dysfunction/failure in intensive care units: results of a multicenter, prospective study. Working group on "sepsis-related problems" of the European Society of Intensive Care Medicine. Crit Care Med 26:1793–1800
25. Keene AR, Cullen DJ (1983) Therapeutic Intervention Scoring System: update 1983. Crit Care Med 11:1–3
26. Oken M, Creech R, Tormey D et al (1982) Toxicity and response criteria of the Eastern Cooperative Oncology Group. Am J Clin Oncol 5:649–655
27. Heyland DK, Stelfox HT, Garland A et al (2016) Predicting performance status 1 year after critical illness in patients 80 years or older: development of a multivariable clinical prediction model. Crit Care Med 44:1718–1726
28. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, Mitnitski A (2005) A global clinical measure of fitness and frailty in elderly people. CMAJ 173:489–495
29. Pugh RJ, Ellison A, Pye K, Subbe CP, Thorpe CM, Lone NI, Clegg A (2018) Feasibility and reliability of frailty assessment in the critically ill: a systematic review. Crit Care 22:49
30. Bagshaw SM, Webb SA, Delaney A et al (2009) Very old patients admitted to intensive care in Australia and New Zealand: a multi-centre cohort analysis. Crit Care 13:R45
31. Robert R, Skrifvars MB, Ranzani OT (2017) Is this critically ill patient elderly or too old? Intensive Care Med 43:1884–1886
32. Boumendil A, Aegerter P, Guidet B, CUB-Rea Network (2005) Treatment intensity and outcome of patients aged 80 and older in intensive care units: a multicenter matched-cohort study. J Am Geriatr Soc 53:88–93
33. Skjaker SA, Hoel H, Dahl V, Stavem K (2017) Factors associated with life-sustaining treatment restriction in a general intensive care unit. PLoS One 12(7):e0181312