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Survival rates following medical intensive care unit admission from 2003 to 2013

An observational study based on a representative population-based sample cohort of Korean patients

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Abstract

The decision as to whether patients should be admitted to a medical intensive care unit (ICU), in the absence of information concerning survival rates or prognostic factors in survival, is often challenging. We analyzed survival trends in relation to hospital discharge and examined patient and hospital characteristics associated with survival following ICU care, using a sample of nationwide claims data in Korea from 2002 through 2013. The Korean government implements a compulsory social insurance program that covers the country's entire population, and the Korean National Health Insurance Service-National Sample Cohort (NHIS-NSC) data from 2002 based on this program were used for this study. The NHIS-NSC is a stratified random sample of 1,025,340 subjects selected from around 46 million Koreans. We evaluated annual survival trends using the Kaplan-Meier test. Analyses of the relationship between survival and patient and hospital characteristics were performed using Cox regression analyses. Employing a multivariate model, variables were selected using the forward selection method to consider the multicollinearity of variables. A total of 32,553 patients admitted to an ICU between 2002 and 2013 were identified among the eligible beneficiaries. The number of patients who had histories of ICU admission steadily increased throughout the study period, and patients older than 80 years constituted a progressively increasing proportion of ICU admissions, from 7.3% in 2002 to 16.9% in 2007 to 23.1% in 2013. The mean number of mechanical equipment items applied consistently increased, while no difference was observed in the trend for overall 1-year survival in patients following ICU treatment across the study period: the 1-year survival rate ranged from 66.7% (year 2003) to 64.2% (year 2010). Advanced age, cancer, renal failure, pneumonia, and influenza were all associated with heightened risk of mortality within 1 year. Our results should prove useful to older patients and their clinicians in their decisions regarding whether to seek ICU care, with the goals of improving the end-of life care and optimizing resource utilization.

Abbreviations: CRRT = continuous renal replacement therapy, ECMO = extracorporeal membrane oxygenation, ICD = International Classification of Disease, ICU = intensive care unit, ID = identification number, NHI = National Health Insurance, NHIS-NSC = National Health Insurance Service-National Sample Cohort.

Keywords: elderly, intensive care unit, prognostic factor, survival

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1. Introduction

In view of the fact that the intensive care unit (ICU) is a cost-intensive and limited healthcare resource, it is imperative to appropriately triage patients such that those considered to have a reasonable likelihood of survival are admitted to the ICU. ICU care is a conspicuous target for cost-savings measures, because long-term users of ICUs usually experience poor outcomes, despite the associated high expenses. Healthcare stakeholders face an ever-increasing dilemma in their attempts to improve patient outcomes following severe illness and injury, while also prioritizing value-based expenditures in healthcare.[1] Along with an overall decrease in mortality among patients admitted to US hospitals, declining mortality has been reported among patients with disorders, such as sepsis, which have commonly been managed in ICUs over the past 2 decades.[2,3] A recent report indicated that, of 482,601 ICU admissions identified in US hospitals, there was a 35% relative decrease in mortality between 1988 and 2012, despite increased age and intensified severity of illness.[4] Declining mortality among ICU patients has also been reported in Australia and New Zealand (4%, from 1993 to 2003) and England (13.4%, 1998–2006).[5,6] However, the decrease in mortality from 2001 to 2012 in US hospitals was accompanied by an increase in discharge to post-acute care facilities and a decrease in home discharge.[4] Concerns have thus been raised that changes in hospital discharge practices, instead of actual improvement in patient outcomes, may be the reason behind reductions in hospital mortality. Recently, the admission of elderly and very elderly patients with a higher prevalence of co-morbidities and cognitive and functional disabilities to ICUs has increased rapidly worldwide,[7] and this subgroup of patients has been the focus of debate. In Australia and New Zealand, the number of very elderly patients admitted to ICUs increased by 5.6% per annum according to an analysis of 120,123 ICU admissions with an associated decline in 2-year mortality.[8] It is not age per se but rather other factors related to advanced age that are predictive of mortality, including diagnosis, co-morbidity, and pre-morbid cognitive and functional status.[9] Prognostic models have been developed and used in risk adjustment to compare the outcomes of patients admitted to different ICUs to identify high-risk or low-risk subgroups for triage, and to support individual decision-making with regard to end-of-life decisions. However, none of the general models, such as acute physiology and chronic health evaluation (APACHE) and the mortality prediction model (MPM) originally designed to predict mortality in a general adult ICU population, are considered sufficiently reliable in clinical practice for elderly patients. Even when an elderly or very elderly patient approaches the end of life, it may be difficult to make a sound decision as to whether to admit him or her to an ICU, because the relevant information on survival rates, not to mention prognostic markers, is often unavailable. In addition, the decision is all the more difficult when the outcome without ICU care carries very high mortality risk.

Few data exist on ICU survival rates or end-of life care practices in Asia, where aging occurs at a faster pace than in any other parts of the world, and where at least half of all patients with critical illness and advanced life-support requirements lives. In this study, we analyzed trends in survival up to 1 year after medical ICU care, and assessed patient and hospital characteristics associated with survival using a sample of nationwide claims data in Korea from 2002 through 2013.

2. Methods

2.1. Data sources

Data from between 2002 and 2013 were obtained from the National Health Insurance Service-National Sample Cohort (NHIS-NSC). The NHIS-NSC is a stratified random sample incorporating sex, age, participant's eligibility status, and income level data from the entire national population, reflecting the health insurance data of hospitals and clinics under the Korean national health insurance system.[10] The NHIS-NSC comprises 1,025,340 subjects selected from around 46 million Korean citizens (2.2%), and includes all relevant medical treatment and prescription data. As a compulsory social insurance system, Korean health care covers the country's entire population in 2 tiers: the National Health Insurance (NHI) program is a wage-based, contributory insurance program covering around 96% of the population, while the Medical Aid program is a government-subsidized public assistance program for medically indigent individuals with low income. The dataset was generated using a stratified sampling according to sex (2 strata) and age (18 strata, infants under 1 year, ages 1 to 4, 5-year age groups between 5 and 79, and 80 years and above), and the participant's eligibility status and income level (41 strata, 20 strata for insured employees, 20 strata for insured self-employed individuals, and 1 for medical aid beneficiaries with the lowest level of income), comprising a total of 1476 strata. The representativeness and validity of this sample database was confirmed by comparing the estimates based on the data and the entire population. The NHIS-NSC contains each patient's unique encrypted identification number (ID), age, sex, death, primary diagnosis, secondary diagnosis, surgical or medical treatment administered, whether the individual was an inpatient or outpatient, type of insurance (i.e., NHI or Medical Aid), medical expenses, medical institution identification number, and prescriptions. Diagnoses were coded according to the International Classification of Disease, Tenth Revision (ICD-10). We defined 8 coexisting illnesses as follows (with coding variance among physicians for the same syndrome accounted for): diabetes mellitus (E10–14), myocardial infarction (I21–I25), chronic heart failure (I50), chronic renal failure (N17–19), cerebral infarction (I60–63), chronic obstructive pulmonary disease (J43, J44, J47), pneumonia and influenza (J09–J18), and cancer (C). Regional distribution analyses were based on a total of 17 districts: Seoul, Busan, Incheon, Daegu, Gwangju, Daejeon, Ulsan, Sejong, Gyeonggi-do, Gangwon-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, Gyeongsangnam-do, and Jeju-do. Hospital characteristics, including bed numbers and location, were determined using the medical institution ID.

2.2. Study population

The study population consisted of patients aged $\geq$ 20 years old with a history of admission to an ICU between January 1, 2002 and December 31, 2013. Payment claims for ICU care were defined as the presence of the physicians' procedure codes for intensive care according to the Healthcare Common Procedure Coding System codes provided by the Health Insurance Review and Assessment service: AJ001–003.[11] Admission to medical ICUs (i.e., for internal medicine, family medicine, and tuberculosis) was included, while admission to surgical ICUs was excluded.

We analyzed the first admission in a given year for patients who had multiple ICU admissions within a year. The primary outcome observed was a 1-year survival trend following ICU discharge. Because the survival data for the inception year (2002) and 2013 were unavailable in the dataset, the survival rate between 2003 and 2012 was analyzed. Potential predictors included age, sex, comorbidity, income level, hospital size (i.e., <250, 250–499, ≥500 beds), metropolitan or non-metropolitan location of the hospital, use of ventilator, use of hemodialysis, and cardiopulmonary resuscitation.

2.3. Statistical analyses

Categorical descriptive data are presented as percentages and continuous descriptive data are presented as means ± SDs. Annual trends in duration of hospitalization were evaluated using the regression test. Survival rates and survival curves according to age and year were estimated using the Kaplan–Meier method. Analyses of the relationship between survival rates and patient and hospital characteristics were performed using Cox regression analyses. We analyzed the data according to 3 different models. For model 1, we selected variables using the forward selection method after considering multicollinearity of all the relevant clinical variables. For model 2, we added hemodialysis as well as other selected covariates in model 1. For model 3, we first performed univariable analysis, and then chose covariates using the forward selection method with only significant variables. Calculation of Akaike information criterion (AIC) showed that model 1 was the best fitting one, so we chose model 1 and showed the result according to model 1. The relationship was considered statistically significant at $P < .05$. All analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC).

2.4. Ethical approval

This is a study using sample data derived from deidentified administrative database. According to Hallym University Sacred Heart Hospital Institutional Review Board research guideline, IRB approval was waived for this study (2017-I064).

3. Results

A total of 32,553 patients admitted to ICUs between 2002 and 2013 were identified among the eligible beneficiaries. The number of ICU admissions increased steadily from 923 per 1,025,340 (0.09%) in 2002 to 2,971 per 1,014,730 (0.18%) beneficiaries in 2013 (Table 1).

About half of ICU admissions occurred in the 60 to 79 year age group across the study period, while the youngest age group (≥20 and <40 years old) made up less than 10% of all ICU admissions. The admission of patients older than 80 years to ICUs steadily increased in proportion from 7.3% in 2002 to 16.9% in 2007 to 23.1% in 2013. However, the percentage of ICU patients younger than 59 years old showed a declining tendency during the study period. Male patients accounted for a higher percentage of ICU admission (57.5–62.4%) compared to female patients throughout the study period. More than 80% and 70% of patients had hypertension and diabetes, respectively, and the prevalence of comorbid rheumatologic disease, pneumonia, and influenza increased over the study period, while comorbid myocardial infarction decreased. The upper-20% income level group accounted for one third of the patients.

The mean duration of stay in an ICU ranged from 14.7 days in 2009 to 16.6 days in 2012, and did not change significantly during the study period (Table 2). The duration of ICU stays decreased significantly only among the youngest age group, from 16.9 days in 2002 to 10.6 days in 2013. The mean number of medical equipment items and procedures applied in the ICU was 2.3 in 2002; this encompasses mechanical ventilation, arterial pressure monitoring, tubal feeding, Foley catheter insertion, total parenteral nutrition, blood transfusion, peripherally inserted central catheter, central venous pressure monitoring, continuous renal replacement therapy (CRRT), tracheostomy, and extracorporeal membrane oxygenation (ECMO) (Table 3). This number consistently increased over the study years to 3.5, 4.2, 4.6, and 5.2 in 2005, 2009, 2011, and 2013, respectively.

The 30-day survival rate after ICU admission ranged from 86.39% (2010) to 88.71% (2012), while the 1-year survival rate ranged from 66.65% (2003) to 64.21% (2010). No differences in the trend were observed with regard to the overall 1-year survival rate in patients following ICU treatment across the study period (S1 Table, http://links.lww.com/MD/D221). Furthermore, the 30-, 60-, and 180-day survival rates did not change significantly across the study period (data not shown). The annual trend in survival probability after ICU admission did not significantly improve in any age group from 2003 to 2012, with the exception of those aged 60 to 79 years old (Figs. 1–5): the 1-year survival rate in this age group increased slightly from 61.56% in 2003 to 65.86% in 2012. The 1-year survival rates were 84.62%, 80.12%, and 43.5% in 2003 and 83.33%, 76.86%, and 44.02% in 2012 in patients aged 20 to 39 years, 40 to 59 years, and >80 years old, respectively.

Next, factors determining post-ICU admission survival were examined using Cox regression analyses (Table 4). Advanced age, the presence of chronic pulmonary disease, cancer, renal failure, pneumonia, and influenza were associated with increased risk for 1-year mortality, while the presence of diabetes, myocardial infarction, congestive heart failure, hypertension, and admission to larger hospitals or hospitals in metropolitan areas were associated with lower risk in univariate analyses. In multivariate analyses, the relationship did not change significantly, with the exception of chronic pulmonary disease, which changed the direction of association to lower risk for mortality. The highest hazard ratio of death was for old age, being 1.63 (95% CI, 1.39–1.90), 3.06 (2.63–3.57), and 5.38 (4.60–6.30) in patients aged 40 to 59 years, 60 to 79 years, and >80 years old, respectively, compared to patients aged 20–39 years. The hazard ratio associated with old age increased further in multivariate analyses.

4. Discussion

In this study of patients representing Korea's general population from 2002 to 2013, the number of patients admitted to ICUs increased steadily over the course of the study period. Patients over 80 years of age accounted for the rapidly increasing proportion of ICU admissions. Advanced age, cancer, renal failure, pneumonia, and influenza were all associated with elevated 1-year mortality risk. Despite the increased number of interventions throughout the study period, there were no differences in the overall 1-year survival trend in patients after ICU treatment across the study period.

Table 1

Baseline characteristics of included patients.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
(N)	(923)	(1715)	(1864)	(2023)	(2160)	(2320)	(2261)	(2297)	(2277)	(2776)	(2888)	(2971)
Age group, N (%)												
20-39	80 (8.67)	130 (7.58)	127 (6.81)	129 (6.38)	126 (5.83)	119 (5.13)	134 (5.93)	111 (4.83)	100 (4.39)	117 (4.21)	120 (4.16)	117 (3.94)
40-59	317 (34.34)	503 (29.33)	530 (28.43)	587 (29.02)	581 (26.90)	590 (25.43)	591 (26.14)	629 (27.38)	562 (24.68)	717 (25.83)	713 (24.69)	688 (23.16)
60-79	459 (49.73)	882 (51.43)	970 (52.04)	1033 (51.06)	1116 (51.67)	1219 (52.54)	1171 (51.79)	1189 (51.76)	1159 (50.90)	1368 (49.28)	1428 (49.45)	1481 (49.85)
80+	67 (7.26)	200 (11.66)	237 (12.71)	274 (13.54)	337 (15.60)	392 (16.90)	365 (16.14)	368 (16.02)	456 (20.03)	574 (20.68)	627 (21.71)	685 (23.06)
Sex												
Male	560 (60.67)	1013 (59.07)	1131 (60.68)	1262 (62.38)	1286 (59.54)	1385 (59.70)	1385 (61.26)	1377 (59.95)	1356 (59.55)	1624 (58.50)	1700 (58.86)	1707 (57.46)
Female	363 (39.33)	702 (40.93)	733 (39.32)	761 (37.62)	874 (40.46)	935 (40.30)	876 (38.74)	920 (40.05)	921 (40.45)	1152 (41.50)	1188 (41.14)	1264 (42.54)
Underlying disease, N (%)												
Diabetes	684 (74.11)	1238 (72.19)	1369 (73.44)	1533 (75.78)	1607 (74.40)	1765 (76.08)	1737 (76.82)	1790 (77.93)	1784 (78.35)	2167 (78.06)	2329 (80.64)	2357 (79.33)
Myocardial infarction	465 (50.38)	691 (40.29)	792 (42.49)	857 (42.36)	945 (43.75)	962 (41.47)	943 (41.71)	942 (41.01)	912 (40.05)	1036 (37.32)	1084 (37.53)	1064 (35.81)
Congestive heart failure	372 (40.30)	616 (35.92)	682 (36.59)	738 (36.48)	824 (38.15)	818 (35.26)	805 (35.60)	803 (34.96)	901 (39.57)	1069 (38.51)	1125 (38.95)	1198 (40.32)
Cerebrovascular disease	290 (31.42)	519 (30.26)	602 (32.30)	666 (32.92)	730 (33.80)	805 (34.70)	756 (33.44)	814 (35.44)	864 (37.94)	1004 (36.17)	1073 (37.15)	1076 (36.22)
Chronic pulmonary disease	321 (34.78)	572 (33.35)	663 (35.57)	728 (35.99)	804 (37.22)	884 (38.10)	808 (35.74)	874 (38.05)	870 (38.21)	1036 (37.32)	1124 (38.92)	1052 (35.41)
Cancer	194 (21.02)	417 (24.31)	473 (25.38)	490 (24.22)	484 (22.41)	511 (22.03)	553 (24.46)	515 (22.42)	546 (23.98)	638 (22.98)	681 (23.58)	727 (24.47)
Rheumatologic disease	103 (11.16)	286 (16.68)	348 (18.67)	386 (19.08)	435 (20.14)	444 (19.14)	478 (21.14)	484 (21.07)	491 (21.56)	657 (23.67)	734 (25.42)	745 (25.08)
Hypertension	791 (85.70)	1374 (80.12)	1519 (81.49)	1680 (83.04)	1829 (84.68)	1976 (85.17)	1915 (84.70)	1954 (85.07)	1960 (86.08)	2391 (86.13)	2513 (87.02)	2579 (86.81)
Pneumonia and influenza	222 (24.05)	501 (29.21)	628 (33.69)	684 (33.81)	734 (33.98)	766 (33.02)	758 (33.52)	858 (37.35)	830 (36.45)	1055 (38.00)	1174 (40.65)	1123 (37.80)
Level of income, N (%)*												
Medical aid beneficiary	16 (1.73)	30 (1.75)	37 (1.98)	54 (2.67)	36 (1.67)	40 (1.72)	93 (4.11)	54 (2.35)	23 (1.01)	420 (15.13)	393 (13.61)	405 (13.63)
≤20%	123 (13.33)	280 (16.33)	274 (14.70)	331 (16.36)	318 (14.72)	345 (14.87)	319 (14.11)	391 (17.02)	352 (15.46)	408 (14.70)	375 (12.98)	434 (14.61)
>20%, ≤40%	129 (13.98)	260 (15.16)	267 (14.32)	292 (14.43)	336 (15.56)	349 (15.04)	316 (13.98)	298 (12.97)	344 (15.11)	320 (11.53)	356 (12.33)	336 (11.31)
>40%, ≤60%	151 (16.36)	272 (15.86)	309 (16.58)	330 (16.31)	335 (15.51)	397 (17.11)	374 (16.54)	372 (16.20)	377 (16.56)	388 (13.98)	376 (13.02)	435 (14.64)
>60%, ≤80%	189 (20.48)	325 (18.95)	373 (20.01)	418 (20.66)	477 (22.08)	502 (21.64)	457 (20.21)	434 (18.89)	467 (20.51)	457 (16.46)	491 (17.00)	505 (17.00)
>80%	315 (34.13)	548 (31.95)	604 (32.40)	598 (29.56)	658 (30.46)	687 (29.61)	702 (31.05)	748 (32.56)	714 (31.36)	783 (28.21)	897 (31.06)	856 (28.81)
Hospital beds, N (%)												
< 250	45 (4.88)	114 (6.65)	136 (7.30)	191 (9.44)	188 (8.70)	201 (8.66)	157 (6.94)	117 (5.09)	127 (5.58)	138 (4.97)	164 (5.68)	140 (4.71)
250~499	98 (10.62)	249 (14.52)	284 (15.24)	372 (18.39)	368 (17.04)	408 (17.59)	411 (18.18)	420 (18.28)	420 (18.45)	619 (22.30)	646 (22.37)	691 (23.26)
≥500	780 (84.51)	1352 (78.83)	1444 (77.47)	1460 (72.17)	1604 (74.26)	1711 (73.75)	1693 (74.88)	1760 (76.62)	1730 (75.98)	2019 (72.73)	2078 (71.95)	2140 (72.03)
Location, N (%)												
Metropolitan cities	562 (60.89)	934 (54.46)	1027 (55.10)	1047 (51.75)	1179 (54.58)	1205 (51.94)	1189 (52.59)	1175 (51.15)	1106 (48.57)	1412 (50.86)	1432 (49.58)	1416 (47.66)
Other area	361 (39.11)	781 (45.54)	837 (44.90)	976 (48.25)	981 (45.42)	1115 (48.06)	1072 (47.41)	1122 (48.85)	1171 (51.43)	1364 (49.14)	1456 (50.42)	1555 (52.34)
Treatment around and after ICU admission, N (%)												
Cardiopulmonary resuscitation	31 (3.36)	65 (3.79)	80 (4.29)	91 (4.50)	116 (5.37)	120 (5.17)	133 (5.88)	163 (7.10)	149 (6.54)	195 (7.02)	232 (8.03)	176 (5.92)
Hemodialysis	48 (5.20)	172 (10.03)	194 (10.41)	203 (10.03)	198 (9.17)	234 (10.09)	235 (10.39)	228 (9.93)	229 (10.06)	260 (9.37)	264 (9.14)	210 (7.07)
Mechanical ventilation	181 (19.61)	482 (28.10)	571 (30.63)	572 (28.27)	600 (27.78)	638 (27.50)	646 (28.57)	632 (27.51)	648 (28.46)	774 (27.88)	735 (25.45)	718 (24.17)

* Income levels are classified into 6 groups. Medical aid beneficiary are the lowest income group, and 1 to 10 deciles are categorized into 5 groups (≤20%, >20%, ≤40%, >40%, ≤60%, >60%, ≤80%, and >80%).

Table 2

The trend for ICU admission days of patients from 2002 to 2013.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
(N)	(923)	(1715)	(1864)	(2023)	(2160)	(2320)	(2261)	(2297)	(2277)	(2776)	(2888)	(2971)	*P* value
Mean days (SD)	15.9, (17.9)	15.8, (16.9)	16.2, (18.2)	16.0, (18.6)	16.4, (23.6)	15.8, (17.9)	16.4, (25.6)	14.7, (16.6)	15.2, (24.0)	15.7, (19.1)	16.6, (25.5)	15.8, (20.7)	.737
Mean days by age group, N (%)													
20–39 age, N	80	130	127	129	126	119	134	111	100	117	120	117	.001
Mean days, (SD)	16.9, (15.6)	16.7, (23.7)	15.6, (17.1)	13.1 (12.7)	12.5, (13.6)	11.5, (12.2)	14.1 (12.8)	13.4, (19.7)	10.5, (12.2)	14.4, (15.6)	12.1 (14.3)	10.6, (11.8)	
40–59 age, N	317	503	530	587	581	590	591	629	562	717	713	688	.127
Mean days, (SD)	14.7, (14.5)	14.0, (13.3)	14.9, (15.4)	14.0, (16.3)	13.8, (18.9)	13.4, (15.3)	13.8, (18.4)	12.5, (15.0)	12.7, (17.0)	13.5, (18.3)	14.5, (24.2)	13.2, (17.7)	
60–79 age, N	459	882	970	1033	1116	1219	1171	1189	1159	1368	1428	1481	.403
Mean days, (SD)	16.8, (21.0)	16.4, (17.1)	16.9, (19.7)	17.3, (20.2)	17.1, (21.6)	16.8, (19.0)	17.6, (30.8)	15.0, (15.8)	15.8, (26.7)	16.1, (19.3)	17.4, (26.5)	16.4, (21.5)	
80+, N	67	200	237	274	337	392	365	368	456	574	627	685	.284
Mean days, (SD)	13.9, (9.9)	16.8, (18.6)	16.2, (17.5)	16.9, (18.9)	20.0, (36.3)	17.7, (18.7)	17.5, (19.9)	17.5, (19.7)	17.5, (25.4)	17.7, (20.1)	18.2, (26.3)	18.1, (22.7)	

The annual trend was tested using the regression test.

Table 3

The number of applied medical equipment and procedure during ICU admission.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
(N)*	977	1822	1981	2165	2275	2500	2404	2427	2423	2955	3,088	3,217	*P* value§
Mean (SD)	2.3 (7.5)	3.1 (7.4)	3.5 (7.6)	3.5 (8.5)	3.6 (8.6)	3.6 (8.4)	4.1 (9.0)	4.2 (9.0)	4.4 (9.9)	4.6 (9.7)	5.2 (11.2)	5.2 (11.0)	<.0001

Included were mechanical ventilation, arterial pressure monitoring, tubal feeding, Foley catheter insertion, total parenteral nutrition, blood transfusion, peripherally inserted central catheter, central venous pressure monitoring, continuous renal replacement therapy, tracheostomy and extracorporeal membrane oxygenation.

* N=total episode number.

§ The annual trend was tested using the regression test.

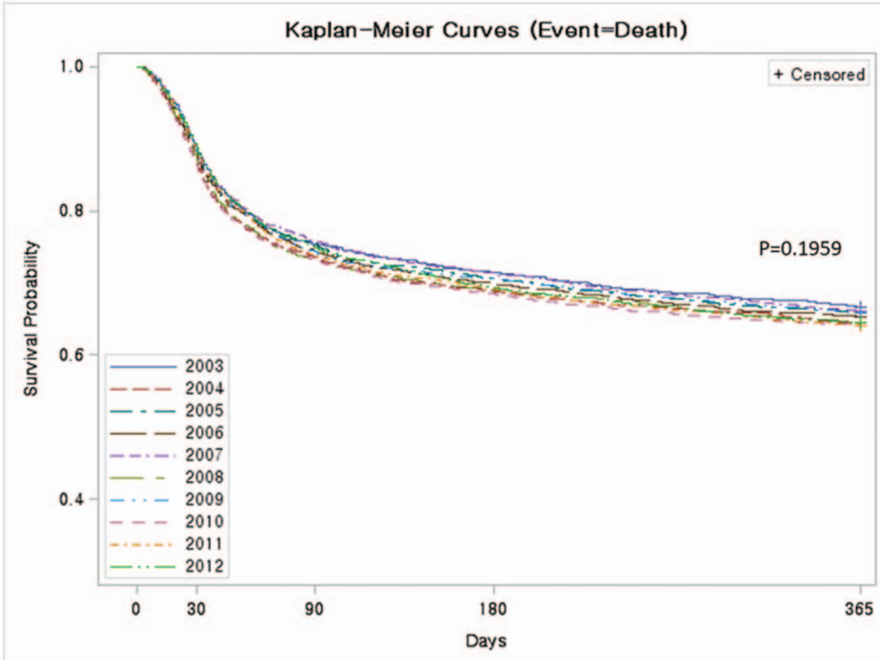

Figure 1. Annual trend for survival probabilities after ICU admission of all study subjects.

4.1. Increased demand for critical care worldwide

The demand for critical care, including treatment in ICUs, has continued to grow in recent years, thereby increasing demand for beds and raising the associated costs; increases in critical care costs have outpaced increases in the gross domestic product (GDP).[12] This has given rise to concerns about the efficiency of ICU utilization, partly because, despite their cost-intensity, emergency and critical care services are often delivered without rigorous assessment.[13] As the global population ages, with the fastest-growing age cohort being those aged ≥80 years,[14] the hospitalization rate in cases of acute illness and the demand for critical care services and ICU admission are projected to increase among this age group.[15] Recent reports from Western countries have universally demonstrated a dramatic increase in ICU

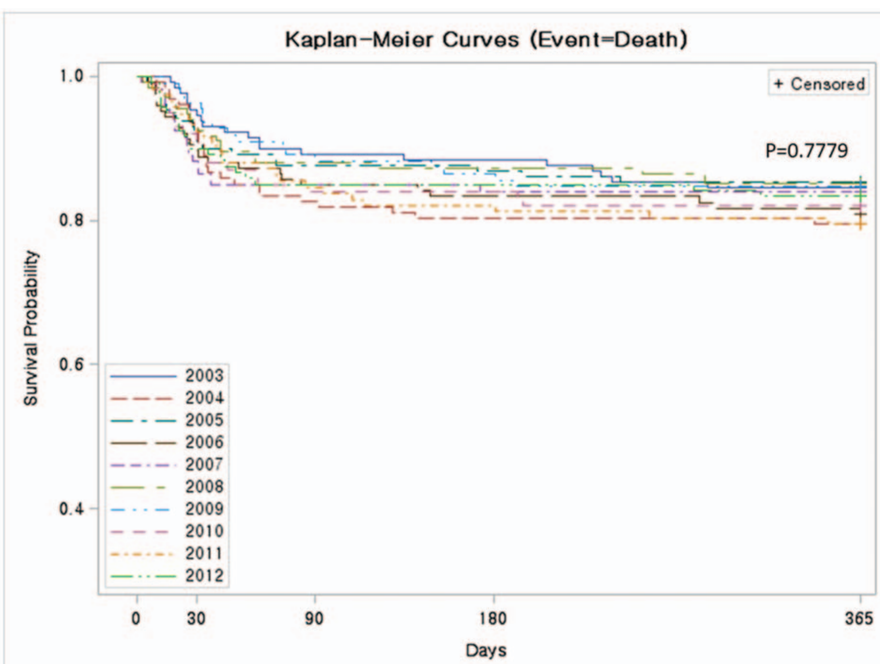

Figure 2. Annual trend for survival probabilities after ICU admission of age group of 20 to 39 years' old.

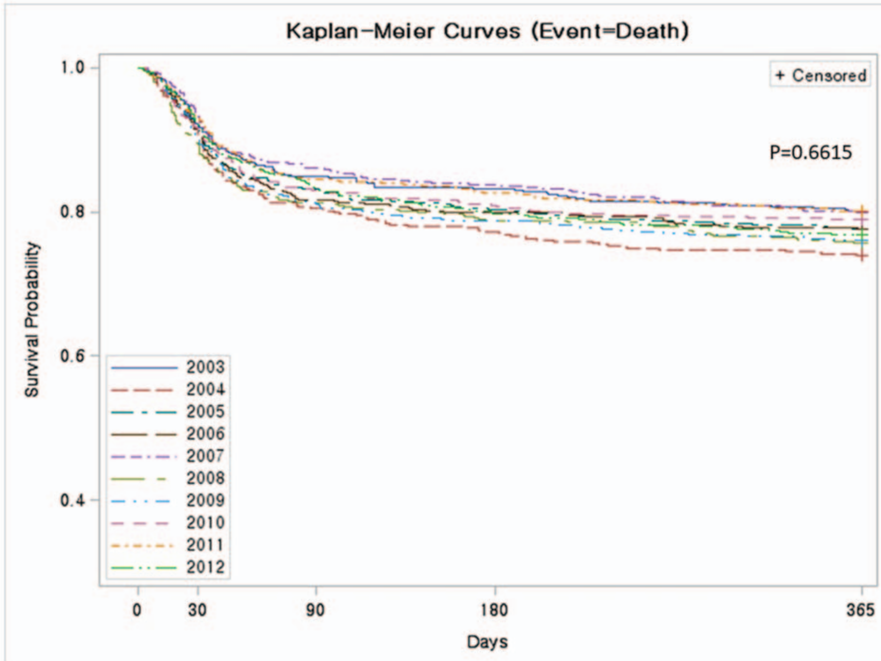

Figure 3. Annual trend for survival probabilities after ICU admission of age group of 40 to 59 years' old.

admissions among the elderly. For example, the admission rates of very old patients in Australia and New Zealand increased by 5.6% per year from 2000 to 2005, and this potentially translated into a 72.4% increase in demand for ICU bed-days by 2015.[15] However, the hospital mortality of elderly patients admitted to the ICU varies widely, from 12% to 56%[16] depending on the patient's premorbid status, the definition of old age, severity scores, and the inclusion of surgical patients. With critical care responsible for more than 20% of hospital costs, and with more than half of the increase in total hospitalizations attributable to additional ICU hospitalizations,[17] much work remains with regard to improving ICU survival rates, which involve not only

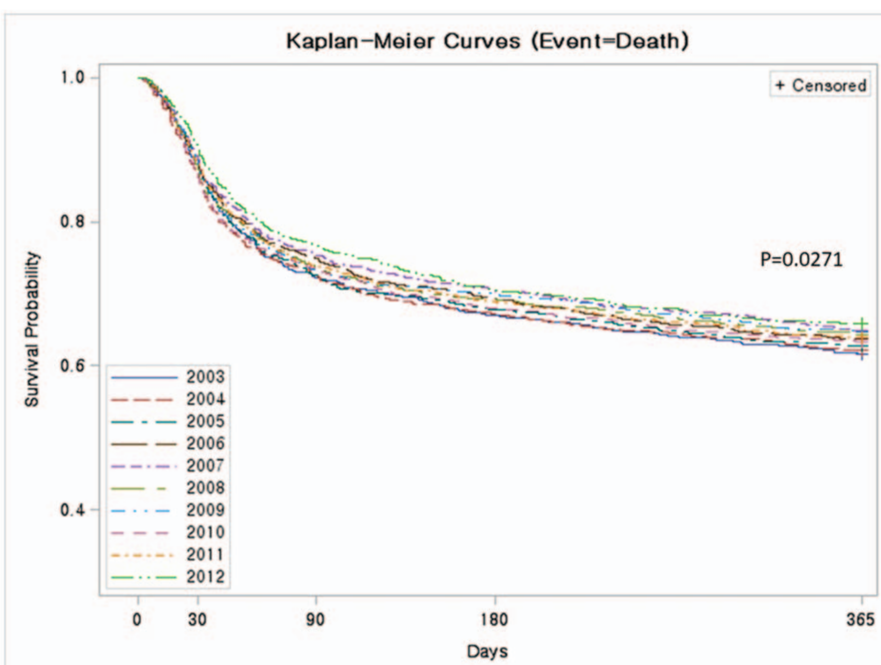

Figure 4. Annual trend for survival probabilities after ICU admission of age group of 60 to 79 years' old.

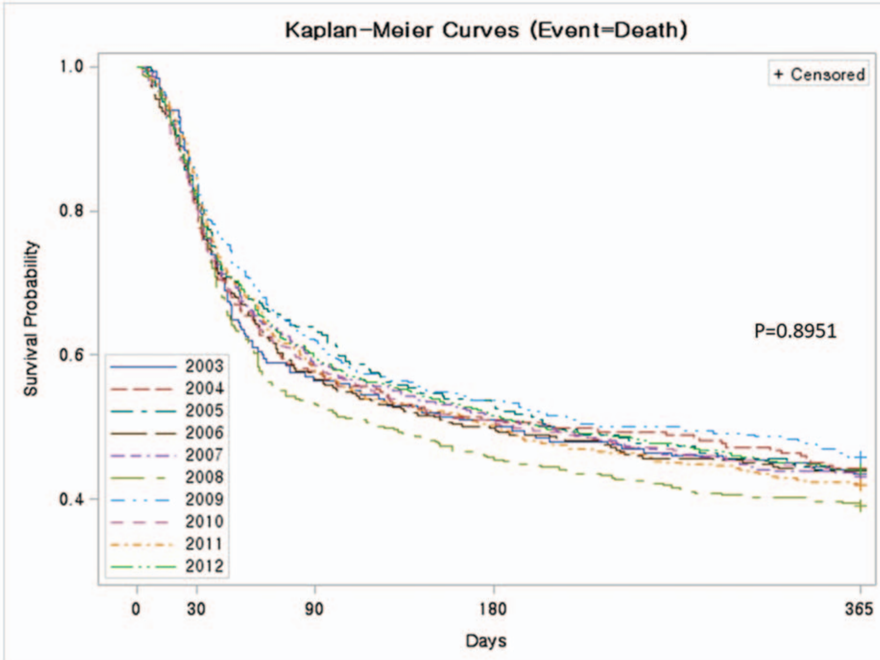

Figure 5. Annual trend for survival probabilities after ICU admission of age group of more than 80 years' old.

the specific treatment administered but also enhanced guidance regarding decisions surrounding end-of life advanced life support.

4.2. The trend in survival rate after ICU care in Korea

While there is a paucity of data on ICU utilization and survival in Asia, where aging advances faster than in any other parts of the world, a recent Korean nationwide study showed that the median cost per ICU admission increased steadily over the 5 years between 2009 and 2014.[18] That study revealed that patients' average age upon admission steadily increased, while in-hospital mortality decreased only very slightly over time; our results support those findings. Furthermore, despite the difference in the dataset used, with that study using data from all patients covered by the Korean National Health System and our study using sample data from the whole population, our overall 30-day survival rate of 86.4% to 88.7% closely matches the in-hospital mortality rate of 13.8% reported by the previous study. The use of advanced mechanical organ support procedures, such as ECMO and CRRT, increased over the study period, which our results are in line with, as we found that the number of designated mechanical equipment items and procedures utilized in ICUs increased steadily from 2.3 in 2002 to 5.2 in 2013. Despite the increased administration of advanced life support, there were no significant increases in long-term survival after ICU admission. A study that used a clinical database from multiple US ICUs showed that mortality upon hospital discharge decreased by 35% from 1988/1989 to 2010/2012; however, the majority of the decline occurred between 1988 and 1989 and between 1993 and 1996,[4] before leveling off. The reasons for the lack of improvement in ICU survival rates are likely to be manifold. Intuitively, increased admission among the very elderly (age > 80 years) could be expected to offset any positive survival benefit gained among the younger age groups. However, our data showed that 10-year survival rates increased modestly only among the 60 to 79 years age group, from 61.56% in 2003 to 65.86% in 2012. It is also possible that the underlying severity of illness prior to ICU admission has changed over time, and that this could also have a bearing on outcomes. In this case, even if ICU care has advanced, any improvement would be negated by an increase in the proportion of patients admitted with non-survivable primary illnesses.

4.3. Factors associated with survival after ICU care

Patient characteristics that were significantly associated with mortality included advanced age, cancer, renal failure, pneumonia, and influenza. By contrast, the presence of diabetes, myocardial infarction, congestive heart failure, and hypertension were associated with lower 1-year mortality risks. Whether age is a primary determinant of ICU mortality has been extensively investigated. A Norwegian study[19] that compared ICU patients aged 50 to 79.9 years old and patients > 80 years old showed that older patients received less mechanical ventilatory support, had shorter median ventilatory support times, and higher mortality rates. The authors reasoned that elderly patients may be prematurely discharged from ICUs in accordance with a deliberate policy of offering intensive care to elderly patients only for a limited period of time and withdrawing that care if no swift response to treatment is evident. However, in our study, the proportion of mechanical ventilation use was higher among the oldest group than among the youngest group (29.3% vs 22.8%), rebutting the hypothesis that a lower intensity of care administered to elderly patients results in lower rates of survival.

A study from 5 US teaching hospitals showed that age was independently associated with lower short-term survival rates and that this was not attributable to older patients' receipt of less intensive therapy.[20] In addition, the majority of older patients'

Table 4

Cox regression analysis for prognostic factor of 1 year mortality after ICU admission.

		95% C.I				95% C.I		
N=18,595*	Crude Hazard Ratio	Lower	Upper	*P* value	Adjusted Hazard Ratio	Lower	Upper	*P* value
Age group								
20-39	Ref				Ref			
40-59	1.25	1.07	1.46	.004	1.63	1.39	1.90	<.0001
60-79	2.24	1.93	2.59	<.0001	3.06	2.63	3.57	<.0001
80+	4.15	3.57	4.83	<.0001	5.38	4.60	6.30	<.0001
Sex								
Male	Ref							
Female	0.96	0.91	1.01	.088				
Underlying disease								
Diabetes	0.74	0.70	0.78	<.0001	0.77	0.72	0.81	<.0001
Acute myocardial infarction	0.58	0.55	0.62	<.0001	0.76	0.72	0.81	<.0001
Congestive heart failure	0.84	0.79	0.88	<.0001	0.79	0.75	0.84	<.0001
Cerebrovascular disease	1.01	0.96	1.07	.662	0.89	0.85	0.94	<.0001
Chronic pulmonary disease	1.13	1.07	1.19	<.0001	0.78	0.74	0.83	<.0001
Cancer	2.59	2.46	2.72	<.0001	2.11	2.00	2.22	<.0001
Renal failure	2.40	2.27	2.52	<.0001	1.85	1.76	1.96	<.0001
Hypertension	0.55	0.52	0.58	<.0001	0.55	0.51	0.59	<.0001
Pneumonia and influenza	2.54	2.42	2.67	<.0001	1.46	1.39	1.54	<.0001
Level of income								
1	1.02	0.90	1.15	.815				
2	0.96	0.85	1.10	.578				
3	0.93	0.82	1.06	.274				
4	0.90	0.79	1.01	.080				
5	0.97	0.86	1.10	.641				
Medical aid beneficiaries								
Hospital size								
<250	Ref				Ref			
250~499	0.74	0.68	0.82	<.0001	0.80	0.73	0.88	<.0001
≥500	0.54	0.49	0.58	<.0001	0.60	0.55	0.65	<.0001
Location								
Metropolitan cities	Ref				Ref			
Other areas	1.19	1.14	1.25	<.0001	1.14	1.09	1.20	<.0001
Treatment around and after ICU admission								
Cardiopulmonary Resuscitation	4.79	4.51	5.09	<.0001	2.66	2.48	2.85	<.0001
Hemodialysis	2.24	2.06	2.43	<.0001				
Mechanical ventilation	3.63	3.45	3.81	<.0001	2.33	2.20	2.47	<.0001

* The number included patients who had ICU admission from 2003 to 2012. CI denotes confidence interval.

deaths occurred either in the ICU or soon after discharge,[21,22] suggesting that the lower long-term survival rate after ICU admission cannot simply be attributed entirely to lower life expectancy associated with advanced age. ICU triage decisions based on chronological age alone would be inappropriate, because additional factors such as frailty, comorbidity, and pre-hospitalization functional status play a significant prognostic role. As such, the development of robust algorithms for predicting the long-term survival of the very elderly after ICU admission is desirable. However, such methods would never be proven perfect when the probability of patients' death is very high with the decision to forego ICU admission. In addition to optimizing prediction models for ICU survival, societal consensus around proper end-of life care should be reached, in tandem with optimal resource utilization.

It is of note that the presence of diabetes, myocardial infarction, congestive heart failure, and hypertension was associated with better survival post-ICU care. Compared to cancer, or renal failure, which conferred worse survival, those may denote more reversible conditions manageable with advanced life support.

4.4. Limitations of study

Our study is the first to observe long-term survival trends after ICU care among an Asian population. The limitations inherent in administrative claims data apply, including the lack of detailed information on pre-morbid conditions that determine long-term prognosis. In addition, indications for ICU admission could not be verified, impeding the adjustment for disease severity. Because our study did not capture the pattern of refusal of ICU admission by patients or their surrogates, selection bias could not be addressed. We used sample data; however, the survival rates were similar to a previous study using whole population data,[18] supporting the validity of using sample data. For this study, the sample data were available until year 2013. Our result may represent the survival rate post-ICU care before the social agreement and legislation on end-of-life care, since in year 2018, the legislation on advanced directives in life-sustaining treatment at the end of life was passed in Korea. Whether ICU use and survival rate after ICU care change after the legislation is the subject of future research. Last, our data pertain to Korean population, and may not be generalizable for other populations with different health care systems or culture.

Our results should prove useful to older patients and their clinicians in their decisions regarding whether to seek ICU care, and offer a stimulus to further understand the association between age and survival, with the goals of improving the survival rate and optimizing resource utilization.

Author contributions

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