Intensive Care Med
DOI 10.1007/s00134-012-2629-6

ORIGINAL

Lior Fuchs
Catherine E. Chronaki
Shinhyuk Park
Victor Novack
Yael Baumfeld
Daniel Scott
Stuart McLennan
Daniel Talmor
Leo Celi

ICU admission characteristics and mortality rates among elderly and very elderly patients

Received: 13 March 2012
Accepted: 13 June 2012

L. Fuchs and C. E. Chronaki equally contributed to this study.

Electronic supplementary material The online version of this article (doi:10.1007/s00134-012-2629-6) contains supplementary material, which is available to authorized users.

L. Fuchs (✉) · V. Novack · D. Talmor
Department of Anesthesia, Critical Care and Pain Medicine, Beth Israel Deaconess Medical Center and Harvard Medical School, 1 Deaconess Rd. CC-470, Boston, MA 02215, USA
e-mail: lfuchs@bidmc.harvard.edu
Tel.: +1-617-9971114
Fax: +1-617-7542735

C. E. Chronaki
FORTH-Institute of Computer Science, Science and Technology Park of Crete, Crete, Greece

S. Park
College of Computer and Information Science, Northeastern University, Boston, MA, USA

V. Novack · Y. Baumfeld
Clinical Research Center, Soroka University Medical Center, Beer-Sheva, Israel

D. Scott
The Harvard–Massachusetts Institute of Technology Division of Health Sciences and Technology (TM, DJS, JL, RGM), Boston, MA, USA

S. McLennan
Institute for Biomedical Ethics, Universität Basel, Basel, Switzerland

L. Celi
Department of Pulmonary and Critical Care, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, USA

Abstract *Purpose:* The effect of advanced age per se versus severity of chronic and acute diseases on the short- and long-term survival of older patients admitted to the intensive care unit (ICU) remains unclear. *Methods:* Intensive care unit admissions to the surgical ICU and medical ICU of patients older than 65 years were analyzed. Patients were divided into three age groups: 65–74, 75–84, and 85 and above. The primary endpoints were 28-day and 1-year mortality. *Results:* The analysis focused on 7,265 patients above the age of 65, representing 45.7 % of the total ICU population. From the first to third age group there was increased prevalence of heart failure (25.9–40.3 %), cardiac arrhythmia (24.6–43.5 %), and valvular heart disease (7.5–15.8 %). There was reduced prevalence of diabetes complications (7.5–2.4 %), alcohol abuse (4.1–0.6 %), chronic obstructive pulmonary disease (COPD) (24.4–17.4 %), and liver failure (5.0–1.0 %). Logistic regression analysis adjusted for gender, sequential organ failure assessment, do not resuscitate, and Elixhauser score found that patients from the second and third age group had odds ratios of 1.38 [95 % confidence interval (CI) 1.19–1.59] and 1.53 (95 % CI 1.29–1.81) for 28-day mortality as compared with the first age group. Cox regression analysis for 1-year mortality in all populations and in 28-day survivors showed the same trend. *Conclusions:* The proportion of elderly patients from the total ICU population is high. With advancing age, the proportion of various preexisting comorbidities and the primary reason for ICU admission change. Advanced age should be regarded as a significant independent risk factor for mortality, especially for ICU patients older than 75.

Keywords Elderly · Outcomes · Critical care · Long-term mortality

Published online: 14 July 2012

Introduction

As the proportion of the elderly in the general population grows, the number of elderly patients being admitted to the intensive care unit (ICU) is also increasing [1–4]. The proportion of patients older than 80 years out of total ICU admissions in various developed countries has been estimated as being between 7 and 25 % and growing [5–9]. A recent analysis in Australia and New Zealand found an annual increase of 5.6 % in the number of patients over 85 years. This trend potentially translates to a 72.4 % increase in demand for ICU bed-days by 2015 [4].

The role of advanced age as opposed to severity of chronic and acute diseases in the short- and long-term survival of older patients admitted to the ICU remains unclear [4, 9–11]. Some studies have concluded that age is not predictive of poor prognosis for ICU patients, and that severity of illness and premorbid functional status primarily determine patient outcome [5, 7–12]. Moreover, the incremental mortality risk associated with age has not been defined in the population over 65 years.

Intensive care unit is an expensive and scarce resource. In the face of growing demand, pragmatic decisions regarding appropriate levels of care may become necessary. The results of this study will inform discussions with patients and families regarding appropriate goals of care. Characterization of the growing population of elderly patients being admitted to the ICU is vital for these discussions.

This study seeks to evaluate the association between the demographic and clinical characteristics of patients over the age of 65 and their 28-day and 1-year mortality.

Patients and methods

Assembly of the cohort

The multiparameter intelligent monitoring of intensive care (MIMIC-II) project [13] was approved by the institutional review boards of the Massachusetts Institute of Technology and Beth Israel Deaconess Medical Center (BIDMC) and granted a waiver of informed consent. The MIMIC-II database is maintained by researchers at the Harvard-MIT Division of Health Sciences and Technology and includes the physiologic information of patients admitted between August 2001 and 2008 to one of BIDMC's ICUs, a large academic tertiary medical center in Boston, MA. The database contains records of demographic and clinical data as well as do not resuscitate (DNR) order on admission to the ICU. Acuity level on admission was calculated using simplified acute physiology score (SAPS-I) [14] and sequential organ failure assessment (SOFA) [15]. Further clinical data added to the database included admission and death records, discharge summaries, and ICD-9 codes for primary reason of admission.

Nonplanned medical and surgical ICU admissions within the study period of ICU patients older than 65 years were initially analyzed. Cardiac vascular surgical ICU and nonsurgical cardiac ICU admissions were excluded, as only nonplanned ICU admissions were analyzed. The cohort was divided into three age groups for analysis: 65–74, 75–84, and age 85 and above.

Statistical analysis

The primary endpoints were 28-day and 1-year mortality. Data were summarized using frequency tables, summary statistics, confidence intervals, and p values, as appropriate. The preferred method of analysis for continuous variables was parametric. Nonparametric analysis methods were used only if parametric assumptions could not be satisfied, even after data transformation attempts. Parametric model assumptions were assessed using normal-plot or Shapiro–Wilk statistic for verification of normality and Levene's test for verification of homogeneity of variances. Categorical variables were tested using Pearson's χ^2 test for contingency. Kaplan–Meier survival curves with log-rank test were built for the analysis of all-cause mortality.

The multivariate analysis for death within 28 days from admission was done using a logistic regression model. The variables were introduced into the model based on clinical and statistical significance (p value ≥ 0.1 on univariate analysis). The final parsimonious model included the following variables: the age groups 75–84 and over 84 versus the age group of 65–74, DNR status, SOFA [15] severity score at admission, and Elixhauser comorbidity score [16, 17]. The 1-year mortality analysis of all patients and the landmark analysis of the 28-day survivors were done using a Cox proportional-hazards survival regression model. For the landmark analysis the model included only patients who survived for 28 days. This type of analysis allows us to assess mortality trends in patients surviving the acute period. The variables introduced into the model included the same variables introduced into the logistic regression model.

Age trends were evaluated by fitting a locally weighted scatterplot smoothing (LOESS) curve of the adjusted mortality probability to the patient age. At each age a low-degree polynomial is fitted to a subset of the data with age values near the point at which adjusted mortality probability is estimated [18].

All p values reported were rounded to three decimal places. All statistical tests and/or confidence intervals, as appropriate, were performed at $\alpha = 0.05$ (two-sided). The data were analyzed using SPSS 18 software.

Results

Demographics

During the study period there were 19,510 ICU admissions (Fig. 1). Of these, 8,916 (45.7 %) were admissions of patients older than 65. These included 2,585 (13.2 %) between 65 and 74, 3,003 (15.4 %) between 75 and 84, and 1,677 (8.6 %) older than 85. This analysis focused on 7,265 first admissions of patients above the age of 65.

Table 1 presents baseline demographic and clinical characteristics of the patient population. With advancing age, patients are more likely to be admitted to the medical ICU (from 58.5 % in age group 1 to 66.4 % in age group 3) while the proportion admitted to surgical ICUs decreases (41.5 % in age group 1 to 33.6 % in age group 3).

With increasing age the prevalence of some preexisting conditions increased, e.g., heart failure, cardiac arrhythmia, and valvular heart disease. However, prevalence of other conditions such as diabetes with complications, alcohol abuse, COPD, liver failure, metastatic cancer, and psychosis significantly decrease with age.

Admission characteristics

Table 2 presents the admission characteristics of the elderly patient population. With advanced age, trauma and infectious etiologies increased: among the patients older than 85 years trauma was the second most prevalent reason for an ICU admission (19.4 %), but only the fifth (10.8 %) among the first age group ($p < 0.001$). With aging, patients received less renal replacement therapy (RRT), vasopressors, and mechanical ventilation. Adjusted for DNR status (multivariate logistic regression), age was associated with decreased odds for receiving RRT [odds ratio (OR) of 0.66 for age 75–85 (95 % CI 0.54–0.79) and of 0.39 for older than 85 years (95 % CI 0.30–0.51)] and decreasing odds of being ventilated [OR of 0.88 for age 75–85 (95 % CI 0.79–0.88) and of 0.64 for older than 85 years (95 % CI 0.56–0.73)].

Clinical outcomes in the elderly

Out of 7,265 ICU admissions, 1,898 patients (26 %) died within 28 days from admission, and out of 5,367 patients who survived to 28 days from admission, 1,357 patients (25 %) died between 28 days to 1 year. Mortality rates in ICU, in hospital, at 28 days, and at 1 year significantly increased with age (Table 3). In the group of patients older than 85 years the 1-year mortality rate was 56 % as compared with 36 % in the group of 65- to 75-year-olds ($p < 0.001$). One-year mortality in those patients who survived to 28 days after ICU admission also increased with age (19.9, 24.8, and 32.9 % mortality rate from first to third age group, respectively, $p < 0.001$). One-year mortality rates for all patients with DNR status on admission were 80.7 % for the first group, 70.5 % for the second group, and 72.6 % for the third group ($p = 0.03$).

Logistic regression analysis (Table 4) showed that, adjusted for baseline characteristics (SOFA, Elixhauser

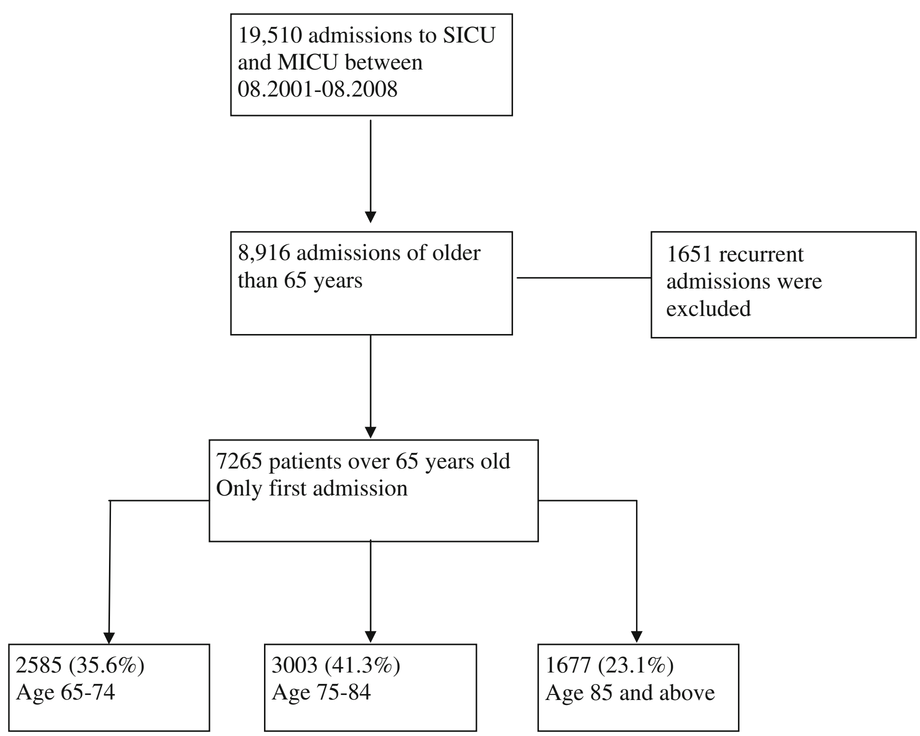

Fig. 1 Patient population flowchart

Table 1 Baseline characteristics of ICU patients, 2001–2008 ($n = 7{,}265$)

Variable	Age group			*p*-value
	65–74 $n = 2{,}585$ (35.6 %)	75–84 $n = 3{,}003$ (41.3 %)	Over 84 $n = 1{,}677$ (23.1 %)	
Unit of discharge, *n* (%)				
Medical	1,511 (58.5)	1,792 (59.7)	1,114 (66.4)	<0.001
Surgical	1,074 (41.5)	1,211 (40.3)	563 (33.6)	
Male gender, *n* (%)	1,387 (53.7)	1,490 (49.7)	658 (39.4)	<0.001
Age, years (±SD)	70.07 ± 2.88	79.87 ± 2.83	89.38 ± 3.26	0.001
Marital status, *n* (%)				
Married	1,391 (53.8)	1,468 (48.9)	502 (29.9)	<0.001
Other	1,194 (46.2)	1,535 (51.1)	1,175 (70.1)	
Comorbidities, *n* (%)				
Elixhauser score	6.17 ± 8.01	6.35 ± 7.60	6.58 ± 7.12	0.23
Diabetes uncomplicated	560 (21.7)	625 (20.8)	299 (17.9)	0.01
Diabetes complicated	194 (7.5)	117 (3.9)	40 (2.4)	<0.001
Congestive heart failure	669 (25.9)	974 (32.4)	675 (40.3)	<0.001
Alcohol abuse	106 (4.1)	44 (1.5)	10 (0.6)	<0.001
Cardiac arrhythmias	634 (24.6)	1,038 (34.6)	729 (43.5)	<0.001
Valvular disease	194 (7.5)	347 (11.6)	264 (15.8)	<0.001
HTN	1,048 (40.6)	1,321 (44.0)	740 (44.2)	0.02
Chronic renal failure	202 (7.8)	196 (6.5)	103 (6.1)	0.06
COPD	628 (24.4)	671 (22.4)	292 (17.4)	<0.001
Liver failure	130 (5.0)	59 (2.0)	16 (1.0)	<0.001
Metastatic cancer	215 (8.3)	191 (6.4)	60 (3.6)	<0.001
Psychosis	79 (3.1)	73 (2.4)	21 (1.3)	0.001
Depression	97 (3.8)	103 (3.4)	83 (5.0)	0.03

HTN hypertension, *COPD* chronic obstructive pulmonary disease

Table 2 Hospitalization characteristics

	Age group			*p*-value
	65–74 $n = 2{,}585$ (35.4 %)	75–84 $n = 3{,}003$ (41.1 %)	Over 84 $n = 1{,}677$ (23.5 %)	
Admission source				
ED	1,671 (64.6)	2,225 (74.1)	1,398 (83.4)	<0.001
Other hospital	432 (16.7)	379 (12.6)	143 (8.5)	
Other	482 (18.6)	399 (13.3)	136 (8.1)	
Primary reason of admission, *n* (%)				
Infectious	253 (9.8)	330 (11.0)	231 (13.8)	<0.001
Cardiovascular	561 (21.7)	685 (22.8)	389 (23.2)	
Respiratory	329 (12.8)	374 (12.5)	219 (13.1)	
Cancer	330 (12.8)	270 (9.0)	86 (5.1)	
GI	394 (15.3)	464 (15.5)	268 (16.0)	
GU	69 (2.7)	105 (3.5)	42 (2.5)	
Trauma	279 (10.8)	446 (14.9)	325 (19.4)	
Treatment complication	143 (5.5)	130 (4.3)	34 (2.0)	
Other	222 (8.6)	197 (6.6)	81 (4.6)	
Acuity score on admission				
SOFA	5.37 ± 3.97	5.25 ± 3.72	5.09 ± 3.53	0.06
SAPS-I	14.09 ± 5.07	15.12 ± 4.99	15.21 ± 4.67	<0.001
Intensity of care				
RRT during hospitalization	228 (11.1 %)	229 (7.6 %)	80 (4.8 %)	<0.001
Use of vasopressors	707 (27.4 %)	782 (26.0 %)	405 (24.2 %)	0.07
Mechanical ventilation	1346 (52.1 %)	1452 (48.4 %)	666 (39.7 %)	<0.001
DNR at admission	176 (6.8)	461 (15.4)	496 (29.6)	<0.001

ED emergency department, *GI* gastrointestinal, *GU* genitourinary, *SOFA* sequential organ failure assessment, *SAPS* simplified acute physiology score, *RRT* renal replacement therapy, *DNR* do not resuscitate

Table 3 Clinical outcomes ($n = 7{,}265$)

	Age group			*p*-value
	65–74 $n = 2{,}585$ (35.4 %)	75–84 $n = 3{,}003$ (41.1 %)	Over 84 $n = 1{,}677$ (23.5 %)	
LOS in days (median, IQR)				
Hospital	9 (5–15)	8 (5–14)	7 (4–11)	<0.001
ICU	2.41 (1.22–5.04)	2.24 (1.27–4.58)	2.07 (1.13–3.76)	<0.001
Mortality, *n* (%)				
In-hospital	486 (18.8)	706 (23.5)	468 (27.9)	<0.001
In-ICU	285 (11.0)	423 (14.1)	245 (14.6)	<0.001
28-Day mortality	528 (20.4)	840 (28.0)	580 (34.6)	<0.001
1-Year mortality	937 (36.2)	1,377 (45.9)	941 (56.1)	<0.001

LOS length of stay, *IQR* interquartile range, *ICU* intensive care unit

Table 4 Logistic regression models of 28-day mortality of ICU patients

	Odds ratio	95 % CI	*p*-value
Age groups (vs. 65–74)			
75–84	1.52	1.32–1.74	<0.001
85 and up	1.85	1.57–2.17	<0.001
Gender, male	1.06	0.95–1.20	0.31
SOFA, per point	1.23	1.21–1.24	<0.001
DNR at admission	3.64	3.14–4.21	<0.001
Elixhauser score, per point	1.04	1.03–1.05	<0.001

SOFA sequential organ failure assessment, *DNR* do not resuscitate

Table 5 Cox regression model for 1-year mortality in ICU patients

	Hazard ratio	95 % CI	*p*-value
Age groups (vs. 65–74)			
75–84	1.21	1.06–1.38	0.01
85 and over	1.59	1.37–1.85	<0.001
Gender, male	1.06	0.95–1.18	0.30
SOFA, per point	1.04	1.02–1.05	<0.001
DNR at admission	1.87	1.61–2.17	<0.001
Elixhauser score, per point	1.07	1.05–1.07	<0.001

Landmark analysis in 28-day survivors, $n = 5{,}317$
SOFA sequential organ failure assessment, *DNR* do not resuscitate

score, DNR status at admission, and gender), patients between 75 and 85 and over 85 years old had odds ratios of 1.52 (95 % CI 1.32–1.74) and 1.85 (95 % CI 1.57–2.17) for death within 28 days when compared with the reference group (65–75 years). Similarly, Cox regression analysis for 1-year mortality in 28-day survivors (Table 5) showed the same trend [hazard ratio (HR) of 1.21 and 1.59 for the second and third age groups, respectively]. Over age of 75 there is a linear increase in adjusted mortality probability at 28 days from ICU admission and at 1 year among 28-day ICU survivors (Fig. 2a, b). Sensitivity analysis in the group of ventilated patients showed a similar age-related increased mortality risk pattern at 28 days from ICU admission and for 1 year among 28-day survivors (Supplementary Figure 3a, b).

Discussion

In this retrospective observational study our main findings were that the elderly and very elderly constitute a major proportion of the ICU population. Among these patients, with advancing age, the proportion of various preexisting comorbidities as well as the primary reasons for ICU admission change. Mortality in the elderly population following ICU admission is high, and patient age is a significant independent risk factor for ICU mortality in a nonlinear fashion.

Proportion of elderly in the ICU

Our findings are consistent with a recent large cohort from Australia and New Zealand [4]. In that study, among 120,123 admissions to 57 ICUs, 13 % were very elderly patients (>80 years), showing an annual ICU admission increase of 5.6 % per year. We found that 45 % of our ICU patients were over age of 65; 10.35 % were age 85 and over. Knowing the proportion of elderly patients that are being admitted to the ICU will enable policy-makers to plan for future needs. Care of elderly ICU patients should also be a focus of future comparative effectiveness research in the critically ill as premorbid conditions, the reasons for admission, and both short- and long-term outcomes differ in this population.

Risk factors for elderly ICU admission

The current study identifies a number of characteristics among elderly ICU patients of particular importance. In the older age groups, ICU admission is commonly

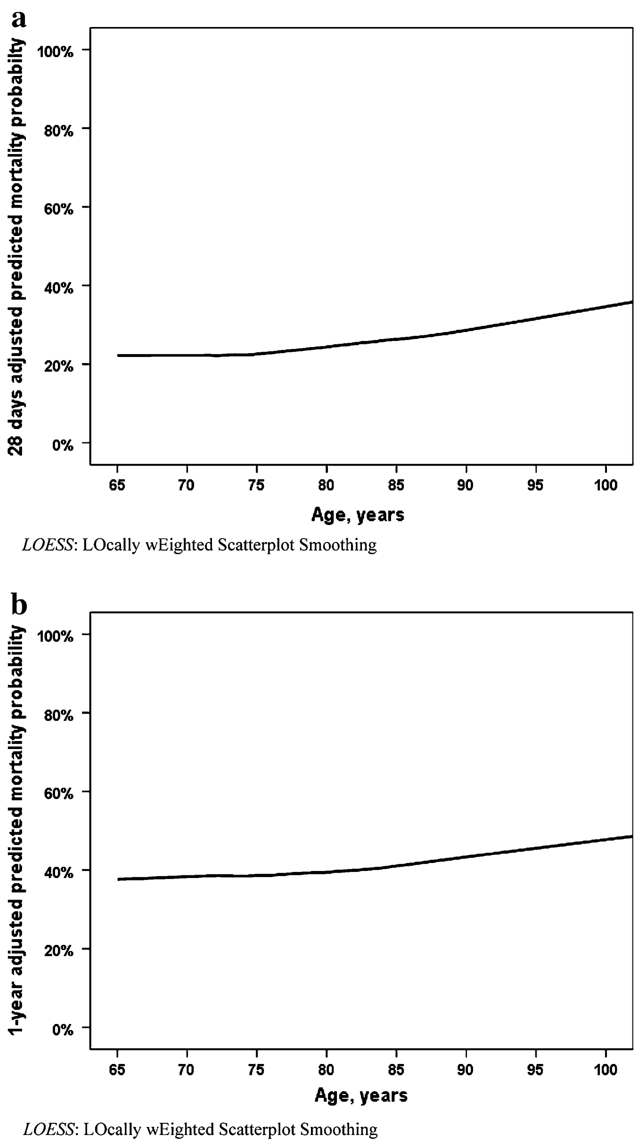

Fig. 2 **a** LOESS adjusted 28-day mortality probability by age. Risks are adjusted for gender, SOFA at admission, Elixhauser, and DNR status. **b** LOESS adjusted 1-year mortality probability by age in 28-day survivors. Risks are adjusted for gender, SOFA at admission, Elixhauser, and DNR status

associated with potentially preventable conditions. We found that with advanced age heart failure, cardiac arrhythmia, and valvular heart disease are more prevalent in the ICU population. To what extent these comorbidities are a reflection of advanced age with increased prevalence of chronic diseases as opposed to factors that are associated with increased risk of ICU admission is yet to be defined. On the other hand, other comorbidities significantly decreased with age: diabetes with complications, alcohol abuse, COPD, liver failure, metastatic cancer, psychosis, and drug abuse. As these diseases are rarely reversible, it is reasonable to assume that some of these comorbidities are major contributors to mortality with aging. Trauma was found to be a major reason for ICU admission and rises significantly with age (second most frequent ICU admission cause among the third age group and only fifth among the first). Primary prevention strategies should be focused on reducing trauma risk for the very elderly population (medication adjustment, home adjustment, behavioral instructions) [19]. Gastrointestinal (GI) bleed is another example of a potentially preventable disease [20, 21].

Outcomes in the elderly

Over the age of 85, 56 % of all our patients died within 1 year from admission (36.2 % for age 65–75). This is consistent with rates from previous studies [22–23]. Wunsch et al. found that the risk is concentrated early after hospital discharge (the first 6 months) and among those who require mechanical ventilation. Roch and colleagues [24] demonstrated a mortality hazard ratio of 2.56 when very elderly (median age of 84) MICU survivors were compared with an age- and gender-matched cohort in the general population. None of these studies compared long-term mortality rates of different elderly age groups as we did. By comparing the outcomes of the oldest elderly group versus the youngest elderly group at 1 year from ICU admission, we show that age remains an independent mortality risk factor over time. This extends the recent Eldicus trial findings of an association between age and mortality at 28 days from ICU admission [25]. That trial, involving numerous European ICUs [25], also suggests that triage decisions of elderly patients are influenced by age. Of note, the mortality rates reported in the Eldicus trial were higher than ours (27.9 vs. 20.4 %, 35.5 vs. 28 %, and 41.5 vs. 34.6 % for first to third age group, respectively). The difference in short-term mortality rate between Eldicus and our cohort highlights the impact of triage on ICU survival. In our medical center, as opposed to those in the Eldicus trial, there is no ICU refusal policy and a higher proportion of elderly patients is admitted to the ICU (10 vs. 3.3 % of total ICU patients over age 85).

Age and ICU mortality

Advanced age alone does not preclude successful ICU outcome [5, 7–12, 25, 26]. However, our data suggest that, after age 75, age becomes a significant independent risk factor for mortality. This risk is most substantial during the period of ICU admission but persists thereafter. This association holds true in the subgroup of sicker patients who received mechanical ventilation during ICU admission. We do not have a clear explanation why the association between age and mortality is stronger after age 75, except that it might be related to the average life expectancy in the USA, which is 78 [Data from World Bank, Last updated: March 30, 2012].

Boumendil et al. [27] have previously demonstrated that very elderly patients receive lower treatment intensity (circulatory support, renal support, and mechanical ventilation). Our findings are consistent with theirs, and in our cohort, use of RRT and mechanical ventilation decreased with advanced age even after adjustment for DNR status (OR of 0.39 and 0.64 for older than 85 years, respectively). We did not find clinically significant age-related differences in prevalence of use of vasopressors (Table 2). Thus, we cannot exclude the possibility that physician restriction of treatment contributed to the high mortality in our elderly patients.

The current work has several limitations. This is a retrospective, single-center study. We did not study the characteristics and mortality rates of the very elderly patients who were admitted to the hospital but not to the ICU, but other studies that compared elderly ICU mortality with controlled nonhospitalized or hospitalized non-ICU patients have shown significant higher mortality rates for the very elderly ICU patients [23, 24]. Our objective in this study was to evaluate the influence of age among elderly patients admitted to the ICU. We did not perform subgroup analysis based on different admission diagnosis due to the limited sample size. We also acknowledge that quality-of-life assessment post-ICU admission is an important end point which this study failed to address. Finally, the high ICU bed ratio in our medical center (14 % of total hospital beds) does not reflect the majority of hospitals in the country or around the world and might partially explain our somewhat lower mortality rates compared with the mortality rates described in the literature.

The information presented here may be useful in informing triage decisions as the proportion of the elderly population continues to increase and shortage of critical care resources is anticipated to worsen [22]. However, mortality data alone clearly do not provide adequate information for making such decisions. What constitutes sufficient "benefit" for a particular elderly patient from an ICU admission requires broader consideration. Particularly important will be the patient's quality of life following discharge. While this issue has been looked at in a research setting [7, 22, 28], we propose that objective measures of quality of life be obtained as part of routine care during follow-up after hospital discharge to be able to quantify the value of ICU care. Discussion and the collaborative involvement of the healthcare team and families in such decisions are also essential from an early stage in chronic diseases that commonly present in the ICU. Such collaborative decisions reflect a partnership approach that prevents unhelpful disputes about paternalism and autonomy in ethics. This accords well with good healthcare practice and an atmosphere of mutual problem solving. The need to represent the truth of the situation in such discussion is important, so decisions are made in the light of a realistic appraisal of the facts of the patient's predicament. Where this is done with tact and consideration, with the emphasis on doing what is fitting in the context of the patient's life and present illness, there is often little disagreement about what should happen.

Conclusions

Elderly and very elderly patients will continue to be a significant and increasing proportion of ICU patients. This population has demographic and clinical characteristics that should be recognized. With advancing age, the proportion of various preexisting comorbidities as well as the primary reason for ICU admission change. Primary prevention of prevalent reasons for elderly ICU admission such as falls and gastrointestinal bleeding may reduce elderly ICU admission. Mortality in this cohort is substantial, and advanced age should be regarded as a significant independent risk factor specifically for ICU patients older than 75.

Conflicts of interest None of the authors have any financial interests or potential conflicts to disclose.

References

1. Oeppen J, Vaupel JW (2002) Demography. Broken limits to life expectancy. Science 296:1029–1031
2. Fowler RA, Adhikari NK, Bhagwanjee S (2008) Clinical review: critical care in the global context—disparities in burden of illness, access, and economics. Crit Care 12:225
3. Nguyen YL, Angus DC, Boumendil A, Guidet B (2011) The challenge of admitting the very elderly to intensive care. Ann Intensive Care 1:29
4. Bagshaw SM, Webb SA, Delaney A, George C, Pilcher D, Hart GK, Bellomo R (2009) Very old patients admitted to intensive care in Australia and New Zealand: a multi-centre cohort analysis. Crit Care 13:R45
5. de Rooij SE, Govers A, Korevaar JC, Abu-Hanna A, Levi M, de Jonge E (2006) Short-term and long-term mortality in very elderly patients admitted to an intensive care unit. Intensive Care Med 32:1039–1044

6. Hamel MB, Davis RB, Teno JM, Knaus WA, Lynn J, Harrell F Jr, Galanos AN, Wu AW, Phillips RS (1999) Older age, aggressiveness of care, and survival for seriously ill, hospitalized adults. SUPPORT Investigators. Study to understand prognoses and preferences for outcomes and risks of treatments. Ann Intern Med 131:721–728
7. Kaarlola A, Tallgren M, Pettila V (2006) Long-term survival, quality of life, and quality-adjusted life-years among critically ill elderly patients. Crit Care Med 34:2120–2126
8. Somme D, Maillet JM, Gisselbrecht M, Novara A, Ract C, Fagon JY (2003) Critically ill old and the oldest-old patients in intensive care: short- and long-term outcomes. Intensive Care Med 29:2137–2143
9. de Rooij SE, Abu-Hanna A, Levi M, de Jonge E (2005) Factors that predict outcome of intensive care treatment in very elderly patients: a review. Crit Care 9:R307–R314
10. Nathanson BH, Higgins TL, Brennan MJ, Kramer AA, Stark M, Teres D (2011) Do elderly patients fare well in the ICU? Chest 139:825–831
11. Sacanella E, Perez-Castejon JM, Nicolas JM, Masanes F, Navarro M, Castro P, Lopez-Soto A (2009) Mortality in healthy elderly patients after ICU admission. Intensive Care Med 35:550–555
12. Chelluri L, Pinsky MR, Donahoe MP, Grenvik A (1993) Long-term outcome of critically ill elderly patients requiring intensive care. JAMA 269:3119–3123
13. Saeed M, Lieu C, Raber G, Mark RG (2002) MIMIC II: a massive temporal ICU patient database to support research in intelligent patient monitoring. Comput Cardiol 29:641–644
14. Le Gall JR, Loirat P, Alperovitch A, Glaser P, Granthil C, Mathieu D, Mercier P, Thomas R, Villers D (1984) A simplified acute physiology score for ICU patients. Crit Care Med 12:975–977
15. Arts DG, de Keizer NF, Vroom MB, de Jonge E (2005) Reliability and accuracy of sequential organ failure assessment (SOFA) scoring. Crit Care Med 33:1988–1993
16. Elixhauser A, Steiner C, Harris DR, Coffey RM (1998) Comorbidity measures for use with administrative data. Med Care 36:8–27
17. Southern DA, Quan H, Ghali WA (2004) Comparison of the Elixhauser and Charlson/Deyo methods of comorbidity measurement in administrative data. Med Care 42:355–360
18. Cleveland WS (1979) Robust Locally Weighted regression and smoothing scatterplots. J Am Stat Assoc 368:829–836
19. Tinetti ME, Baker DI, McAvay G, Claus EB, Garrett P, Gottschalk M, Koch ML, Trainor K, Horwitz RI (1994) A multifactorial intervention to reduce the risk of falling among elderly people living in the community. N Engl J Med 331:821–827
20. Pilotto A (2004) Aging and upper gastrointestinal disorders. Best Pract Res Clin Gastroenterol 18(Suppl):73–81
21. Ben Chaabane N, Ben Youssef H, Loghmeri H, Helara O, Melki W, Bdioui F, Safer L, Saffar H (2011) Upper gastrointestinal bleeding in elderly patients in a Tunisian hospital: a retrospective study. Arab J Gastroenterol 12:158–161
22. Tabah A, Philippart F, Timsit JF, Willems V, Francais A, Leplege A, Carlet J, Bruel C, Misset B, Garrouste-Orgeas M (2010) Quality of life in patients aged 80 or over after ICU discharge. Crit Care 14:R2
23. Wunsch H, Guerra C, Barnato AE, Angus DC, Li G, Linde-Zwirble WT (2010) Three-year outcomes for medicare beneficiaries who survive intensive care. JAMA 303:849–856
24. Roch A, Wiramus S, Pauly V, Forel JM, Guervilly C, Gainnier M, Papazian L (2011) Long-term outcome in medical patients aged 80 or over following admission to an intensive care unit. Crit Care 15:R36
25. Sprung CL, Artigas A, Kesecioglu J, Pezzi A, Wiis J, Pirracchio R, Baras M, Edbrooke DL, Pesenti A, Bakker J, Hargreaves C, Gurman G, Cohen SL, Lippert A, Payen D, Corbella D, Iapichino G (2012) The Eldicus prospective, observational study of triage decision making in European intensive care units. Part II: intensive care benefit for the elderly. Crit Care Med 40:132–138
26. Lerolle N, Trinquart L, Bornstain C, Tadie JM, Imbert A, Diehl JL, Fagon JY, Guerot E (2010) Increased intensity of treatment and decreased mortality in elderly patients in an intensive care unit over a decade. Crit Care Med 38:59–64
27. Boumendil A, Aegerter P, Guidet B, Network CU-R (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
28. de Rooij SE, Govers AC, Korevaar JC, Giesbers AW, Levi M, de Jonge E (2008) Cognitive, functional, and quality-of-life outcomes of patients aged 80 and older who survived at least 1 year after planned or unplanned surgery or medical intensive care treatment. J Am Geriatr Soc 56:816–822