SPECIAL ARTICLE

Delays in Emergency Care and Mortality during Major U.S. Marathons

Anupam B. Jena, M.D., Ph.D., N. Clay Mann, Ph.D., Leia N. Wedlund, and Andrew Olenski, B.S.

ABSTRACT

BACKGROUND
Large marathons frequently involve widespread road closures and infrastructure disruptions, which may create delays in emergency care for nonparticipants with acute medical conditions who live in proximity to marathon routes.

METHODS
We analyzed Medicare data on hospitalizations for acute myocardial infarction or cardiac arrest among Medicare beneficiaries (≥65 years of age) in 11 U.S. cities that were hosting major marathons during the period from 2002 through 2012 and compared 30-day mortality among the beneficiaries who were hospitalized on the date of a marathon, those who were hospitalized on the same day of the week as the day of the marathon in the 5 weeks before or the 5 weeks after the marathon, and those who were hospitalized on the same day as the marathon but in surrounding ZIP Code areas unaffected by the marathon. We also analyzed data from a national registry of ambulance transports and investigated whether ambulance transports occurring before noon in marathon-affected areas (when road closures are likely) had longer scene-to-hospital transport times than on nonmarathon dates. We also compared transport times on marathon dates with those on nonmarathon dates in these same areas during evenings (when roads were reopened) and in areas unaffected by the marathon.

RESULTS
The daily frequency of hospitalizations was similar on marathon and nonmarathon dates (mean number of hospitalizations per city, 10.6 and 10.5, respectively; P=0.71); the characteristics of the beneficiaries hospitalized on marathon and nonmarathon dates were also similar. Unadjusted 30-day mortality in marathon-affected areas on marathon dates was 28.2% (323 deaths in 1145 hospitalizations) as compared with 24.9% (2757 deaths in 11,074 hospitalizations) on nonmarathon dates (absolute risk difference, 3.3 percentage points; 95% confidence interval, 0.7 to 6.0; P=0.01; relative risk difference, 13.3%). This pattern persisted after adjustment for covariates and in an analysis that included beneficiaries who had five or more chronic medical conditions (a group that is unlikely to be hospitalized because of marathon participation). No significant differences were found with respect to where patients were hospitalized or the treatments they received in the hospital. Ambulance scene-to-hospital transport times for pickups before noon were 4.4 minutes longer on marathon dates than on nonmarathon dates (relative difference, 32.1%; P=0.005). No delays were found in evenings or in marathon-unaffected areas.

CONCLUSIONS
Medicare beneficiaries who were admitted to marathon-affected hospitals with acute myocardial infarction or cardiac arrest on marathon dates had longer ambulance transport times before noon (4.4 minutes longer) and higher 30-day mortality than beneficiaries who were hospitalized on nonmarathon dates. (Funded by the National Institutes of Health.)

From the Department of Health Care Policy, Harvard Medical School (A.B.J., A.O.), and Massachusetts General Hospital (A.B.J.) — both in Boston, and the National Bureau of Economic Research (A.B.J.) and Harvard University (L.N.W.), Cambridge – all in Massachusetts; and the Department of Pediatrics, University of Utah School of Medicine, and the National EMS Information System Technical Assistance Center — both in Salt Lake City (N.C.M.). Address reprint requests to Dr. Jena at the Department of Health Care Policy, Harvard Medical School, 180 Longwood Ave., Boston, MA 02115, or at jena@hcp.med.harvard.edu.

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Preparation for large public events frequently involves road closures, an increase in emergency medical services, and interventions to ensure participant safety. In some instances, such as marathons, these changes may have unintended health consequences for nonparticipants. For example, widespread road closures and diversion of emergency medical services that occur during marathons may result in delays in care for persons with medical emergencies in areas affected by the marathon. Although studies have examined the effect of sporting events on emotional stress and acute cardiovascular events[1-4] and on running-related mortality among marathon participants,[5,6] data are lacking on whether large infrastructure disruptions during marathons adversely affect nonmarathon participants who require medical care. Many studies have documented the adverse effects that delays in care have on mortality across various settings and conditions[7-13]; these findings suggest that widespread road closures and infrastructure disruptions during marathons could adversely affect health outcomes in nonparticipants.

We compared 30-day mortality among Medicare beneficiaries with acute myocardial infarction or cardiac arrest who were hospitalized on the day of a major marathon, those who were hospitalized on the same day of the week as the day of the marathon in the 5 weeks before or the 5 weeks after the marathon, and those who were hospitalized on the same day as the marathon but in surrounding ZIP Code areas unaffected by the marathon. We investigated whether marathons were associated with changes in hospital destination, hospital care, and admission volume and used data on ambulance arrival and transport times from a nationwide registry to examine whether marathons were associated with increased scene-to-hospital transport time and delays in patients seeking care.

We sought to determine whether marathons are associated with higher mortality because of infrastructure changes that result in delays in care rather than because of race participation. We therefore focused on persons who had a relatively low likelihood of marathon participation (i.e., Medicare beneficiaries ≥65 years of age who were hospitalized for acute myocardial infarction or cardiac arrest). Many Medicare beneficiaries who are hospitalized with these nonelective conditions are of advanced age and have multiple coexisting medical conditions (Table 1).

METHODS

MARATHONS AND STUDY POPULATION

We identified the dates of the 11 largest U.S. urban marathons (according to the number of runners) during the period from 2002 through 2012; the 11 cities were Boston, Chicago, Honolulu, Houston, Los Angeles, Minneapolis, New York City, Orlando (Florida), Philadelphia, Seattle, and Washington, D.C.

PRIMARY OUTCOME MEASURE AND DATA SOURCES

Our primary outcome was 30-day mortality after admission. We used several data sources. Medicare Provider Analysis and Review (MedPAR) 100% files, which contain information on all fee-for-service Medicare beneficiaries using hospital inpatient services, were used to identify hospitalizations for acute myocardial infarction (*International Classification of Diseases, Ninth Revision* [ICD-9] code 410.X1) or cardiac arrest (ICD-9 code 427.5) among Medicare fee-for-service beneficiaries (≥65 years of age) between January 1, 2002, and November 30, 2012. Dates of death and demographic characteristics of the beneficiaries were obtained from Medicare Beneficiary Summary files. Information on chronic medical conditions of the beneficiaries was obtained from the Chronic Conditions Data Warehouse of the Centers for Medicare and Medicaid Services.

In addition to these data, we matched the Medicare carrier file (20% sample) to the MedPAR file using the beneficiary identification number and claim date. Unlike MedPAR files, carrier files include claims for ambulance rides, which allowed us to identify whether a patient was brought to the hospital by ambulance and, if so, the miles driven. Ambulance rides were identified according to Healthcare Common Procedure Coding System code A0425. This 20% matched sample was used only for the analysis of miles driven by the ambulance on marathon dates versus nonmarathon dates.

Finally, to estimate ambulance travel times on marathon dates, we used the National Emergency Medical Services Information System (NEMSIS),[14] a national repository of emergency medical services activations. NEMSIS includes ambulance travel times, pickup times, incident and destination locations, and patient characteristics. We

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Table 1. Characteristics of Patients Admitted to Marathon-Affected Hospitals with Acute Myocardial Infarction or Cardiac Arrest in Cities during Major Marathons.*

Characteristic	Premarathon Dates (N=5607)	Marathon Dates (N=1145)	Postmarathon Dates (N=5467)	P Value†
Mean age — yr	76.7	76.3	76.7	0.54
Female sex — %	51.0	49.3	49.2	0.14
White race — %‡	67.9	66.0	69.0	0.11
Medicaid eligibility — %	40.0	38.6	37.3	0.06
Median household yearly income in ZIP Code area — $	60,091	59,532	60,776	0.20
Preexisting medical conditions — %§				
Alzheimer's disease	23.2	20.2	23.0	0.08
Atrial fibrillation	20.5	18.5	18.9	0.06
Chronic kidney disease	37.5	38.3	35.7	0.07
Chronic obstructive pulmonary disease	32.7	31.9	33.7	0.34
Diabetes	50.7	51.8	50.2	0.60
Congestive heart failure	58.9	57.9	59.0	0.76
Hyperlipidemia	66.0	67.1	65.8	0.70
Hypertension	80.8	81.1	80.2	0.65
Stroke or transient ischemic attack	24.3	23.4	23.9	0.73
Cancer	14.6	15.6	15.2	0.56

* Hospitals located in ZIP Code areas through which the marathon route passed were defined as marathon-affected hospitals. Control hospitals were defined as all hospitals in the hospital referral regions that surrounded the hospital referral region in which a marathon-affected hospital was located.
† P values were estimated with the use of two-sample Student's t-tests or chi-square tests for equality of proportions, as appropriate.
‡ Race was determined according to the Medicare Beneficiary Summary file.
§ Information on preexisting medical conditions in the beneficiaries was obtained from the Chronic Conditions Data Warehouse of the Centers for Medicare and Medicaid Services.

analyzed data submitted by participating agencies in the cities we studied during 2012. The outcome of interest was elapsed travel time from scene departure to hospital arrival on a marathon date versus the same day of the week as the day of the marathon in the 5 weeks before and the 5 weeks after the marathon. We also analyzed the time of scene departure on marathon dates versus nonmarathon dates to assess delays in ambulance arrival at the scene or in patients seeking care. To ensure that we captured transports of nonrunners and to approximate characteristics of Medicare beneficiaries hospitalized for acute myocardial infarction or cardiac arrest, we restricted our NEMSIS analysis to transports involving patients 70 years of age or older (a sensitivity analysis is provided in the Supplementary Appendix, available with the full text of this article at NEJM.org). Because of confidentiality requirements, we were not provided with geographic data.

CLASSIFICATION OF HOSPITALS AND DATES OF HOSPITALIZATIONS

We identified areas within the marathon routes according to ZIP Code. For marathons that spanned areas outside city limits, we included as part of the marathon-affected area the towns that the marathon passed through. For instance, the Boston marathon passes through suburban towns such as Newton and Brookline, and so these additional ZIP Codes were included in the marathon-affected area. Hospitals located in ZIP Code areas through which the marathon route passed were defined as marathon-affected hospitals. We identified a control set of ZIP Codes that included all ZIP Code areas in the hospital referral regions that neighbored the hospital referral re-

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gion in which the marathon took place.[15] We defined control hospitals as all hospitals located in these surrounding hospital referral regions.

We compared 30-day mortality among patients admitted to marathon-affected hospitals on a marathon date with 30-day mortality among patients admitted to the same hospitals on the same day of week as the day of the marathon in the 5 weeks before and after the marathon. For instance, our control dates for Boston's 2012 marathon, which occurred on Monday, April 16, included the five Mondays before and the five Mondays after that date. Dates of hospitalizations were classified as "marathon" or "nonmarathon" according to the admission date relative to the marathon date. Overall, 121 marathon dates (11 cities over 11 years) and 1210 nonmarathon dates were analyzed.

MORTALITY ANALYSIS

We assessed whether patient characteristics (e.g., age, sex, race, and preexisting chronic medical conditions) were balanced among Medicare beneficiaries admitted to marathon-affected hospitals on marathon dates versus nonmarathon dates. We then plotted unadjusted 30-day mortality according to the week relative to the marathon date among the beneficiaries hospitalized in marathon-affected hospitals versus control hospitals (control hospitals were included to assess for regional trends in mortality that may be correlated with marathon dates). Because unmeasured patient characteristics that are correlated with mortality may vary between marathon dates and nonmarathon dates, we used a hospitalization-level multivariable logistic model to estimate the 30-day mortality among the beneficiaries hospitalized in marathon-affected hospitals as a function of hospital admission date (marathon date vs. nonmarathon date); the sex, age, or race of the patient; any one of 10 preexisting chronic medical conditions; the median household income in the ZIP Code area; the interaction between city and marathon day (to allow marathon effects to vary across cities); and the fixed effects for hospital. The fixed effects for hospital accounted for differences in mortality among beneficiaries hospitalized on marathon dates versus nonmarathon dates that may be mediated by patients being admitted to different hospitals. Our estimates therefore compared mortality on marathon dates versus nonmarathon dates among beneficiaries admitted to the same hospital. We report adjusted 30-day mortality among beneficiaries admitted to marathon-affected hospitals on marathon dates versus nonmarathon dates using the marginal standardization form of predictive margins averaged over the distribution of covariates in our sample.[16,17] Using an identical model, we estimated the 30-day mortality among beneficiaries admitted to control hospitals, hypothesizing that the higher 30-day mortality among beneficiaries admitted to marathon-affected hospitals on marathon dates should not be observed in these hospitals. Both models used robust variance estimators to account for clustering of admissions within hospitals. The 95% confidence interval around the reported estimates reflects an alpha level of 0.025 in each tail (or $P \leq 0.05$).

SENSITIVITY ANALYSES

We conducted several sensitivity analyses. First, to ensure that we did not analyze hospitalizations that occurred as a result of participation in the marathon, we conducted a subgroup analysis that included only beneficiaries with five or more chronic medical conditions (the median number of conditions in our population); this group was unlikely to include marathon runners. We also performed an automated query of local newspapers to identify potential instances of deaths among marathon runners. Second, in a permutation test, we simulated how the observed difference in mortality among beneficiaries hospitalized on marathon dates versus nonmarathon dates compared with the difference that might be expected from chance alone, as calculated by assigning marathon-affected hospitals to "placebo" marathon dates chosen randomly throughout the year and then estimating the difference in unadjusted mortality among the beneficiaries hospitalized on the placebo marathon dates versus nonmarathon dates (1000 replications were performed). Additional analyses included alternative mortality end points, estimation of a hierarchical mortality model, inclusion of additional marathons, and an expanded definition of marathon-affected areas to address potential misclassification. (Further details on the automated query of local newspapers and additional analyses are provided in the Supplementary Appendix.)

ANALYSIS OF POTENTIAL CAUSES

We assessed several potential causes to explain differences in mortality among beneficiaries hospitalized on marathon dates versus nonmarathon

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dates. An influx of spectators into marathon-affected areas could lead to increases in the rate of acute myocardial infarction or cardiac arrest among visitors hospitalized on marathon dates, which could raise mortality if hospital resources are stretched. Alternatively, if patients delay seeking care during marathons, those hospitalized may have a higher unobserved risk of death. We assessed these possibilities by analyzing whether the number of hospitalizations for acute myocardial infarction or cardiac arrest varied across dates. Similarly, we used NEMSIS files to analyze whether the distribution of ambulance departure times varied between marathon and nonmarathon dates; delays in patients seeking care would be expected to shift the distribution of ambulance departure times to later in the day.

Second, we analyzed whether hospital care differed between marathon and nonmarathon dates, which may occur if hospitals are relatively short-staffed during marathons. We analyzed rates of percutaneous coronary intervention, mechanical circulatory support (defined as intraaortic balloon counterpulsation or insertion of a percutaneous ventricular assist device), and coronary-artery bypass grafting (procedure codes are provided in the Supplementary Appendix).

Third, we analyzed whether the distribution of hospitals providing care changed during marathons as a result of road closures that prompted diversions of ambulances or private vehicles. We computed each hospital's share of total acute myocardial infarction or cardiac arrest hospitalizations on marathon dates and nonmarathon dates and used a Spearman correlation analysis to assess the correlation between these shares. A high correlation would imply that patients were not admitted to different hospitals on marathon dates than on nonmarathon dates.

Fourth, we analyzed whether the out-of-town composition of hospitalized patients changed during marathons, which could have led to higher mortality on marathon dates if unobserved risks of mortality were higher among patients residing outside marathon-affected ZIP Code areas. We compared distributions of ZIP Code of residence among the beneficiaries hospitalized in marathon-affected hospitals on marathon dates with those on nonmarathon dates. We also conducted a subgroup analysis of mortality that included only beneficiaries who lived in marathon-affected ZIP Code areas.

Fifth, we assessed whether scene-to-hospital ambulance travel was delayed on marathon dates. First, we used the 20% carrier files to compare the mean miles driven by ambulances on marathon dates versus nonmarathon dates. Next, because miles were reported in integers and road closures may lead to delays without increases in miles, we used NEMSIS files to compare scene-to-hospital transport time on marathon dates with that on nonmarathon dates, during mornings (defined as the period from 3 a.m. through noon), when roads should be closed, and evenings (defined as the period from 7 p.m. through 11:59 p.m.), when roads should be reopened. Finally, because delays in the care of acute myocardial infarction can lead to cardiac arrest, we used MedPAR files to estimate the probability of a diagnosis of concurrent cardiac arrest among patients with acute myocardial infarction on marathon and nonmarathon dates; we hypothesized that a greater proportion of admissions for acute myocardial infarction with concurrent cardiac arrest on marathon dates could indicate delayed care.

RESULTS

PATIENT CHARACTERISTICS

Our study included 1145 hospitalizations for acute myocardial infarction or cardiac arrest in marathon-affected hospitals on marathon dates and 11,074 hospitalizations on nonmarathon dates in the 5 weeks before and the 5 weeks after the marathon. The daily frequency of hospitalizations did not differ significantly between marathon dates and nonmarathon dates (mean number of hospitalizations per city, 10.6 and 10.5, respectively; $P=0.71$) (Table S1 in the Supplementary Appendix). Patient characteristics of age, sex, race, and preexisting medical conditions were clinically and statistically similar on premarathon, marathon, and postmarathon dates (Table 1).

30-DAY MORTALITY ON MARATHON AND NONMARATHON DATES

Unadjusted 30-day mortality was higher among beneficiaries admitted to marathon-affected hospitals on marathon dates than among beneficiaries admitted on nonmarathon dates, but this was not the case among beneficiaries admitted to control hospitals (Fig. 1). Among beneficiaries admitted to marathon-affected hospitals, unadjusted 30-day mortality was 28.2% (323 deaths

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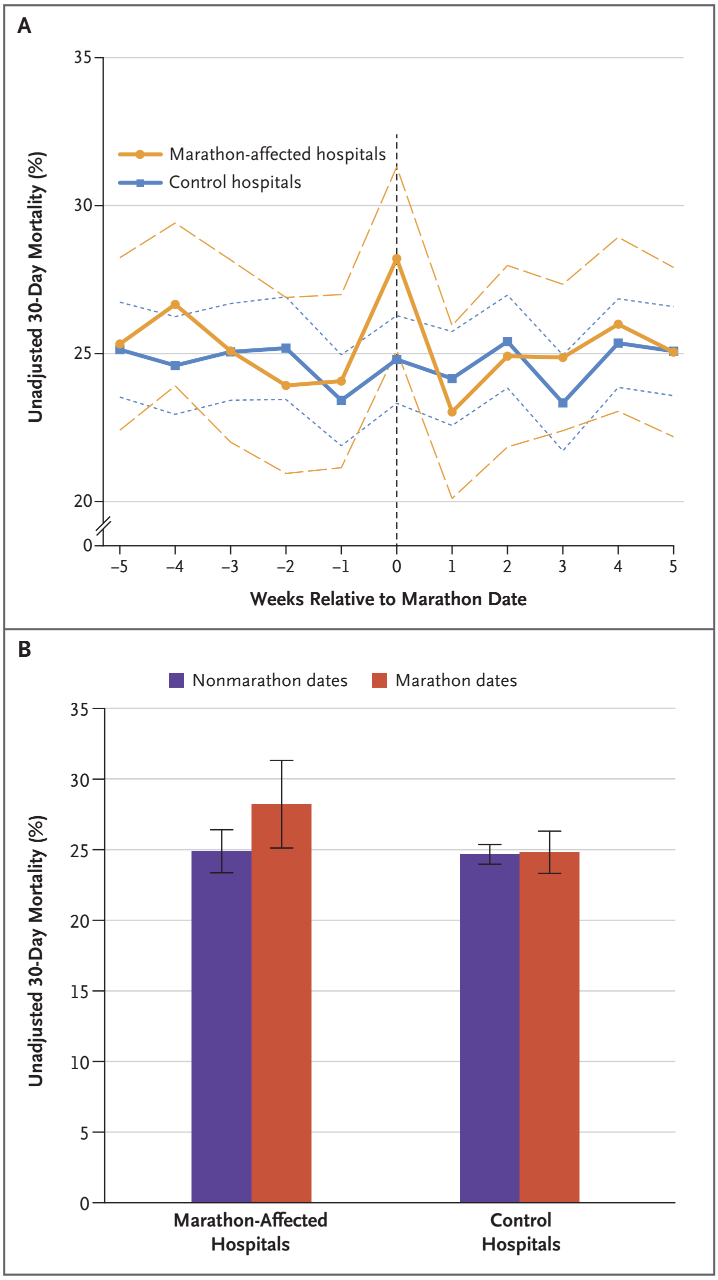

Figure 1. Unadjusted 30-Day Mortality among Medicare Beneficiaries Hospitalized for Acute Myocardial Infarction or Cardiac Arrest on Marathon Dates and Nonmarathon Dates in Marathon-Affected Hospitals and Control Hospitals.

Panel A shows the unadjusted 30-day mortality according to hospitalizations on the marathon date (week 0) and in the weeks relative to the marathon date (i.e., the same day of the week as the day of the marathon in the 5 weeks before and the 5 weeks after the marathon). Hospitals located in ZIP Code areas through which the marathon route passed were defined as marathon-affected hospitals. Control hospitals were defined as all hospitals in the hospital referral regions that surrounded the hospital referral region in which a marathon-affected hospital was located. The dashed lines represent 95% confidence intervals, which account for clustering of admissions within hospitals. Panel B shows the unadjusted 30-day mortality among Medicare beneficiaries hospitalized on marathon dates and nonmarathon dates in marathon-affected hospitals and control hospitals. The I bars represent 95% confidence intervals.

in 1145 hospitalizations) on marathon dates versus 24.9% (2757 deaths in 11,074 hospitalizations) on nonmarathon dates (absolute risk difference, 3.3 percentage points; 95% confidence interval [CI], 0.7 to 6.0; P=0.01; relative risk difference, 13.3%). After adjustment for covariates, adjusted 30-day mortality among beneficiaries admitted to marathon-affected hospitals on marathon dates was significantly higher than among beneficiaries admitted on nonmarathon dates (28.6% [95% CI, 26.1 to 31.1] vs. 24.9 [95% CI, 24.1 to 25.6]; absolute adjusted risk difference, 3.7 percentage points [95% CI, 1.1 to 6.4]) (Fig. 2, and Fig. S1 in the Supplementary Appendix). Adjusted mortality among beneficiaries admitted to control hospitals on marathon dates was similar to that among beneficiaries admitted on nonmarathon dates (25.0 [95% CI, 23.6 to 26.4] and 24.7% [95% CI, 24.3 to 25.2], respectively; absolute adjusted risk difference, 0.3 percentage points [95% CI, –1.2 to 1.8]).

Our findings were similar in a subgroup analysis that included only beneficiaries who were unlikely to be marathon runners. In a review of local newspapers, we found no evidence that mortality was higher among runners in the week after the marathon than in the week before the marathon, which suggests that our main findings were not due to deaths occurring among marathon runners. The use of alternative mortality end points and different modeling assumptions and the inclusion of additional marathons in our analyses did not affect our findings. In a permutation test, the observed higher mortality among beneficiaries hospitalized on marathon dates than on nonmarathon dates was greater than the effect sizes observed in 99.4% of the 1000 replications in an analysis performed to compare whether the difference in mortality might be expected from chance alone. (See also Figs. S1 and S2, and Tables S2 through S4 in the Supplementary Appendix.)

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POSSIBLE CAUSES

Hospital location was highly correlated between marathon dates and nonmarathon dates (Spearman correlation coefficient, 0.91: P<0.001), which suggests that patients were not admitted to different hospitals during marathons. Distributions of ZIP Code of residence of beneficiaries who were hospitalized on marathon dates were similar to those of beneficiaries who were hospitalized on nonmarathon dates. In analysis of only beneficiaries who resided within marathon-affected ZIP Code areas, the results of 30-day mortality were similar to those of the main analysis. We found no significant differences in rates of percutaneous coronary intervention, mechanical circulatory support, or coronary-artery bypass grafting performed at marathon-affected hospitals on marathon dates versus nonmarathon dates. (See also Figs. S3 and S4, and Tables S4 and S5 in the Supplementary Appendix.)

Among beneficiaries with acute myocardial infarction admitted to marathon-affected hospitals, the percentage with concurrent cardiac arrest was significantly higher on marathon dates than on nonmarathon dates (5.1% vs. 2.6%; absolute difference, 2.5 percentage points; 95% CI, 1.4 to 3.5; P<0.001), but the corresponding percentages in the control hospitals did not differ significantly between marathon versus nonmarathon dates (Table S6 in the Supplementary Appendix).

We found no significant change in miles driven by ambulances on marathon dates. During mornings, we observed longer ambulance transport times in marathon-affected areas on marathon dates than on nonmarathon dates (i.e., same day of the week as the marathon date in the 5 weeks before and the 5 weeks after the marathon dates): an average of 18.1 minutes on marathon dates as compared with an average of 13.7 minutes on nonmarathon dates (absolute difference, 4.4 minutes; 95% CI, 1.3 to 7.5; P=0.005) (Fig. 3). No greater ambulance transport times were observed in marathon-affected areas during evenings or between marathon and nonmarathon dates in areas not affected by the marathon. We found no significant difference in the distribution of ambulance departure times in marathon-affected areas on marathon dates, which suggests that patients did not delay seeking care during marathons. (See also Figs. S5 and S6, and Tables S7 and S8 in the Supplementary Appendix.)

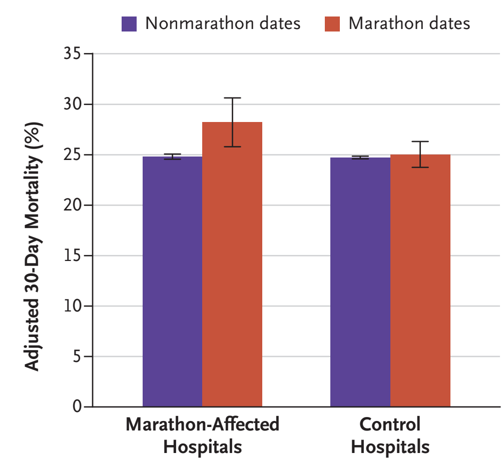

Figure 2. Adjusted 30-Day Mortality among Medicare Beneficiaries Hospitalized for Acute Myocardial Infarction or Cardiac Arrest on Marathon Dates and Nonmarathon Dates in Marathon-Affected Hospitals and Control Hospitals.

The analysis was adjusted for beneficiary sex, age, race, any of 10 chronic medical conditions, the median household income in the ZIP Code area, the interaction between city and marathon day, and fixed effects for hospital. Separate models were estimated for marathon-affected and control hospitals. The I bars represent 95% confidence intervals.

DISCUSSION

We found higher 30-day mortality among Medicare beneficiaries admitted to marathon-affected hospitals with acute myocardial infarction or cardiac arrest on dates of major marathons than among beneficiaries hospitalized on nonmarathon dates (i.e., that same day of the week as the day of the marathon in the 5 weeks before and the 5 weeks after the marathon). The characteristics of the beneficiaries hospitalized on marathon dates were similar to those of the beneficiaries hospitalized on nonmarathon dates, which argues against unmeasured patient factors leading to higher mortality during marathons. We observed no significant differences in mortality among beneficiaries who were admitted to hospitals that were unaffected by marathon routes. Marathon participation was unlikely to be a cause of death among the Medicare beneficiaries in our study, who had a mean age of 76.6 years and had notable chronic medical conditions.

The frequency of hospitalization was similar across marathon and nonmarathon dates, which

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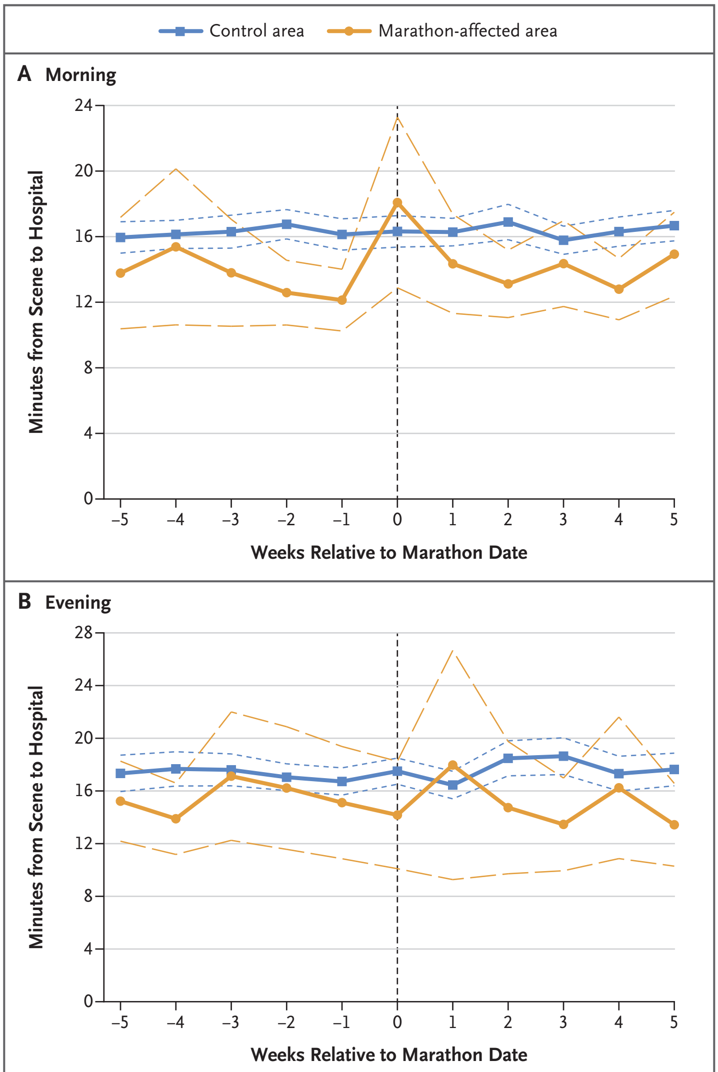

Figure 3. Ambulance Travel Times from Scene to Hospital on a Marathon Date and Nonmarathon Dates in Marathon-Affected Areas and Areas Not Affected by the Marathon.

Morning was defined as the period from 3 a.m. through noon, when road closures attributable to marathons would be more likely. Evening was defined as the period from 7 p.m. through 11:59 p.m., when roads should be reopened. Transport times were computed for persons 70 years of age or older, which was chosen to reflect the mean age of Medicare beneficiaries with acute myocardial infarction and cardiac arrest. During the morning, the mean unadjusted difference in transport time between a marathon day and combined nonmarathon days in marathon-affected areas was 4.4 minutes (95% CI, 1.3 to 7.5) (P=0.005 by a Student's t-test). There was no significant difference in the evening (−1.1 minutes; 95% CI, −6.0 to −3.8; P=0.65). Owing to a lack of geographic information in National Emergency Medical Services Information System data, the analysis could not account for clustering of admissions within hospitals or cities. The dashed lines represent 95% confidence intervals. Sensitivity analyses of morning and age cutoffs are provided in the Supplementary Appendix.

suggests that patients did not forego care until after marathon dates. The distribution of hospitals in which patients were treated was also similar. In an analysis of ambulance transports that occurred during mornings, when road closures attributable to marathons would be more likely, scene-to-hospital transport times were 32.1% longer on marathon dates than on nonmarathon dates (an average of 18.1 minutes vs. 13.7 minutes). No differences in transport times were found in areas unaffected by marathons or in evenings in marathon-affected areas, when roads were reopened. Ambulance departure times were similarly distributed on marathon and nonmarathon dates, which suggests that patients did not delay seeking care and that ambulances were not delayed in reaching patients. The geographic distribution of ZIP Code of residence was similar among beneficiaries hospitalized on marathon dates and those hospitalized on nonmarathon dates, and the main findings did not change when only beneficiaries who resided in marathon-affected ZIP Code areas were included in the analysis; therefore, our findings were unlikely to be attributable to out-of-town visitors. In a review of local newspapers to identify reported instances of deaths occurring among marathon runners, we found no evidence that mortality on marathon days was higher because of marathon participation itself. Finally, rates of acute myocardial infarction with concurrent cardiac arrest were twice as high among beneficiaries hospitalized on marathon dates as among similar beneficiaries hospitalized on nonmarathon dates, a finding that is consistent with delayed care. Taken together, our findings suggest that road closures, diversion of ambulance resources, and ensuing delays in hospital care may explain the higher mortality that we observed among patients with acute myocardial infarction or cardiac arrest who were hospitalized on dates of major marathons.

The differences in mortality that we observed were substantial. If one assumes that there is a causal link between the longer transport times and mortality, the higher 30-day mortality of 28.2% vs. 24.9% (a relative difference of 13.3%) would imply that each year a total of 3.4 additional 30-day mortality events occurred among Medicare beneficiaries with acute myocardial infarction or cardiac arrest who were hospitalized

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on marathon dates in the 11 cities that we studied. The magnitude of these estimates raises the question of whether delays in ambulance transport of 4.4 minutes could reasonably affect mortality. Observational studies of cardiac arrest have shown higher mortality in association with even a few minutes of additional arrest duration.[18-20] Findings from observational studies that showed lower mortality among patients transported by basic life support ambulances versus advanced life support ambulances are also consistent with our findings to the extent that receipt of hospital care may be faster with transport by basic life support ambulances.[21,22] More likely, however, is that large relative increases in ambulance transport time may be a proxy for large absolute increases in transport time among patients who are not brought to the hospital by ambulance and therefore would be more affected by road closures. Approximately 23% of patients in our study were not brought to the hospital by ambulance. Large transport delays for these patients may partly explain our findings.

Large public events may disrupt access to timely medical care for both participants and nonparticipants of these events. Our study suggests that a citywide strategy for emergency medical preparedness should consider the risks not only to event participants but also to others whose care may be delayed. We did not systematically assess how each city addressed the possible effect of road closures on ambulance or private vehicle transports. It is possible that formalized protocols may differ across cities and may sometimes be lacking; a pattern of higher mortality across multiple hospitals within a city on any given marathon date may not be recognized by any single hospital or public service entity. Preparedness strategies should account not only for delays in ambulance transports but also for possible delays in hospital transports by private vehicles.

Our study has limitations. First, we could not definitively identify the cause of higher mortality among beneficiaries hospitalized on marathon dates, although delays in care attributable to road closures are a possible explanation. Second, we focused on acute myocardial infarction and cardiac arrest because patients with these conditions would probably seek care promptly, and delays in care could result in measurable adverse outcomes. Third, our analysis was limited to Medicare beneficiaries, but this is an important population to consider given the high rates of coexisting medical conditions and older age, both of which make marathon participation an unlikely cause of death in this population. Fourth, residual confounding is possible. However, patient characteristics were balanced between beneficiaries hospitalized on marathon dates and beneficiaries hospitalized on nonmarathon dates. Moreover, we found no difference in mortality in counties that were unaffected by marathon routes. Fifth, we did not consider all U.S. marathons. Sixth, ambulance transport data were not available for the entire study period. Finally, our analysis was underpowered to assess whether differences in mortality among beneficiaries hospitalized on marathon dates versus nonmarathon dates were larger or smaller in particular cities and if so, what emergency-response protocols in those cities may be responsible.

In conclusion, we found higher 30-day mortality among Medicare beneficiaries admitted to marathon-affected hospitals with acute myocardial infarction or cardiac arrest on dates of major U.S. marathons than among beneficiaries hospitalized on nonmarathon dates. Our findings are consistent with the idea that delays in care attributable to infrastructure disruptions are a possible explanation.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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