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Long-term outcomes among injured older adults transported by emergency medical services☆

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ABSTRACT

Introduction/Objective: Little is known about the long-term outcomes of injured older adults cared for in trauma systems. We sought to describe mortality and causes of death over time, and the independent association of injury severity, comorbidities, and other factors on 12-month mortality among injured older adults transported by emergency medical services (EMS).

Materials and Methods: This was a population-based cohort study of injured adults $\geq$ 65 years in the United States transported by 44 EMS agencies to 51 hospitals from January 1, 2011 to December 31, 2011, with 12-month follow-up through December 31, 2012. The primary outcomes were time to death and causes of death. We used descriptive statistics and Cox proportional hazards models to generate adjusted hazard ratios (HR).

Results: 15,649 injured older adults were transported by EMS, frequently after a fall (84.5%). Serious injuries (Injury Severity Score [ISS] $\geq$ 16) occurred in 3.5%, with serious extremity injury (Abbreviated Injury Scale score $\geq$ 3) being most common (17.8%). Mortality rates were: 1.6% in-hospital, 5.1% at 30 days, 9.4% at 90 days and 20.3% at 1 year. The adjusted HR for patients in the highest comorbidity quartile was 2.20 (versus lowest quartile, 95% CI 1.97–2.46, $p < .001$), while the HR for ISS $\geq$ 25 was 2.69 (versus ISS 0–8, 95% CI 1.60–4.51, $p = .001$). Cardiovascular etiologies (53.3%) and dementia (32.7%) were the most common causes of death, with injury listed in 12.8% of death certificates.

Conclusions: Injury requiring EMS transport is a sentinel event among older adults, with death typically occurring months later, often due to cardiovascular causes and dementia. A heavy comorbidity burden had an adjusted mortality risk comparable to severe injury.

Introduction

Injury events in older adults frequently require emergency medical services (EMS) [1–4] and are a common cause of functional decline, loss of independence, and mortality [5–8]. Of the 25 million EMS responses in the United States (U.S.) every year, 38% involve adults 65 and over and injury is the most common clinical condition [3]. In Victoria, Australia, 10% of EMS responses are for elderly falls, with 79% requiring transport to a hospital [4]. Injured older adults transported by EMS have the same field triage guidelines applied as younger patients, which are intended to concentrate seriously injured patients in major trauma centers. However, approximately half of seriously injured older adults are missed by field triage processes in the U.S. [9], and the benefit of care in major trauma centers remains unclear in this population [10–12]. Other countries have demonstrated older age to be

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independently associated with a lower likelihood of transport to a major trauma center (with increased mortality) and the highest rate of under-triage [13,14]. Improving the care of injured older adults served by EMS and trauma systems first requires understanding the timing and causes of death during and after hospitalization, as well as the independent role of comorbidities versus injury severity on outcomes. Research on these topics remains sparse.

We evaluated ambulance transport patterns, out-of-hospital and in-hospital care, comorbidities, injury patterns, mortality and causes of death to one year for a population-based cohort of injured older adults transported by 44 EMS agencies to 51 hospitals in 7 Northwest counties in the U.S.

Materials and methods

Study design

This was a population-based cohort study that was reviewed and approved by Institutional Review Boards in all study sites, who waived the requirement for informed consent. We followed the STROBE guidelines for reporting cohort studies [15].

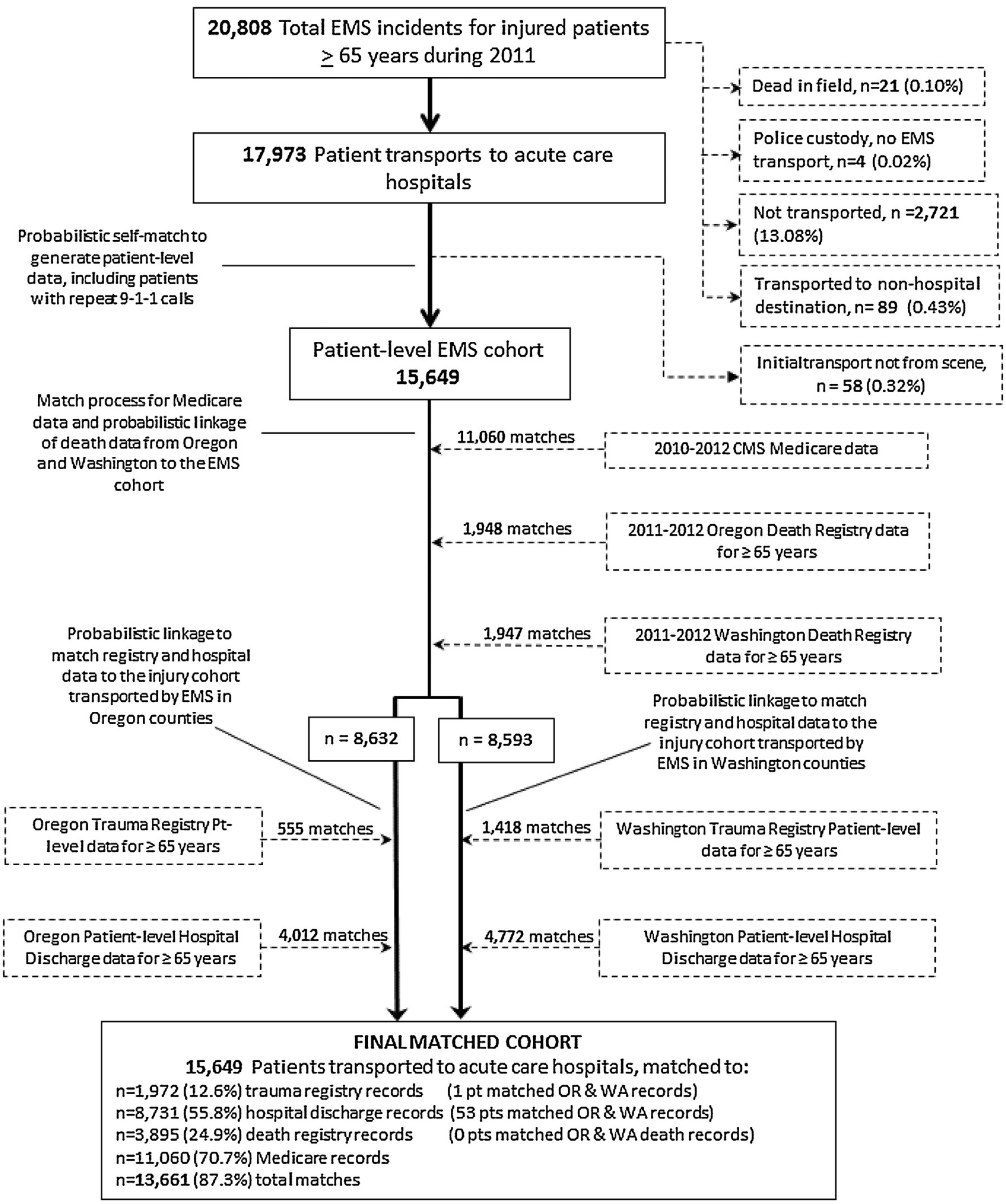

Fig. 1. Schematic of cohort creation.
*A similar schematic is illustrated in the methods paper associated with this project. [21]

Study setting

We conducted the study in 7 counties in the states of Oregon and Washington, representing the Northwestern U.S. We selected the 7 counties to encompass the two largest metropolitan areas in this region (Portland, Oregon - 4 counties; and Seattle, Washington - one county), integrate rural settings (two counties), account for ambulance service areas, and based on existing relationships with the 44 public and private EMS agencies serving these counties. Oregon has 36 counties and Washington has 39 counties. Five of the 7 counties selected for the study are urban/suburban and represent the most densely populated areas in these states, with the two additional counties included to represent rural regions. These EMS agencies work under close medical direction and use standardized field trauma triage protocols based on national guidelines [16].

Oregon and Washington have established, inclusive trauma systems with participating hospitals categorized as Level I – V trauma centers. Level I and II trauma hospitals are considered major trauma centers, consistent with national guidelines [17]. We included all 51 hospitals receiving injured older adults from EMS, plus 6 additional hospitals receiving these patients as subsequent inter-hospital transfers. These 57 hospitals have varying capabilities and services, and include: 3 Level I trauma centers, 7 Level II trauma centers, 10 Level III trauma hospitals, 9 Level IV hospitals, 1 Level V hospital and 27 non-trauma hospitals.

Patient population

We included consecutive injured adults $\geq$65 years transported by EMS from January 1, 2011 through December 31, 2011, with follow-up through December 31, 2012, regardless of receiving hospital, injury severity, or admission status. The presence of injury was based on EMS provider impression of “injury” or “trauma,” representing the full denominator of injured older adults served by EMS in these regions. For patients subsequently transferred to another hospital, we tracked information at all hospitals.

Data processing

EMS data were collected as part of a prospective, all-age cohort study validating the national field triage guidelines using in-hospital outcomes and a probability sampling design [9]. We used probabilistic linkage [18] (LinkSolv, v.9.0.0190, Strategic Matching, Inc., Morrisonville, NY) to match *all* electronic EMS records for injured older adults (including fire and ambulance agencies serving the same patients). We then matched the resulting patient-level dataset to two state trauma registries, two state discharge databases, two state death registries, and Medicare claims data (including one year before and after the date of initial EMS contact). Medicare is a federal health insurance program in the U.S. that covers all persons age 65 and older, with paid claims for medical services available for research [19]. For patients with multiple EMS transports over the study period, we used the initial record (reflecting entry into the cohort) and termed this the “index” event. We have validated these electronic data methods and probabilistic linkage routines [20–22], and have rigorously evaluated record linkage of EMS data into statewide data files [23]. The overall match rate of the EMS cohort into the 7 data files was 87.3%, with 59.4% matching to the index emergency department (ED) visit. Fig. 1] is a schematic detailing construction of the cohort. We independently validated record linkage processes, the resulting variables, and multiply imputed values for this project using a subset of 3140 patients with hand-abstracted records to which all investigators were blinded [21].

Variables

We coded out-of-hospital variables based on standard definitions from the National EMS Information System [24]. Out-of-hospital variables included: age; sex; field triage status; rural versus urban setting of EMS response; initial physiologic measures (Glasgow Coma Scale score, systolic blood pressure, respiratory rate, and heart rate); mechanism of injury; procedures; mode of transport; and receiving hospital. To minimize misclassification bias for field triage status, we triangulated ambulance records, fire department records, trauma registry data, and base hospital phone records. We generated measures of socioeconomic status (unemployment, household income, and education) using U.S. Census data mapped to patient home zip code [25]. For race and ethnicity, we used Medicare, state discharge, and trauma registry data (in this order for patients with multiple sources of data) and collected information separately for the two variables. To assess pre-injury place of residence, we used Medicare claims for skilled nursing or rehabilitation facilities in the 30 days prior to initial EMS contact. Patients with complete Medicare coverage and no such claims were assumed to be living in the community at the time of injury.

Variables from the index ED/hospital visit included: Abbreviated Injury Scale (AIS) scores; [26] Injury Severity Score (ISS); [26,27] ICD9-CM diagnosis codes; ICD9-CM procedure codes (categorized using the AHRQ Clinical Classification System [CCS] [28]); inter-hospital transfer; length of hospital stay; and discharge disposition (including in-hospital mortality). We used a mapping function (ICDPIC module for Stata v11, StataCorp, College Station, TX) to convert ICD9-CM diagnosis codes into AIS and ISS measures [17], which has been validated [29]. For hospital procedures, we combined CCS categories into groups commonly used to describe trauma care: major non-orthopedic surgery (brain, spine, neck, chest and abdominal-pelvic operations); orthopedic surgery; blood transfusion; as well as cardiac procedures. We grouped ICD9-CM diagnosis codes using the standard ICD9 categorization schema [30], then refined the list into 14 categories with clinical relevance to this population, including: injury; cardiovascular; dementia; neurologic (non-dementia); infection; respiratory; cancer; blood disorders and anemia; endocrine and metabolic; gastrointestinal; renal and genitourinary; surgical and procedural complications; psychiatric and behavioral; and other. Finally, we calculated the Charlson Comorbidity Index (CCI) [31] using Medicare records for the 12 months prior to EMS contact and other data sources that recorded comorbidity information.

Outcomes

The primary outcome was time-to-death, measured from the date of initial EMS contact to 365 days. We used standardized death certificate data (available for 95.6% of deaths) from Oregon and Washington to describe causes of death and the location of death. We categorized all causes of death, regardless of order, to account for contributing factors and potential variability among providers completing these certificates.

Data analysis

We used descriptive statistics to characterize the sample, the index visit, and mortality up to 12 months. We then used Cox proportional hazards regression models to estimate the hazard ratio (HR) for death following EMS transport, unadjusted and adjusted for predictors and confounders of mortality. The model included demographic and socioeconomic factors, comorbidities, physiology, mechanism, field triage status, hospital interventions, injury severity, injury type, and transfer status. We used robust (sandwich) estimates of variance in the Cox regression models and

Table 1
Characteristics of the index emergency department/hospital visit for injured older adults transported by emergency medical services (n = 15, 649).

Demographics:		
Mean – age (years)	81.8	
65 – 74 years	3,883	(24.8%)
75 – 84 years	4,911	(31.4%)
85 – 94 years	5,933	(37.9%)
≥ 95 years	922	(5.9%)
Women	10,613	(67.8%)
Race:		
White	14,414	(92.4%)
Black	351	(2.2%)
Asian	549	(3.5%)
Native American	83	(0.5%)
Other	205	(1.3%)
Ethnicity – Latino	329	(2.1%)
Home neighborhood socioeconomic characteristics:		
Mean unemployment	8.6%	
Mean household income	$63,318	
Mean high school education	90.6%	
Pre-injury comorbidities:		
Mean – Charleston Comorbidity Index (CCI)	2.2	
CCI categories (among 11,584 patients with known comorbidity status at time of initial EMS contact)[†]:		
Congestive heart failure	2,668	(23.0%)
Myocardial infarction	2,572	(22.2%)
Diabetes	2,378	(20.5%)
Chronic renal insufficiency	2,373	(20.5%)
COPD	2,307	(19.9%)
Dementia	2,142	(18.5%)
Cerebrovascular disease	1,815	(15.7%)
Cancer	1,401	(12.1%)
Peripheral vascular disease	1,377	(11.9%)
Rheumatoid arthritis	430	(3.7%)
Ulcers	209	(1.8%)
Paralysis	186	(1.6%)
Liver disease	107	(0.9%)
Out-of-hospital characteristics:		
Geographic region type for EMS response:		
Urban county	15,046	(96.1%)
Rural county	603	(3.9%)
Met field triage criteria, per EMS	1,554	(9.9%)
Systolic blood pressure ≤ 100 mmHg	654	(4.2%)
Heart rate ≤ 60 or ≥ 120	1,570	(10.0%)
Respiratory rate ≤ 10 or ≥ 24	347	(2.2%)
Glasgow Coma Scale (GCS) ≤ 8	72	(0.5%)
GCS 9 – 12	335	(2.1%)
GCS 13 – 15	15,243	(97.4%)
Assisted ventilation	90	(0.6%)
Intravenous or intraosseus line	3,112	(19.9%)
Mechanism of Injury:		
Fall	13,219	(84.5%)
Motor vehicle crash	869	(5.6%)
Motor vehicle vs. pedestrian	108	(0.7%)
Penetrating injury (Gunshot wound or stabbing)	130	(0.8%)
Assault	75	(0.5%)
Other	1,248	(8.0%)
Type of initial hospital:		
Level I	1,385	(8.9%)
Level II	1,119	(7.2%)
Level III	2,787	(17.8%)
Level IV/V	2,296	(14.7%)
Non-trauma hospital	8,062	(51.5%)
Index ED/hospital visit:		
Mean Injury Severity Score (ISS)	5.6	
ISS 0 – 8	11,127	(71.1%)
ISS 9 – 15	3,969	(25.4%)
ISS 16 – 24	447	(2.9%)
ISS ≥ 25	106	(0.7%)
Head Abbreviated Injury Scale (AIS) score ≥ 3	757	(4.8%)
Chest AIS ≥ 3	1,042	(6.7%)
Abdominal-pelvic AIS ≥ 3	241	(1.5%)
Extremity AIS ≥ 3	2,787	(17.8%)
Diagnosis categories:[‡]		
Injury	13,669	(87.4%)
Cardiovascular	10,628	(67.9%)
Endocrine/Metabolic	7,432	(47.5%)
Psychiatric/behavioral	4,396	(28.1%)
Neurologic (non-dementia)	4,230	(27.0%)

Table 1 (*Continued*)

Demographics:		
Respiratory	3,617	(23.1%)
Renal/genitourinary	3,536	(22.6%)
Gastrointestinal	3,446	(22.0%)
Blood disorders/anemia	3,191	(20.4%)
Infection	2,895	(18.5%)
Dementia	1,468	(9.4%)
Surgical/procedural complication	1,221	(7.8%)
Cancer	1,035	(6.6%)
Other	11,371	(72.7%)
Major non-orthopedic surgery	258	(1.7%)
Orthopedic surgery	3,129	(20.0%)
Cardiac procedures	130	(0.8%)
Blood transfusion	1,279	(8.2%)
Inter-hospital transfer	1,681	(10.7%)
Mean – length of stay (days)	2.4	
Discharge disposition:		
Expired	253	(1.6%)
Rehabilitation or skilled nursing facility	5,196	(33.2%)
Hospice	263	(1.7%)
Intermediate care facility	519	(3.3%)
Home	9,419	(60.2%)

[*] EMS = emergency medical services.

[†] Values in the table represent the entire cohort (n = 15,649), including multiply imputed values, except for individual comorbidities, which are based on observed values for 11,584 patients.

[‡] The cohort was defined through the lens of EMS providers, including all patients where EMS recorded a primary impression of "injury" or "trauma," regardless of subsequent diagnoses. All patients had an injury mechanism (e.g., fall), but only 87.4% of patients had an ICD9 diagnosis code for injury recorded from the index ED/hospital visit. Patients could have multiple diagnoses, so percentages do not add to 100%.

generated adjusted survival curves (overall and for key subgroups based on injury severity, injury type and comorbidity burden). We also tested for clinically-relevant effect modification between comorbidities, injury severity, and injury type. All hypothesis tests and associated *p*-values were two-sided, using $p < .05$ to identify statistical significance.

We used multiple imputation (MI) for missing values [32] to preserve the population-based sampling design and minimize bias. We have demonstrated the validity and rigor of MI for handling missing EMS, ED and in-hospital trauma data under a variety of conditions [23,33,34]. We generated 10 multiply imputed datasets using flexible chains regression models [35] (IVEware v0.1, University of Michigan, MI), then combined the results using Rubin's rules to account for overall variance [32]. For key variables, the proportion of missing values ranged from 0% (mortality to 1-year) to 44.9% (hospital disposition). Missingness was higher for variables tied to the index ED/hospital visit, reflecting the 59.4% match rate of clinical records to the initial EMS incident. To assure the accuracy of multiply imputed values, we independently validated imputed values for key variables compared to 3140 hand-abstracted records [21]. For sensitivity analyses, we analyzed an identical model using complete case analysis (no imputed values). We used SAS (v. 9.4, SAS Institute, Cary, NC).and Stata (v. 15.0, StataCorp, College Station, Texas) for all analyses.

Results

There were 15,649 injured older adults transported by EMS over the 12-month period. Mean age was 81.8 years, 67.8% were women, 65.3% had at least one comorbidity, 84.5% were injured by falls, and 16.0% of patients were initially transported to a major trauma center. Serious injury (Injury Severity Score [ISS] $\geq$16) was present in 3.5% of patients, with serious extremity injuries being the most common injury type (17.8% with extremity Abbreviated Injury Scale [AIS] score $\geq$3). During the index visit, 1.7% of patients had non-orthopedic surgery and 20.0% had orthopedic surgery. In Table 1, we characterize the sample and the index visit. In Fig. 2, we illustrate ambulance transport patterns and patient characteristics by triage status and type of receiving hospital. Patients transported to major trauma centers tended to be younger, have fewer comorbidities, more serious injuries, and higher unadjusted in-hospital mortality, particularly among patients meeting the field triage guidelines.

Mortality rates were 1.6% in-hospital, 5.1% at 30 days, 9.4% at 90 days and 20.3% at one year. There were few deaths in the field (n = 21, 0.7% of all deaths following injury). In Table 2, we show unadjusted and adjusted hazard ratios for death within one year. In the adjusted model, extremity AIS $\geq$ 3 was independently associated with one-year mortality (HR 1.51, 95% CI 1.24–1.84, $p < .001$), but serious head, chest, and abdominal-pelvic injuries were not ($p > .05$ for all). Orthopedic surgery was associated with lower 1-year mortality (HR 0.61, 95% CI 0.50 – 0.74, $p < .001$), while other major surgery was associated with increased mortality (HR 1.42, 95% CI 1.03–1.94, p = .03). The adjusted risk of death was similar between patients with a heavy comorbidity burden (HR for highest versus lowest CCI quartiles, 2.20, 95% CI 1.97–2.46, $p < .001$) and those with severe injuries (HR for ISS $\geq$ 24 versus ISS 0–8, 2.69, 95% CI 1.60–4.51, $p = .001$). Mechanism of injury was independently associated with death ($p < .001$), particularly for patients with a fall. While there appear to be mortality differences by hospital type, these findings reflect the initial ED destination (not accounting for inter-hospital transfers) and differences in the structure of trauma systems between the two states; the analysis was not designed to test outcome differences at the hospital level. Fig. 3 illustrates adjusted survival overall and stratified by injury severity, injury type, and comorbidity burden. There was no evidence of effect modification between CCI, ISS or AIS values ($p > .05$ for all interactions). The complete case analysis demonstrated similar results (data not shown).

In Fig. 4A, we show the number of deaths per day among the 3175 patients who died following EMS transport. While the greatest number of deaths-per-day occurred during the first 7 days, this time period accounted for only 9.3% of all deaths over the 12 month follow-up period. Most deaths (n = 1,712, 53.9% of all deaths) occurred more than 90 days after EMS transport. Causes of death varied over time, with injury causes being common within

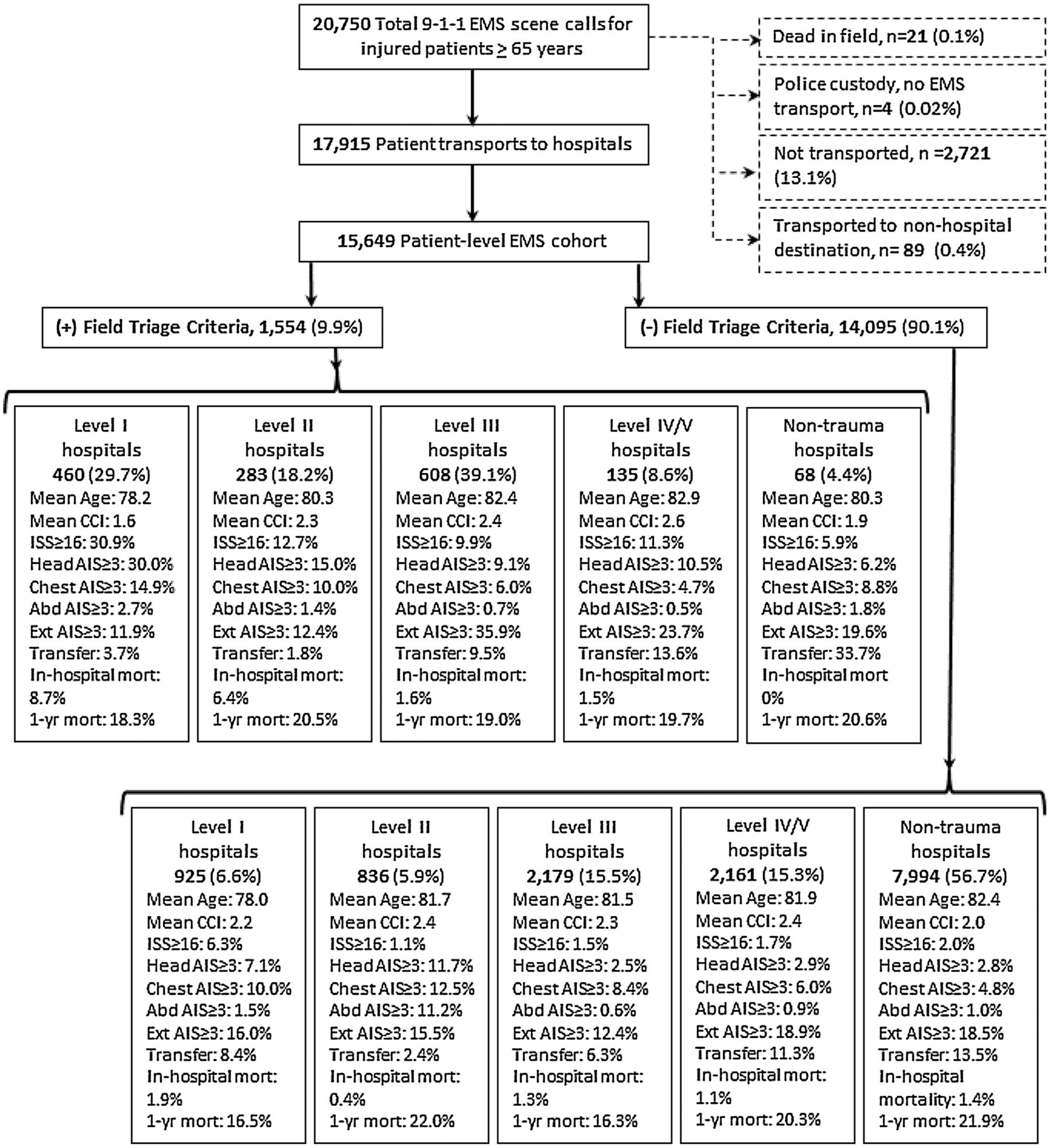

Fig. 2. Ambulance transport patterns for injured adults ≥ 65 years by triage status and hospital type, including patient characteristics.

the first 7 days and declining quickly thereafter (Fig. 4A and eFig. 1 in the supplemental on-line appendix). Overall, cardiovascular etiologies (53.3%) and dementia (32.7%) were the most common causes of death, with injury listed as a cause in 12.8% of deaths (Fig. 4B).

The location of death changed over time (eFig. 2 in the supplemental on-line appendix). Within the first 7 days of EMS contact, 64.3% of deaths occurred in the hospital (ED or inpatient), but this pattern quickly shifted to nursing homes and long-term care facilities. Overall, 33.2% of deaths occurred in nursing homes/ long-term care facilities, 24.5% in-hospital, 18.0% in non-home community settings (adult foster care, assisted living and residential care), 12.6% in hospice, 10.8% at home, and 1.0% in other locations.

In the subgroup of patients with adequate Medicare data to assess pre-injury place of residence (n = 5495, 35.1% of the sample), there were 229 (4.2%) patients with a claim for a skilled nursing or rehabilitation facility in the 30 days prior to initial EMS contact (Table 3). Patients with such a claim had a higher proportion of discharge to a skilled nursing or rehabilitation facility from the hospital compared to community-dwelling patients, and a lower proportion discharged to home. Mortality was higher in the skilled nursing/rehabilitation group across all time points. We repeated this analysis using Medicare claims within 7 days of EMS contact with similar results (data not shown).

Discussion

We characterize the natural history of injured older adults served by EMS in 7 counties, including ambulance transport patterns, acute care processes, mortality over 12 months, and factors independently associated with mortality. The population-based sampling design and inclusion of *all* injured older adults transported by EMS were unique aspects of the cohort, as many of

Table 2
Unadjusted and adjusted hazard ratios for 1-year mortality among injured older adults transported by emergency medical services (n = 15,649).

	Hazard ratio (95% CI)			Hazard ratio (95% CI)		
	Unadjusted			Adjusted		
65 – 74 years	1 (reference)		<.001	1 (reference)		<.001
75 – 84 years	1.79	(1.59 – 2.02)		1.73	(1.53 – 1.95)	
85 – 94 years	2.84	(2.54 – 3.17)		2.67	(2.37 – 3.00)	
≥ 95 years	4.67	(4.05 – 5.38)		4.58	(3.93 – 5.32)	
Female	0.65	(0.60 – 0.70)	<.001	0.65	(0.60 – 0.69)	<.001
Race:			<.001			<.001
White	1 (reference)			1 (reference)		
Black	0.68	(0.50 – 0.92)		0.84	(0.61 – 1.16)	
Asian	1.83	(1.40 – 2.40)		2.81	(1.95 – 4.05)	
Native American	0.61	(0.47 – 0.79)		0.66	(0.51 – 0.85)	
Other	0.61	(0.31 – 1.22)		0.86	(0.47 – 1.58)	
Ethnicity – Latino	0.54	(0.38 – 0.79)	.001	0.49	(0.31 – 0.76)	.002
Percent unemployment: 0-25%ile	1 (reference)		<.001	1 (reference)		.035
26-50%ile	1.16	(1.04 – 1.28)		1.09	(0.96 – 1.24)	
51-75%ile	1.27	(1.14 – 1.41)		1.20	(1.03 – 1.38)	
76-100%ile	1.31	(1.18 – 1.45)		1.24	(1.06 – 1.45)	
Median household income: 0-25%ile	1 (reference)		< .001	1 (reference)		.69
26-50%ile	0.98	(0.89 – 1.08)		0.98	(0.87 – 1.10)	
51-75%ile	0.88	(0.80 – 0.97)		0.94	(0.83 – 1.06)	
76-100%ile	0.81	(0.73 – 0.89)		1.01	(0.86 – 1.18)	
Percent with high school education, 0-25%ile	1 (reference)		.009	1 (reference)		.53
26-50%ile	1.00	(0.90 – 1.10)		1.01	(0.90 – 1.13)	
51-75%ile	0.91	(0.82 – 1.01)		0.97	(0.85 – 1.11)	
76-100%ile	0.86	(0.77 – 0.95)		0.91	(0.78 – 1.06)	
Charlson Comorbidity Index – quartile 1	1 (reference)		<.001	1 (reference)		<.001
Quartile 2	1.03	(0.91 – 1.18)		0.99	(0.87 – 1.12)	
Quartile 3	1.58	(1.43 – 1.74)		1.45	(1.31 – 1.60)	
Quartile 4	2.45	(2.20 – 2.72)		2.20	(1.97 – 2.46)	
Systolic blood pressure ≤ 100 mmHg	1.70	(1.47 – 1.98)	<.001	1.60	(1.37 – 1.88)	<.001
Heart rate ≤ 60 or ≥ 120	1.20	(1.08 – 1.34)	.001	1.08	(0.96 – 1.22)	.19
Respiratory rate ≤ 10 or ≥ 24 breaths per minute	1.67	(1.34 – 2.09)	<.001	1.65	(1.28 – 2.11)	<.001
Glasgow Coma Scale (GCS) 13 – 15	1 (reference)		<.001	1 (reference)		<.001
GCS 9 – 12	2.69	(2.25 – 3.21)		2.36	(1.96 – 2.85)	
GCS 3 – 8	4.61	(3.06 – 6.95)		3.30	(2.11 – 5.16)	
Assisted ventilation	3.31	(2.31 – 4.73)	<.001	2.22	(1.46 – 3.39)	<.001
Field triage positive	0.96	(0.85 – 1.08)	.50	0.88	(0.76 – 1.02)	.10
Mechanism of injury:						
Fall	1 (reference)		<.001	1 (reference)		<.001
Penetrating injury	0.44	(0.23 – 0.82)		0.46	(0.24 – 0.86)	
Motor vehicle crash	0.24	(0.17 – 0.34)		0.35	(0.24 – 0.50)	
Motor vehicle vs. pedestrian	0.65	(0.38 – 1.10)		0.89	(0.51 – 1.55)	
Other	0.76	(0.65 – 0.90)		0.87	(0.74 – 1.02)	
Receiving hospital level:			<.001			<.001
Non-trauma hospital	1 (reference)			1 (reference)		
Level I	1.28	(1.07 – 1.53)		1.20	(0.97 – 1.47)	
Level II	0.97	(0.83 – 1.14)		1.04	(0.86 – 1.24)	
Level III	1.20	(1.02 – 1.40)		1.15	(0.95 – 1.38)	
Level IV/V	1.30	(1.13 – 1.49)		1.32	(1.12 – 1.55)	
Injury Severity Score (ISS) 0 – 8	1 (reference)		<.001	1 (reference)		.001
ISS 9 – 15	1.28	(1.15 – 1.42)		1.14	(1.00 – 1.30)	
ISS 16 – 24	1.86	(1.55 – 2.22)		1.50	(1.14 – 1.96)	
ISS ≥ 25	3.02	(2.08 – 4.39)		2.69	(1.60 – 4.51)	
Head Abbreviated Injury Scale (AIS) score ≥ 3	1.57	(1.21 – 2.03)	.001	1.13	(0.87 – 1.47)	.35
Chest AIS ≥ 3	0.83	(0.60 – 1.14)	.23	0.89	(0.71 – 1.11)	.30
Abdominal-pelvic AIS ≥ 3	0.92	(0.64 – 1.33)	.66	0.83	(0.56 – 1.23)	.34
Extremity AIS ≥ 3	1.26	(1.13 – 1.40)	< .001	1.51	(1.24 – 1.84)	<.001
Major non-orthopedic surgery	1.40	(1.04 – 1.88)	.025	1.42	(1.03 – 1.94)	.030
Orthopedic surgery	0.88	(0.78 – 0.99)	.033	0.61	(0.50 – 0.74)	<.001
Cardiac procedure	0.87	(0.51 – 1.49)	.66	0.87	(0.52 – 1.47)	0.61
Blood transfusion	1.38	(1.21 – 1.56)	< .001	1.38	(1.18 – 1.61)	<.001
Inter-hospital transfer	0.84	(0.73 – 0.97)	.014	0.89	(0.77 – 1.03)	.12

[*] Abbreviations: CI, confidence interval.

these patients are excluded from trauma registries [36] and therefore invisible to quality improvement efforts in trauma systems. Falls were common, as were serious extremity injuries requiring orthopedic surgery. In-hospital mortality was relatively low, but more than tripled by 30 days, and was substantially higher at one year. The mortality risk of chronic disease was similar to that of severe injury, demonstrating the important role of comorbidities in this population. Our findings suggest that many older adults do not fit the traditional paradigm of US trauma systems, where the focus is on early aggressive interventions to avert early preventable mortality.

Long-term mortality in our sample differed from previous all-age trauma samples. While only 1.6% of patients died during their index hospitalization, 20.3% had died within one year. This 1-year mortality rate is almost three times higher than the 7.2% 1-year mortality rate of adult trauma patients included in the Washington

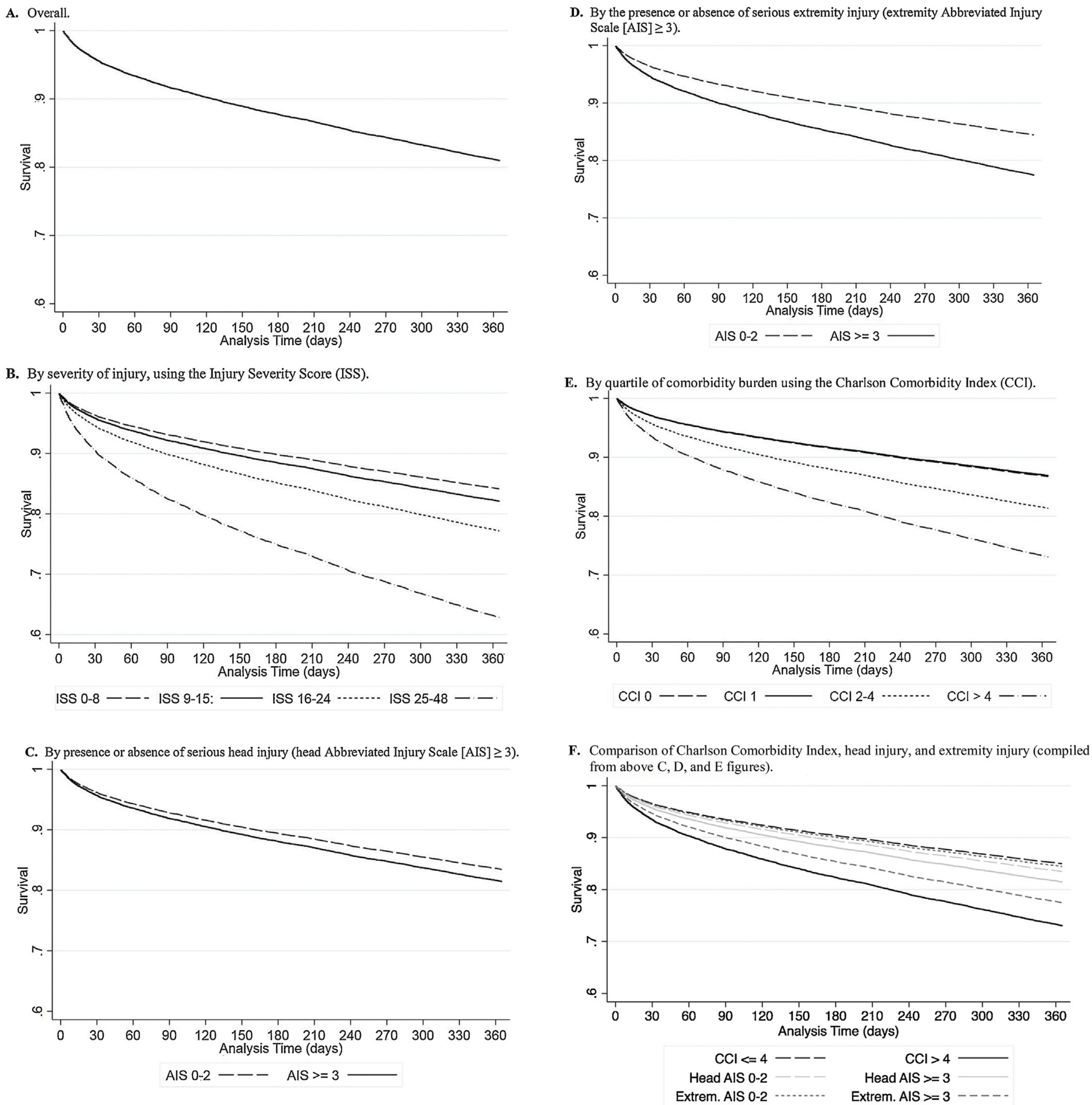

Fig. 3. Adjusted survival curves to one year for injured older adults transported by emergency medical services - overall, by injury severity, injury type, and comorbidity burden (n = 15,649).
*All y axes are truncated at adjusted survival 0.60 to 1.00.

State Trauma Registry [37] and the 7.8% among Danish trauma patients served by EMS [38]. Our data also illustrate that the post-discharge period is a particularly high-risk time for injured older adults, with notable differences between in-hospital mortality and 30-day mortality. Causes of death also changed over time, with the causal role of injury limited to the first week after injury and declining quickly thereafter. Non-injury causes of death were most common overall, suggesting that an injury event requiring EMS is often a sentinel event for older adults, and possibly a causal factor in decline. The causes of death in our sample were similar, but not identical, to the overall causes of death among all persons 65 years and older in the U.S. [39]. Heart disease and respiratory disease were in similar positions (first and third leading causes of death), but dementia was the second most common cause in our sample compared to the fifth leading cause of death overall for older adults in the U.S. [39]. Trauma systems were developed on the premise that 50% of deaths following injury occur at the scene, 30% within hours (those most amenable to early intervention), and 20% within days or weeks due to sepsis and multi-organ failure [40]. Our findings illustrate a very different pattern for injured older adults, with relatively few deaths occurring early and the majority occuring months later, often from chronic diseases.

Comorbidities were common and carried a high mortality risk, highlighting the need for targeted clinical management. Whether

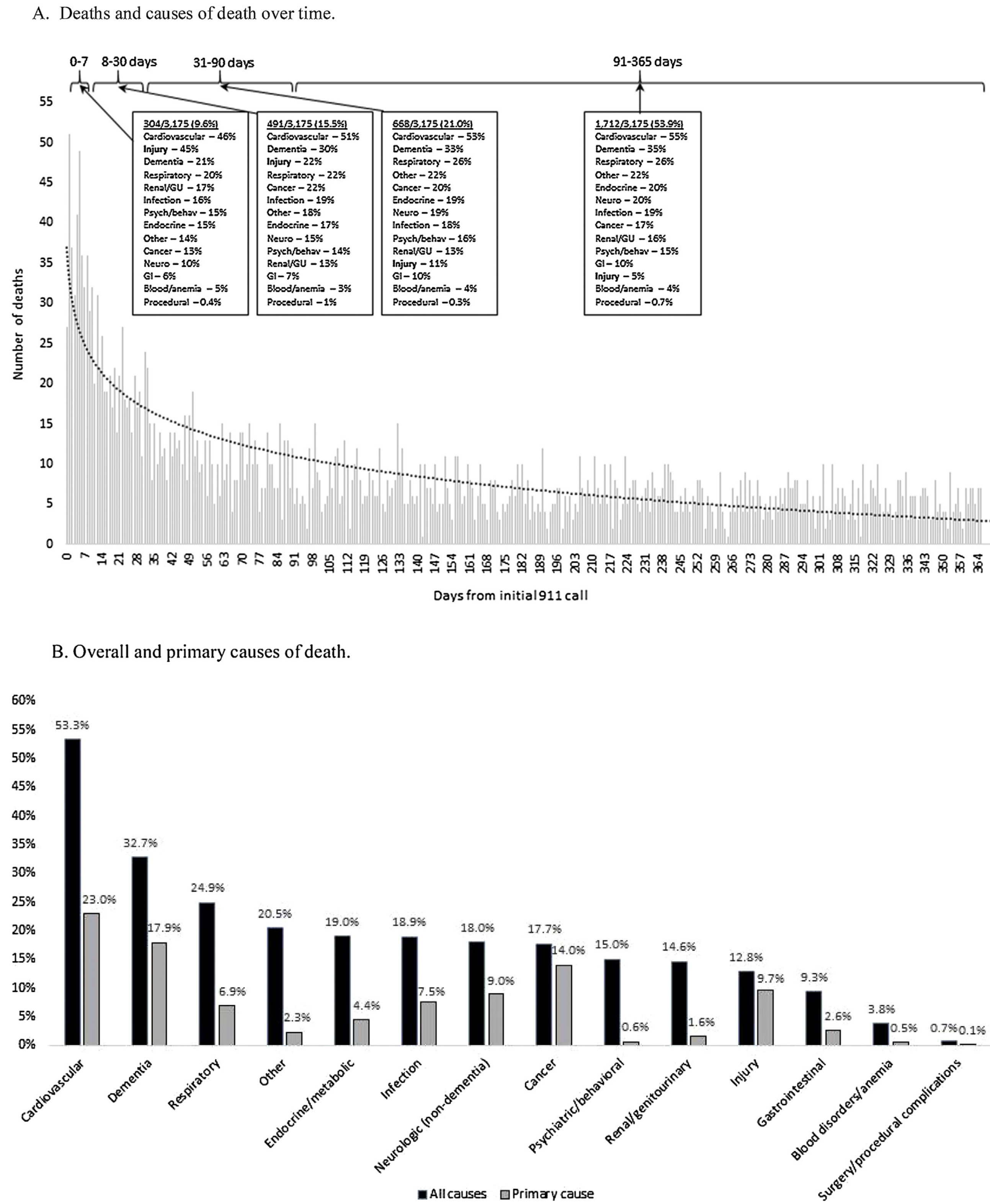

Fig. 4. Timing and causes of death among injured older adults transported by emergency medical services who died within one year (n = 3175 deaths).
*Death certificate data with cause of death were available for 3037 of 3175 (95.6%) of deaths. Cause of death categories include all listed causes and are therefore not mutually exclusive. The dotted line in Fig. 4A represents a fitted curve to the distribution of deaths over time (R^2 = 0.68).

U.S. trauma centers adequately prioritize the management of comorbidities is unclear. There are reports of improved outcomes in certain trauma centers that have implemented dedicated multidisciplinary geriatric trauma services [41]. Orthopedic surgery was associated with a reduction in 1-year mortality, although we cannot rule out the possibility of selection bias related to patients incurring these injuries and selected for surgery. Nonetheless, this association has been shown before among older adults with hip fractures, particularly for patients receiving early orthopedic fixation [42,43]. Timely orthopedic intervention among

Table 3
Hospital disposition and mortality to one year by pre-injury place of residence among injured older adults transported by emergency medical services (n = 5495).

	SNF or rehabilitation (n = 229, 4.2%)		Community dwelling (n = 5,266, 95.8%)	
Hospital discharge disposition:				
Expired	5	(2.2%)	66	(1.3%)
Skilled nursing or rehabilitation facility	85	(37.2%)	1405	(26.7%)
Hospice	5	(2.0%)	71	(1.4%)
Intermediate care facility	10	(4.5%)	196	(3.7%)
Home	124	(54.2%)	3529	(67.0%)
Mortality:				
30-day	17	(7.4%)	279	(5.3%)
60-day	27	(11.8%)	411	(7.8%)
90-day	35	(15.3%)	530	(10.1%)
365-day	92	(40.2%)	1154	(21.9%)

*Pre-injury place of residence was available for 5495 (35.1% of the sample) based on completeness of Medicare claims for the 30 days prior to EMS contact. We defined residence in a skilled nursing facility (SNF) or rehabilitation facility at the time of injury based on a claim for either type of facility in the 30 days prior to EMS contact; patients with no claims for such facilities during the same time period were considered to reside in the community.

qualifying older adults is a potential quality focus for trauma centers, as Level I trauma centers have been shown to have slower time-to-surgery, longer length of stay, and higher readmission rates for patients with isolated hip fractures compared to non-trauma centers [44]. The elevated mortality risk among patients undergoing non-orthopedic surgery likely reflects patients with more severe injuries requiring operative intervention.

The association of race and ethnicity with mortality differed from previous disparities research. We found that Asians had higher adjusted mortality than Caucasions, while Native Americans and Latinos had lower mortality. While our analysis was not designed to explore racial and ethnic disparities, there is previous trauma research demonstrating that race in injured older adults functions differently than for younger patients [45]. Our results add further evidence to this seemingly paradoxical association between race, ethnicity, and age following injury.

There is a need to reconsider how injured older adults are cared for in trauma systems. Chronic disease played a prominent role in determining outcome after injury, as did serious extremity injuries. With an aging population, trauma centers have the opportunity to embrace these findings and create systems of care to address the unique needs of older adults. Potential models include having a geriatrician imbedded in the trauma service [46], designing geriatric-specific trauma units [41], evidence-based protocols for managing comorbidities and preventing delirium [47], and adoption of the "Age-Friendly Health System's 4 M's (Mobility, Mentation, Medications, and what Matters)." [48] Closer collaboration with post-discharge care and primary care providers are additional areas of focus, reflecting the need for more coordinated care that does not end at hospital discharge. However, trauma systems were not originally designed to care for older adults, who have many non-trauma conditions that must be addressed (e.g., comorbidities, frailty, cognitive decline, etc.). As an example, older adults with isolated hip fractures have traditionally been cared for outside of major trauma centers in the U.S. and excluded from trauma registries, despite the need for early operative intervention, high morbidity and mortality.

There were limitations in our study. The results do not address whether changes in trauma systems, trauma centers, or hospital services will improve survival following injury in older adults. Whether (or which) injured older adults should be managed in major trauma centers remains on open question. Our results illustrate that acute hospital care is only one aspect of the care continuum following injury in older adults. We intentionally included a broad sample, without restriction by living setting, existing conditions (e.g., dementia), or end-of-life wishes. This cohort provides a real-world depiction of injured older adults served by EMS and transported to acute care hospitals in the U.S. Patients with do-not-resuscitate orders, advanced dementia, or residing in institutional settings (e.g., skilled nursing facilities) may have different treatment goals and management strategies than patients with higher baseline functional status and independence. A more selective sample (e.g., community-dwelling older adults) may have produced different results, as we demonstrate differences in hospital disposition and mortality by pre-injury living status.

We relied on administrative, registry, and claims data, which allowed us to capture information for a population-based cohort transported by EMS to a wide variety of hospitals. While it is possible that these data sources were influenced by hospital billing practices or other nuances of administrative data, our independent validation using a subgroup of patients with hand-abstracted data did not demonstrate notable differences [21]. Finally, we were unable to measure patient functional status following injury, which is an important outcome measure for older adults.

Conclusions

Injured older adults transported by EMS had high 1-year mortality, often occurring months after injury from cardiovascular causes and dementia. Comorbidities are common and carried a mortality risk comparable to severe injury. Whether the design of trauma systems and trauma centers need to be adapted to better serve this population requires further study.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2019.04.028.

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