Trends in Short- and Long-Term Survival Among Out-of-Hospital Cardiac Arrest Patients Alive at Hospital Arrival

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Background—Out-of-hospital cardiac arrest (OHCA) is associated with a poor prognosis and poses a significant burden to the healthcare system, but few studies have evaluated whether OHCA incidence and survival have changed over time.

Methods and Results—A population-based cohort study was conducted, including 34 291 OHCA patients >20 years of age who were transported alive to the emergency department of an acute-care hospital from April 1, 2002, to March 31, 2012, in Ontario, Canada. Patients with life-threatening trauma and those who died before hospital arrival were excluded. The overall age- and sex-standardized incidence of OHCA patients who were transported alive was 36 cases per 100 000 persons and did not significantly change over the study period. Cardiac risk factor prevalence increased significantly, whereas the rate of most cardiovascular conditions decreased significantly. The 30-day survival improved from 9.4% in 2002 to 13.6% in 2011; 1-year survival improved from 7.7% to 11.8% (P<0.001). Patients hospitalized in 2011 were significantly more likely to survive 30 days (adjusted odds ratio, 1.47 [95% CI, 1.22–1.77]) and 1 year (adjusted odds ratio, 1.55 [95% CI, 1.27–1.91]) compared with 2002. A significant interaction between temporal trends in survival improvement and age group was observed in which the improvement in survival was largest in the youngest age groups.

Conclusions—OHCA patients who were transported alive are increasingly likely to have cardiovascular risk factors but less likely to have previous cardiovascular conditions. The overall incidence of OHCA patients transported to hospital alive did not change over the past decade. Short- and longer-term survival after OHCA has substantially improved, with younger patients experiencing the greatest improvement. **(*Circulation*. 2014;130:1883-1890.)**

Key Words: out-of-hospital cardiac arrest ■ survival ■ trends

Out-of-hospital cardiac arrest (OHCA) affects ≈360 000 patients each year in the United States, representing a substantial burden to the healthcare system.[1] The Resuscitation Outcomes Consortium estimated survival to hospital discharge after OHCA at 7.9% among patients who were treated by emergency medical service personnel.[2] Despite significant efforts to improve the outlook for OHCA patients, recent studies have diverged regarding whether outcomes for OHCA are improving.[3–7] Sasson et al[3] compiled data from 79 studies including 142 740 patients and demonstrated that survival to hospital discharge remained unchanged from 1980 to 2008. In contrast, several European[4,5] and Asian countries[6,7] have reported temporal improvements in survival after OHCA. However, these studies captured limited clinical information on OHCA patients, and, therefore, the association between changes in patient comorbidities and survival trends remain unclear.

Editorial see p 1844
Clinical Perspective on p 1890

Many of these countries have a nationwide surveillance or a nationally coordinated system to manage patients with out-of-hospital emergencies. In these contexts, it is possible that quality improvement initiatives could be designed and translated more effectively, leading to improved survival for OHCA patients. It remains unclear whether findings from these studies are applicable in North America, where emergency medical services are organized by smaller jurisdictions and patients are managed by hundreds of destination hospitals.[2] In Ontario, for example, the population of 13.8 million is served by 53 individual land-based emergency medical service providers, with ≈280 destination hospitals providing postarrest care.[8] Population-level surveillance studies are critical to inform policy and evaluate current systems of care.

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Received April 16, 2014; accepted September 11, 2014.
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The online-only Data Supplement is available with this article at http://circ.ahajournals.org/lookup/suppl/doi:10.1161/CIRCULATIONAHA.114.010633/-/DC1.
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Accordingly, the main objective of this study was to evaluate recent trends in the patient characteristics, incidence, and the survival of patients after OHCA.

Methods

Data Sources

Our analytic data sets were created by linking together multiple large administrative databases in Ontario using unique encrypted patient identification numbers to protect patient confidentiality. The Canadian Institute of Health Information Discharge Abstract Database was used to identify comorbidities and in-hospital interventions.[9,10] The National Ambulatory Care Reporting System database, which contains information regarding emergency department visits, was used to identify patients transported to the emergency department of an acute-care hospital after OHCA and to identify comorbid information.[11] The Ontario Registered Persons Database, which includes vital statistics for all Ontarians, was used to determine mortality after the index event. The Ontario Health Insurance Plan physician claims database, which captures information on the services provided by physicians in Ontario, was used to identify additional diagnostic testing and in-hospital services. The Ontario Drug Benefit prescription database was used to determine outpatient prescription drug use for patients aged ≥65 years.[12]

Study Sample

Our study sample is described in detail in Figure I, available in the online-only Data Supplement. Adult OHCA patients who were transported alive to the emergency department of an acute-care hospital in Ontario from April 1, 2002, to March 31, 2012, were identified using the *International Classification of Disease, Tenth Revision*, codes associated with cardiac arrest (I460, I461, I469, I4900, I4901, R960, R961, R98, and R99) and the Canadian Classification of Health Interventions codes for cardiopulmonary resuscitation (1HZ30JN and 1HZ30JY). Patients <20 years of age and those who had an arrest attributed to life-threatening trauma were not included. We excluded OHCA patients who died before arrival to the emergency department arrival because of the limitations of our data source but included patients who received resuscitative efforts in the emergency department. Patients with incomplete records or invalid Ontario health card numbers were also excluded. For those who had multiple arrests during the study period, only the first event was considered.

Survival After OHCA

We evaluated 30-day and 1-year survival, but did not examine in-hospital survival because this measure is biased by differences in hospital discharge practices.[13] Survival duration was estimated from the day of arrival to the emergency department to the day of death. Mortality was assessed through March 31, 2013, with complete follow-up for each included patient.

Statistical Analysis

The patient cohort was stratified by the Canadian fiscal year (April 1 to March 31) of the index OHCA. Temporal trends in characteristics were compared using the Cochran-Armitage Trend test for categorical variables and linear regression for continuous variables, using year of the OHCA as the independent variable. Rates of targeted temperature management (TTM) were calculated among patients who survived the day of presentation to the emergency department. We calculated the age- and sex-standardized rate of OHCA patients transported to the hospital alive through direct standardization to the 2006 Ontario population. We also calculated incidence rates for 4 predetermined age groups (20–49, 50–64, 65–74, and ≥75 years) and for men and women separately. Temporal changes in incidence rates were evaluated using Poisson regression models.

We then examined the independent association between year of the index OHCA (treated as a continuous variable) and 30-day and 1-year survival using logistic regression with generalized estimating equations to account for clustering of patients within hospitals.[14] The model adjusted for age, sex, income quintile of the patient's neighborhood of residence, rural residence, cardiac risk factors (diabetes mellitus, hypertension, and dyslipidemia), previous cardiovascular conditions (chronic atherosclerosis, ischemic heart disease, previous myocardial infarction, unstable angina, heart failure, arrhythmia, cerebrovascular disease, and peripheral vascular disease), medical comorbidities (renal disease, chronic lung disease, and cancer), and the Charlson-Deyo comorbidity score. To test whether temporal trends in survival differed by age groups, we repeated this analysis by stratifying our cohort into age groups (20–49, 50–64, 65–74, and ≥75 years) and tested the significance of the interaction between year of arrest and age group. Using the same method, we also examined the potential differences in temporal improvement by sex.

To ensure our results were robust, we undertook additional sensitivity analyses using the Epistry Cardiac Arrest database, which is a well-validated, population-based database of consecutive OHCA cases, collected prospectively from emergency medical service and hospital records. It is used as the primary data capture tool for randomized, controlled trials by the Resuscitation Outcomes Consortium.[15] A subset of this database, the Toronto Epistry data set, captures patients with OHCA in the Greater Toronto Area. First, we used this data set as a gold standard to determine the accuracy of our diagnostic coding strategy. Second, we compared the independent association between year of OHCA and survival in the linked data set and the Toronto Epistry data set in the overlapping time period from January 1, 2006, to December 31, 2010. Third, we evaluated potential changes in the survival estimates using Toronto Epistry data, first using the original adjustment variables and then with additional clinical variables known to predict survival, such as location of cardiac arrest and initial presenting rhythm. Finally, we also made use of the Epistry data potential changes in presenting cardiac arrest rhythm over time and estimated the total number of OHCA patients in Ontario.

This study was approved by the ethics board at the Sunnybrook Health Sciences Center for use of the Toronto Epistry data and the population-based administrative data. Informed consent was waived, as permitted under Ontario privacy laws for research using administrative data and the Toronto Epistry data set. Two-tailed *P* values <0.05 were considered significant. Analyses were performed with the use of SAS software, version 9.3 (SAS Institute, Cary, NC).

Results

Baseline Characteristics and Therapy

From April 1, 2002, to March 31, 2012, 34 291 OHCA patients were treated and transported alive to an emergency department in Ontario. Patient- and hospital-related characteristics for each fiscal year are shown in Table I in the online-only Data Supplement and grouped into 5 time periods in Table 1. The mean age of our study cohort was 67.4 years, and 65.2% of patients were men, with no significant change over the decade. A statistically significant trend for an increased prevalence of cardiac risk factors was observed for diabetes mellitus (29.2–37.8%), hypertension (62.3–68.6%), and dyslipidemia (21.2–30.4%) in the study period. In contrast, the prevalence of many previous cardiovascular conditions decreased over time. For example, myocardial infarction decreased from 18.4% in 2002 to 13.1% in 2011, heart failure from 21.6% to 18.1%, and cerebrovascular disease from 8.5% to 6.1%. The prevalence of other medical conditions such as renal disease, primary or metastatic cancer, and the mean Charlson-Deyo comorbidity score did not significantly change over the study period. Patients in later years were also more likely to have undergone previous cardiac testing, cardiac catheterization, or installation of an implantable cardioverter-defibrillator.

Information on medical therapy in the 12 months before OHCA was available for 20 060 patients over 65 years

Table 1. Trends in the Demographic and Clinical Characteristics of OHCA Patients Who Were Transported to the Hospital Alive From Fiscal Year 2002 to 2011

Variable	2002–2003	2004–2005	2006–2007	2008–2009	2010–2011	*P* Value for Trend
No. of patients	6320	6295	6606	7345	7725	
Demographics, %						
Age, mean±SD, y	67.6±15.4	67.5±15.6	67.2±15.8	67.3±15.9	67.2±16.1	0.152
Men	65.0	64.8	65.0	65.6	65.7	0.210
Rural	15.4	14.2	13.9	13.2	12.1	<0.001
Cardiac risk factors, %						
Diabetes mellitus	29.5	31.3	33.2	35.8	37.3	<0.001
Hypertension	61.8	64.1	65.4	66.8	68.5	<0.001
Dyslipidemia	20.8	24.7	27.7	31.4	30.5	<0.001
Previous cardiovascular conditions, %*						
Chronic atherosclerosis	24.2	20.7	18.8	18.7	18.4	<0.001
Ischemic heart disease	25.9	20.0	15.6	13.8	13.3	<0.001
Myocardial infarction	17.1	14.1	13.5	12.9	12.8	<0.001
Unstable angina	7.6	7.1	5.6	4.8	4.3	<0.001
Heart failure	21.3	18.8	17.8	17.1	17.8	<0.001
Arrhythmias	18.8	16.6	15.1	14.9	15.9	<0.001
Cerebrovascular disease	8.1	7.7	5.9	6.2	5.9	<0.001
Peripheral vascular disease	7.2	6.7	5.4	5.0	4.8	<0.001
Medical comorbidities, %						
Chronic lung disease	14.3	12.3	11.6	10.8	11.7	<0.001
Renal disease	7.6	7.3	8.1	8.4	7.8	0.185
Primary cancer	6.5	6.7	6.3	6.8	6.4	0.880
Metastatic cancer	3.0	3.1	2.9	2.9	2.8	0.424
Charlson-Deyo comorbidity score, mean±SD	1.52±2.13	1.42±2.08	1.42±2.12	1.49±2.15	1.52±2.15	0.312
Medications in the past year, %†						
Statins	32.2	40.5	47.7	52.8	56.1	<0.001
β-Blockers	37.9	40.5	43.1	45.9	46.8	<0.001
ACE inhibitors or ARBs	57.0	58.9	61.2	63.1	62.8	<0.001
Cardiac assessment or procedures in the past 5 y, %						
Assessment of ventricular function	38.4	39.0	41.2	47.1	51.9	<0.001
Assessment of ischemia	23.1	24.4	24.1	25.4	26.8	<0.001
Cardiac catheterization	10.3	10.2	11.1	12.0	12.5	<0.001
Percutaneous coronary intervention	2.0	2.7	3.4	4.1	4.5	<0.001
Permanent pacemaker	2.4	2.6	2.2	2.1	2.4	0.431
Coronary artery bypass grafting	1.8	1.9	1.9	1.9	1.8	0.790
Implantable cardioverter-defibrillator	0.5	1.0	1.0	1.1	1.5	<0.001
Hospital characteristics, %						
Teaching hospital	15.8	14.6	16.5	18.3	18.4	<0.001
Cardiac catheterization facility	25.3	27.1	28.6	33.0	32.6	<0.001
Cardiac arrest volume, mean±SD	59.4±32.3	56.7±29.3	59.3±31.8	61.7±32.1	62.4±31.7	<0.001

ACE indicates angiotensin-converting-enzyme inhibitor; ARB, angiotensin receptor blocker; and OHCA, out-of-hospital cardiac arrest.

*Previous cardiovascular conditions within the past 5 years were identified.

†Data on medication available for 20 060 patients >65 years of age who are eligible for the Ontario Drug Benefit Program were included.

(Table 1 and Table I in the online-only Data Supplement). The use of statin medications increased substantially from 29.9% to 57.3%, β-blockers from 36.7% to 48.1%, and angiotensin-converting enzyme inhibitors or angiotensin receptor blockers from 57.8% to 63.2% from 2002 to 2011. The use of TTM among OHCA patients who survived the index event date is shown in Figure II in the online-only Data Supplement. The use of in-hospital TTM was 0.4% in 2002, remained at

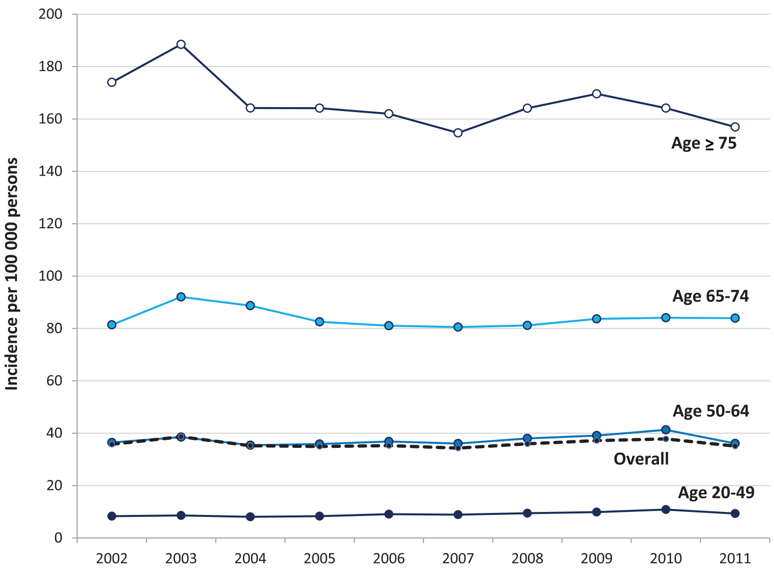

Figure 1. Trends in the incidence of out-of-hospital cardiac arrest (OHCA) patients transported alive to hospital, 2002–2011. The age- and sex-standardized incidence rates for OHCA patients who were transported alive to emergency departments in Ontario are shown by age group and overall (dotted line). The 2006 Ontario population was used as the reference population.

<10.0% from 2002 to 2005, and then increased to 11.4% in 2006 and to 40.5% in 2011 ($P<0.001$).

Using the Epistry data set, we examined changes in the clinical characteristics and presenting rhythm of 7419 OHCA patients alive at hospital arrival from 2006 to 2010 to gain additional insights into the mechanism of an improving survival trend (Table III in the online-only Data Supplement). We observed that changes in the clinical characteristics in the Epistry data set were similar to the overall cohort, with increasing rates of diabetes mellitus and dyslipidemia, decreasing rates of ischemic heart disease and heart failure, increasing medication use, and no significant change in the proportion of men or average age in the population. Despite these changes, there was no substantial trend in the initial presenting rhythms as determined by the first responders (Table III in the online-only Data Supplement). In 2006, 28.3% of patients had a shockable rhythm (ventricular tachycardia or ventricular fibrillation), and 69.0% had a nonshockable rhythm (asystole or pulseless electric activity). In 2010, 28.7% of patients had a shockable rhythm and 66.5% a nonshockable rhythm.

Trends in the Incidence of OHCA Patients Alive at Hospital Arrival

Figure 1 shows the age- and sex-standardized incidence rates for OHCA patients who were transported to the hospital alive from fiscal year 2002 to 2011. The overall incidence at 36 cases per 100 000 persons per year did not significantly change over the study period. For patients 20 to 49 years of age, the standardized incidence rate of OHCA was 8.3 per 100 000 in 2002 and increased to 9.3 per 100 000, representing a 28% relative increase over the entire study period. For patients ≥75 years of age, the standardized incidence of OHCA decreased from 174.0 per 100 000 in 2002 to 156.9 per 100 000 in 2011, representing a 10% relative decrease. The overall incidence of OHCA did not significantly change for men and women at 48.1 per 100 000 and 24.5 per 100 000, respectively.

Trends in Survival for OHCA Patients Alive at Hospital Arrival

Among OHCA patients transported alive to the hospital, the unadjusted survival at 30 days and 1 year is shown in by each fiscal year in Table II in the online-only Data Supplement and grouped into 5 time periods in Table 2. In 2002, 9.4% of patients survived to 30 days and 7.7% survived to 1 year after cardiac arrest. Survival improved significantly over time, and, in 2011, 13.6% of patients survived to 30 days and 11.8% survived to 1 year after cardiac arrest ($P<0.001$ for trend). Both 30-day survival and 1-year survival improved for patients in all of the age groups and in men and women. The largest increase in survival was seen among patients aged 20 to 49 years, in which the 30-day survival improved from 8.8% to 19.1% and the 1-year survival improved from 7.6% to 18.2% in the study period.

The multivariable adjusted odds ratio for survival at 30 days after OHCA was 1.47 (95% CI, 1.22–1.77) in 2011 as compared with 2002 (Figure 2A). The adjusted odds ratio for 1-year survival was 1.55 (95% CI, 1.27–1.91) in 2011 as compared with 2002 (Figure 2B). Although improvement was seen in all of the age groups, a significant interaction between survival improvement and age group was observed in which improvement was largest in the youngest age groups (Figure 3A, interaction $P<0.001$ for 30-day survival; Figure 3B, interaction $P=0.001$ for 1-year survival). Men and women experienced no significant differences in improvement in survival after OHCA (Figure IIIA and IIIB in the online-only Data Supplement).

Additional Sensitivity Analyses

Comparing the provincial data with the Toronto Epistry data, the algorithm for identifying patients with OHCA who were transported to the hospital alive using provincial data were shown to have 70% sensitivity and 72% positive predictive value. In addition, there was no substantial difference in adjusted odds ratios for 30-day and 1-year survival from January 1, 2006, to December 31, 2010, comparing 3 different methods: the original data set with adjustment, Epistry data set with original adjustment variables, and Epistry data set with additional clinical variables that included location of cardiac arrest and presenting rhythm (Table IV in the online-only Data Supplement).

Table 2. Unadjusted Survival of Out-of-Hospital Cardiac Arrest Patients Who Were Transported to the Hospital Alive at 30 Days and 1 Year From Fiscal Year 2002 to 2011, Stratified by Age Groups and Sex

	2002–2003	2004–2005	2006–2007	2008–2009	2010–2011	*P* Value for Trend
Overall, No.	6320	6295	6606	7345	7725	
30-d survival, %	8.7	8.6	9.6	11.3	13	<0.001
1-y survival, %	7.1	7.4	8.4	9.6	11.3	<0.001
Age 20–49, No.	888	881	981	1058	1107	
30-d survival, %	9.2	9.5	11.8	14.6	18.7	<0.001
1-y survival, %	8.1	9.0	11.1	13.5	17.7	<0.001
Age 50–64, No.	1482	1523	1680	1912	2054	
30-d survival, %	10.1	9.9	12.4	15.4	15.9	<0.001
1-y survival, %	9.0	8.7	11.1	14.0	14.4	<0.001
Age 65–74, No.	1461	1466	1416	1524	1652	
30-d survival, %	10.4	8.8	9.5	11.9	13.1	<0.001
1-y survival, %	9.0	7.2	8.1	10.2	11.2	0.001
Age ≥75, No.	2489	2425	2529	2851	2912	
30-d survival, %	6.5	7.4	6.8	6.9	8.9	0.007
1-y survival, %	4.5	6.1	5.6	4.9	6.7	0.020
Men, No.	4105	4078	4292	4819	5072	
30-d survival, %	9.4	8.8	10.6	12.1	13.8	<0.001
1-y survival, %	7.8	7.6	9.3	10.7	12.1	<0.001
Women, No.	2215	2217	2314	2526	2653	
30-d survival, %	7.3	8.3	7.7	9.6	11.6	<0.001
1-y survival, %	5.8	6.9	6.6	7.6	9.6	<0.001

Discussion

Our population-based study, which included 34 291 patients who were transported to an acute-care hospital for treatment, extends previous knowledge in the field of OHCA. First, we found substantial changes in the baseline characteristics of OHCA patients alive at hospital arrival, where patients were increasingly more likely to have cardiovascular risk factors but less likely to have previous cardiovascular conditions. Second, although the overall incidence of OHCA patients transported to the hospital alive did not change over time, the incidence increased in the youngest age group but decreased in the oldest patients. Significant improvements in survival were observed in which patients were 50% more likely to survive to 30 days and 1 year, even after accounting for temporal changes in baseline characteristics. Finally, there were disparities in the magnitude of survival improvement across age groups, favoring younger patients.

Few studies have documented temporal changes in the clinical characteristics of OHCA patients resuscitated in the field and arriving at the hospital. From 2002 to 2011, there was a significant increase in the prevalence of diabetes mellitus, hypertension, and dyslipidemia. This pattern has also been observed in the general Canadian population and was attributed to a combination of several factors, including rising incidence of risk factors, enhanced diagnosis, and increased survivorship.[10,16–18] We also observed a decreasing prevalence of established cardiovascular diseases (ischemic heart disease, myocardial infarction, cerebrovascular disease, and peripheral vascular disease), whereas the overall demographics and noncardiac comorbidities among OHCA patients who were alive at hospital arrival did not change significantly over time. The decrease in cardiovascular disease in the general population has been explained by improved primary and secondary prevention in the general population. The implications of the changing trends in clinical characteristics and OHCA survival are unclear. Additional work is needed to fully delineate the connection between individual risk factors and specific cardiovascular conditions with cardiac arrest outcomes.

The incidence of OHCA patients transported to the hospital alive is sensitive to multiple factors, including the actual incidence of disease, early recognition of cardiac arrest, and the success of prehospital treatment. Nonetheless, it is interesting to note that trends in the incidence of OHCA observed in our study mirror the overall incidence of cardiovascular disease in Canada, with an increasing trend among younger patients and a decreasing trend among older patients.[19] It has been hypothesized that the modest increase in cardiovascular incidence in the young is attributed to an increasing burden of diabetes mellitus, hypertension, and obesity. In contrast, the lowering incidence among older patients has been attributed predominantly to the increased use of evidence-based medical therapy for primary and secondary prevention.[17,19]

The improving survival trends in our study are consistent with observations from countries that have nationally coordinated systems to manage or improve the care of out-of-hospital emergencies, and many factors are likely responsible for the improving trend of OHCA survival. Improvements in bystander cardiopulmonary resuscitation rates, early response

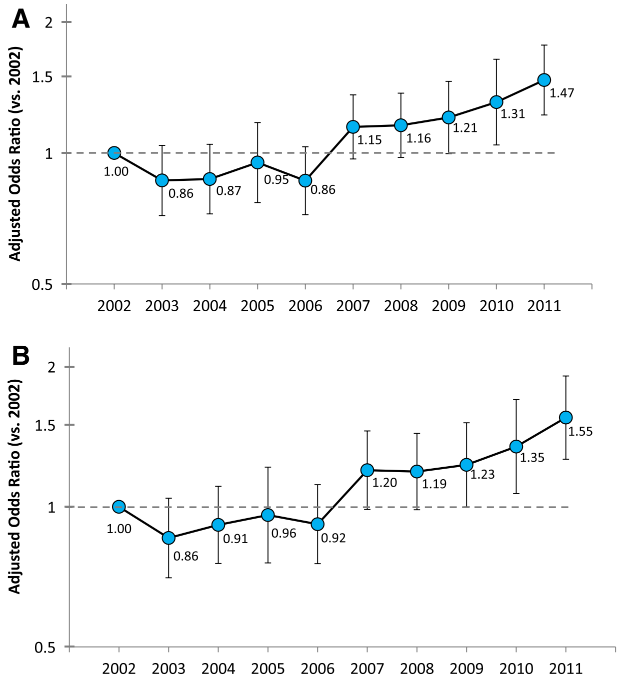

Figure 2. Adjusted odds ratio for 30-day and 1-year survival. The adjusted odds ratios of out-of-hospital cardiac arrest (OHCA) patients who were transported to hospital alive at (**A**) 30 days and (**B**) 1 year are shown. The reference year was fiscal year 2002. Models were adjusted for age, income quintile, rural location, diabetes mellitus, hypertension, dyslipidemia, chronic atherosclerosis, ischemic heart disease, myocardial infarction, heart failure, cerebrovascular disease, unstable angina, peripheral vascular disease, arrhythmias, renal disease, chronic lung disease, cancer, and Charlson-Deyo comorbidity score. Adjusted odds ratios (*y* axis in log scale) were plotted against year of event (*x* axis). I bars represent 95% CIs.

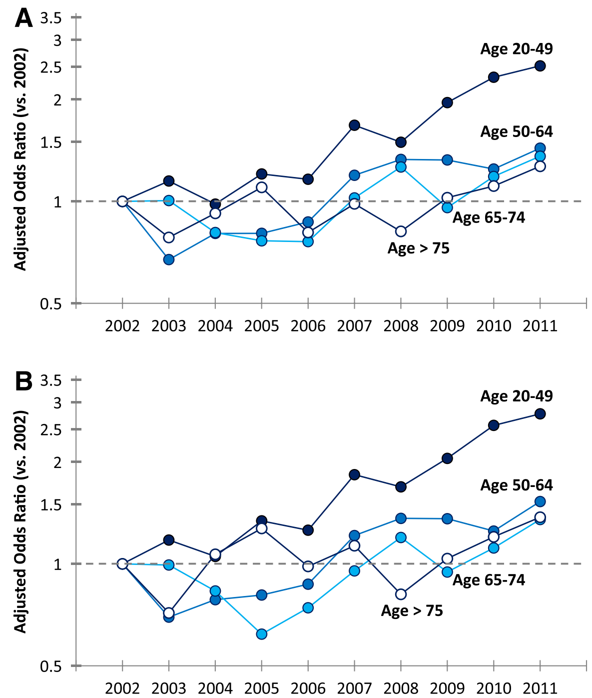

Figure 3. Adjusted odds ratios for 30-day and 1-year survival by age groups. The adjusted odds ratios of out-of-hospital cardiac arrest (OHCA) patients who were transported to hospital alive at (**A**) 30 days and (**B**) 1 year are shown. Patients aged 20-49 years are represented in dark blue, aged 50-64 years in blue, aged 65-74 years in light blue, aged ≥75 in white. The reference year was fiscal year 2002. The same variables for adjustment were used as described in Figure 1.

time by emergency medical services, and access to an automated external defibrillator have all been demonstrated to be associated with improvement in survival.[4–6] In addition, recent evidence and practice guidelines emphasized the importance of single defibrillation shocks and high-quality cardiopulmonary resuscitation.[20–23] On the other hand, we did not find a consistent trend in the rates of shockable and nonshockable rhythm in OHCA patients in the Epistry data, suggesting that changes in initial presenting rhythm were not a main determinant of survival improvement. We also observed a substantial increase in the use of TTM after OHCA that corresponded with the timeframe when survival improvement was occurring. Although the optimal use of TTM in OHCA patients remains controversial,[24,25] its use may also be a marker of improved overall postarrest in-hospital care and management for OHCA patients. Before cardiac arrest, we also observed a significant increase in the use of evidence-based cardiac medications, including statins and β-blockers. In the setting of myocardial infarction, these medications have been shown to reduce the severity of infarction and reduce the risk of subsequent cardiac events.[26] Future studies are warranted to evaluate whether the increased use of these medications is associated with improved survival after OHCA.

Although improvement in survival was similar among men and women, discrepancies were observed by age group, in which the largest improvement was seen in younger patients. Potential explanations include differences in treatment aggressiveness and effectiveness across age groups and greater physiological reserve to tolerate periods of hypoperfusion among younger patients. Given that the majority of OHCAs occur in older patients, additional efforts are needed to identify reasons underlying these discrepancies.

Several potential limitations of our study warrant discussion. First, our cohort only included OHCA patients who survived to the destination hospital. Based on the Epistry data and the existing literature, we estimated that >13 000 patients with OHCA are assessed and ≈8000 patients are treated annually in Ontario by emergency medical service personnel.[2] More than 40% of those treated died on scene or en route to the hospital. Although our study cohort only represented ≈25% of the OHCA patients assessed in the province, the majority of untreated OHCA patients are composed of patients with a clear evidence of death (rigor mortis), compelling reasons that treatment would be considered futile (eg, a do-not-resuscitate directive or terminal illness), or lack of response to full resuscitative measures. Most of these patients are unlikely to receive benefit from more aggressive prehospital and in-hospital treatment.[27] In addition, gradual implementation of termination of resuscitation rules in communities across Ontario occurred during our study period. For example, the proportion of patients who died on arrival decreased substantially from 24.2% to 6.2% from 2002 to 2011. Therefore, exclusion of these patients was needed to avoid overestimation of survival improvement in OHCA patients. Second, we were unable to disentangle the proportion of patients who died because of cardiac-related trauma versus those who died because of major trauma. Previous studies have demonstrated that cardiac conditions only account for 0.19% to 0.33% of road-related trauma and are therefore unlikely to impact our study finding.[28,29] Third, although the use of administrative data sources in Ontario have been well validated for myocardial infarction, heart failure, and cardiac procedures, no previous studies have evaluated the validity of these data for OHCA. In addition, these data sources do not include clinical information regarding prehospital evaluation and treatment. Accordingly, we performed a series of validation analyses using data from the Toronto Epistry data set, showing that our algorithm performed reasonably well against research-quality clinical data, even when additional variables known to affect survival, such as rhythm and bystander cardiopulmonary resuscitation, were included. Furthermore, misclassification errors should not change over time, because we applied the same codes over the entire study period, allowing for reliable interpretation of the temporal trends found in our study. Our data source did not include medication information on patients <65 years of age and did not include information on neurologic and functional status or discharge destination of patients. We were, therefore, unable to analyze trends in functional recovery or explore the potential impact of medical therapy in younger patients. In addition, our data were limited to Ontario. However, previous studies have shown similar patient characteristics and outcomes for cardiac patients comparing Ontario and the United States, suggesting that our findings should be applicable other regions.[30]

In conclusion, OHCA patients transported to the hospital alive are increasingly more likely to have cardiovascular risk factors but less likely to have previous cardiovascular conditions. Although the overall incidence of this group did not change over the past decade, short- and longer-term survival after OHCA has improved substantially, with the strongest improvement in younger patients.

Acknowledgments

We acknowledge the hard work and dedication of all of the emergency medical services and fire agencies participating in the Resuscitation Outcomes Consortium studies at the Toronto site. Research in the prehospital setting would not have been possible without the tireless efforts of their paramedics and firefighters. Special thanks to the prehospital and in-hospital data guardians and research coordinators at each of the participating destination hospitals for their diligence and patience in abstracting the additional data required to contribute to Toronto Epistry.

Sources of Funding

This study was funded by an operating grant from the Canadian Institute of Heath Research and by research funding from the Sunnybrook Health Sciences Center Department of Medicine and the Sunnybrook Research Institute. This study was supported by the Institute for Clinical Evaluative Sciences, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care. Dr Tu is supported by a Canada Research Chair in Health Services Research and a Career Investigator Award from the Heart and Stroke Foundation of Ontario. Dr Wijeysundera is supported by a Distinguished Clinical Scientist Award from the Heart and Stroke Foundation of Canada. Dr Austin is supported by a Career Investigator Award from the Heart and Stroke Foundation. Dr Ko is supported by a Clinician Scientist Award from the Heart and Stroke Foundation of Ontario. Dr Scales is supported by a Fellowship in Translational Health Research from the Physicians' Services Incorporated Foundation. Dr Morrison is supported by the Robert and Dorothy Pitts Chair in Acute Care and Emergency Medicine, Li Ka Shing Knowledge Institute, St Michael's Hospital, and support from the National Institutes of Health Resuscitation Outcome Consortium grant. The Toronto Epistry study was supported by a series of cooperative agreements to 9 regional clinical centers and 1 data coordinating center (5U01 HL077863-University of Washington Data Coordinating Center, HL077866-Medical College of Wisconsin, HL077867-University of Washington, HL077871-University of Pittsburgh, HL077872-St Michael's Hospital, HL077873-Oregon Health and Science University, HL077881-University of Alabama at Birmingham, HL077885-Ottawa Hospital Research Institute, HL077887-University of Texas Southwest Medical Center/Dallas, and HL077908-University of California San Diego) from the National Heart, Lung, and Blood Institute in partnership with the National Institute of Neurological Disorders and Stroke, US Army Medical Research and Material Command, The Canadian Institutes of Health Research–Institute of Circulatory and Respiratory Health, Defence Research and Development Canada, Heart and Stroke Foundation of Canada, and the American Heart Association. This study was conducted independent of the funding or participating organizations. No endorsement by any organizations is intended or should be inferred.

Disclosures

Dr Cheskes has received honorarium from Zoll Medical for academic and educational speaking. The other authors report no conflicts.

References

1. Go AS, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Borden WB, Bravata DM, Dai S, Ford ES, Fox CS, Franco S, Fullerton HJ, Gillespie C, Hailpern SM, Heit JA, Howard VJ, Huffman MD, Kissela BM, Kittner SJ, Lackland DT, Lichtman JH, Lisabeth LD, Magid D, Marcus GM, Marelli A, Matchar DB, McGuire DK, Mohler ER, Moy CS, Mussolino ME, Nichol G, Paynter NP, Schreiner PJ, Sorlie PD, Stein J, Turan TN, Virani SS, Wong ND, Woo D, Turner MB; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics: 2013 update–a report from the American Heart Association. *Circulation*. 2013;127:e6–e245.
2. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, Rea T, Lowe R, Brown T, Dreyer J, Davis D, Idris A, Stiell I; Resuscitation Outcomes Consortium Investigators. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA*. 2008;300:1423–1431.
3. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes*. 2010;3:63–81.
4. Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, Jans H, Hansen PA, Lang-Jensen T, Olesen JB, Lindhardsen J, Fosbol EL, Nielsen SL, Gislason GH, Kober L, Torp-Pedersen C. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. *JAMA*. 2013;310:1377–1384.
5. Hollenberg J, Herlitz J, Lindqvist J, Riva G, Bohm K, Rosenqvist M, Svensson L. Improved survival after out-of-hospital cardiac arrest is associated with an increase in proportion of emergency crew: witnessed cases and bystander cardiopulmonary resuscitation. *Circulation*. 2008;118:389–396.
6. Kitamura T, Iwami T, Kawamura T, Nitta M, Nagao K, Nonogi H, Yonemoto N, Kimura T; Japanese Circulation Society Resuscitation Science Study Group. Nationwide improvements in survival from out-of-hospital cardiac arrest in Japan. *Circulation*. 2012;126:2834–2843.
7. Ro YS, Shin SD, Song KJ, Lee EJ, Kim JY, Ahn KO, Chung SP, Kim YT, Hong SO, Choi JA, Hwang SO, Oh DJ, Park CB, Suh GJ, Cho SI, Hwang SS. A trend in epidemiology and outcomes of out-of-hospital cardiac arrest by urbanization level: a nationwide observational study from 2006 to 2010 in South Korea. *Resuscitation*. 2013;84:547–557.
8. Ontario Ministry of Health and Long-Term Care. *Emergency Health Services Branch*. http://www.health.gov.on.ca/english/public%5Cprogram/ehs/ehs_mn.html. Accessed April 1, 2014.

9. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario: determination of prevalence and incidence using a validated administrative data algorithm. *Diabetes Care*. 2002;25:512–516.
10. Tu K, Campbell NR, Chen ZL, Cauch-Dudek KJ, McAlister FA. Accuracy of administrative databases in identifying patients with hypertension. *Open Med*. 2007;1:e18–e26.
11. Czarnecki A, Chong A, Lee DS, Schull MJ, Tu JV, Lau C, Farkouh ME, Ko DT. Association between physician follow-up and outcomes of care after chest pain assessment in high-risk patients. *Circulation*. 2013;127:1386–1394.
12. Juurlink DN, Mamdani MM, Lee DS, Kopp A, Austin PC, Laupacis A, Redelmeier DA. Rates of hyperkalemia after publication of the Randomized Aldactone Evaluation Study. *N Engl J Med*. 2004;351:543–551.
13. Drye EE, Normand SL, Wang Y, Ross JS, Schreiner GC, Han L, Rapp M, Krumholz HM. Comparison of hospital risk-standardized mortality rates calculated by using in-hospital and 30-day models: an observational study with implications for hospital profiling. *Ann Intern Med*. 2012;156(1 pt 1):19–26.
14. Liang K, Zeger S. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*. 1986;42:121–130.
15. Morrison LJ, Nichol G, Rea TD, Christenson J, Callaway CW, Stephens S, Pirrallo RG, Atkins DL, Davis DP, Idris AH, Newgard C; ROC Investigators. Rationale, development and implementation of the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Resuscitation*. 2008;78:161–169.
16. Lipscombe LL, Hux JE. Trends in diabetes prevalence, incidence, and mortality in Ontario, Canada 1995-2005: a population-based study. *Lancet*. 2007;369:750–756.
17. Lee DS, Chiu M, Manuel DG, Tu K, Wang X, Austin PC, Mattern MY, Mitiku TF, Svenson LW, Putnam W, Flanagan WM, Tu JV; Canadian Cardiovascular Outcomes Research Team. Trends in risk factors for cardiovascular disease in Canada: temporal, socio-demographic and geographic factors. *CMAJ*. 2009;181:E55–E66.
18. Robitaille C, Dai S, Waters C, Loukine L, Bancej C, Quach S, Ellison J, Campbell N, Tu K, Reimer K, Walker R, Smith M, Blais C, Quan H. Diagnosed hypertension in Canada: incidence, prevalence and associated mortality. *CMAJ*. 2012;184:E49–E56.
19. Tu JV, Nardi L, Fang J, Liu J, Khalid L, Johansen H; Canadian Cardiovascular Outcomes Research Team. National trends in rates of death and hospital admissions related to acute myocardial infarction, heart failure and stroke, 1994-2004. *CMAJ*. 2009;180:E118–E125.
20. Field JM, Hazinski MF, Sayre MR, Chameides L, Schexnayder SM, Hemphill R, Samson RA, Kattwinkel J, Berg RA, Bhanji F, Cave DM, Jauch EC, Kudenchuk PJ, Neumar RW, Peberdy MA, Perlman JM, Sinz E, Travers AH, Berg MD, Billi JE, Eigel B, Hickey RW, Kleinman ME, Link MS, Morrison LJ, O'Connor RE, Shuster M, Callaway CW, Cucchiara B, Ferguson JD, Rea TD, Vanden Hoek TL. Part 1: executive summary–2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122(18 suppl 3):S640–S656.
21. Cheskes S, Schmicker RH, Christenson J, Salcido DD, Rea T, Powell J, Edelson DP, Sell R, May S, Menegazzi JJ, Van Ottingham L, Olsufka M, Pennington S, Simonini J, Berg RA, Stiell I, Idris A, Bigham B, Morrison L; Resuscitation Outcomes Consortium (ROC) Investigators. Perishock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest. *Circulation*. 2011;124:58–66.
22. Idris AH, Guffey D, Aufderheide TP, Brown S, Morrison LJ, Nichols P, Powell J, Daya M, Bigham BL, Atkins DL, Berg R, Davis D, Stiell I, Sopko G, Nichol G; Resuscitation Outcomes Consortium (ROC) Investigators. Relationship between chest compression rates and outcomes from cardiac arrest. *Circulation*. 2012;125:3004–3012.
23. Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, Bigham B, Morrison LJ, Larsen J, Hess E, Vaillancourt C, Davis DP, Callaway CW; Resuscitation Outcomes Consortium (ROC) Investigators. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? *Crit Care Med*. 2012;40:1192–1198.
24. Dumas F, Grimaldi D, Zuber B, Fichet J, Charpentier J, Pène F, Vivien B, Varenne O, Carli P, Jouven X, Empana JP, Cariou A. Is hypothermia after cardiac arrest effective in both shockable and nonshockable patients? Insights from a large registry. *Circulation*. 2011;123:877–886.
25. Nielsen N, Wetterslev J, Cronberg T, Erlinge D, Gasche Y, Hassager C, Horn J, Hovdenes J, Kjaergaard J, Kuiper M, Pellis T, Stammet P, Wanscher M, Wise MP, Åneman A, Al-Subaie N, Boesgaard S, Bro-Jeppesen J, Brunetti I, Bugge JF, Hingston CD, Juffermans NP, Koopmans M, Køber L, Langørgen J, Lilja G, Møller JE, Rundgren M, Rylander C, Smid O, Werer C, Winkel P, Friberg H; TTM Trial Investigators. Targeted temperature management at 33°C versus 36°C after cardiac arrest. *N Engl J Med*. 2013;369:2197–2206.
26. Taylor F, Huffman MD, Macedo AF, Moore TH, Burke M, Davey Smith G, Ward K, Ebrahim S. Statins for the primary prevention of cardiovascular disease. *Cochrane Database Syst Rev*. 2013;(1):CD004816.
27. Morrison LJ, Verbeek PR, Vermeulen MJ, Kiss A, Allan KS, Nesbitt L, Stiell I. Derivation and evaluation of a termination of resuscitation clinical prediction rule for advanced life support providers. *Resuscitation*. 2007;74:266–275.
28. Christian MS. Incidence and implications of natural deaths of road users. *BMJ*. 1988;297:1021–1024.
29. Büttner A, Heimpel M, Eisenmenger W. Sudden natural death 'at the wheel': a retrospective study over a 15-year time period (1982-1996). *Forensic Sci Int*. 1999;103:101–112.
30. Ko DT, Tu JV, Austin PC, Wijeysundera HC, Samadashvili Z, Guo H, Cantor WJ, Hannan EL. Prevalence and extent of obstructive coronary artery disease among patients undergoing elective coronary catheterization in New York State and Ontario. *JAMA*. 2013;310:163–169.

CLINICAL PERSPECTIVE

Out-of-hospital cardiac arrest (OHCA) is associated with a poor prognosis and poses a significant burden to the healthcare system. However, few studies have evaluated whether OHCA incidence and survival have changed over time. We performed an observational study using a population-based cohort study including 34 291 OHCA patients who were transported alive to an acute-care hospital from 2002 to 2012 in Ontario. Over this time period, OHCA patients were increasingly more likely to have cardiovascular risk factors but less likely to have previous cardiovascular conditions. The overall incidence of OHCA patients transported to the hospital alive did not change over the past decade. Short- and longer-term survival after OHCA has substantially improved, with younger patients experiencing the greatest improvement.

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