Ambulance diversion and myocardial infarction mortality

Abstract

Objective: To examine the relationship between ambulance diversions and the incidence of myocardial infarction deaths in New York City.

Methods: We obtained data for 1999 and 2000 on all 9,743 deaths due to myocardial infarction in New York City, as well as periods of diversion status for 58 New York City area hospitals operating under a central ambulance dispatch by the New York City Fire Department. Negative binomial regressions were used to model the percentage increase in myocardial infarction deaths associated with diversion status.

Results: On average, 2.67 deaths from myocardial infarction occurred in each New York City borough per day. On the seven borough-days when more than 20 percent of a borough's available emergency department time was spent on diversion, there was a 47 percent (95 confidence interval, 27 to 67 percent) increase in borough-wide deaths from myocardial infarction, or 8.78 additional deaths over the two-year study period. On the 46 borough-days in which at least 25 percent of a borough's emergency departments were simultaneously on diversion, there was a 17 percent (95 percent confidence interval, 2 to 31 percent) increase in myocardial infarction mortality in that borough, or 20.88 additional deaths over the study period. In contrast, there was no association between low levels of ambulance diversion and deaths from myocardial infarctions.

Conclusions: In New York City in 1999/2000, both high levels of total ambulance diversion hours as well as high levels of simultaneous hospital diversion were associated with increased deaths from myocardial infarction.

Introduction

Emergency department crowding is a growing problem in the United States.[1,2,3] A survey of US emergency departments found over 90% of emergency department directors citing crowding as a problem, with almost 40% reporting crowding on a daily basis.[3] A frequently employed method of mitigating emergency department crowding is invoking diversion status, where the central dispatcher diverts incoming ambulances to other hospitals.[1] As a result, as emergency department crowding has worsened, the frequency of ambulance diversions has increased.[4,5] The United States General Accounting Office's 2001 nationwide survey of hospitals found that nearly 10 percent of hospitals were on diversion more than 20 percent of the time.[6]

Ambulance diversion increases out-of-hospital transport times, delaying emergency medical care.[5,7] Delays in emergency care can have grave consequences for certain emergency patients, particularly those suffering an acute myocardial infarction. In these patients, the rapidity with which reperfusion therapy is initiated has a significant impact on patient mortality.[8,9,10] Although EMS protocol in most cities (including New York) mandates that a hospital's diversion status be overridden for a patient in extremis, such as during an acute myocardial infarction, there is evidence that this rule is not always followed. A Toronto study of ambulance transport of patients with chest pain concluded that prehospital delays during periods of heavy diversion were similar in all patients, regardless of the severity of illness.[11] In addition, for patients with suspected myocardial infarctions, time to thrombolysis was longer during periods of emergency department crowding.[12]

To our knowledge, only one study, an observational cohort in Northern California, has evaluated clinical outcomes associated with ambulance diversion.[7] This analysis, however, did not differentiate between types of injury or illness, and captured only those deaths that occurred en route or in the field. We hypothesize that ambulance diversion has more substantial effects on critically ill patients for whom time to treatment is of utmost importance, such as patients with acute myocardial infarction. The aim of our study was thus to determine whether ambulance diversion is associated with an increase in the daily incidence of deaths from myocardial infarction.

METHODS

Study Design/Sources of Data

Our study is observational and retrospective in nature, using data for the study period of January 2, 1999, to December 31, 2000. We relied on two sources of data. The first, supplied by The New York City Department of Health and Mental Hygiene, was contained information collected from the death certificates of all persons dying of myocardial infarctions in New York City during the study period. These data included age, sex, race, ethnicity, zip code of residence, and the borough in which the death occurred. There is no information on whether the diagnosis of myocardial infarction was confirmed by a post-mortem examination. All myocardial infarction deaths occurring within the study period were included in our analysis if the patient was over the age of 18. The mortality data provided had no missing values in the date, age, sex, or borough of death variables.

The second source of data was collected by the New York City Fire Department, which provided the central dispatch service for the City's emergency response system over the same study period. These data included time, date, duration, and nature (critical adult, psychiatric, obstetric, or pediatric) of ambulance diversions for all 58 NYC area hospitals that operate emergency rooms. To capture those ambulance diversions that might affect patients suffering a myocardial infarction, we included in our study only critical adult diversions.

The study protocol was approved by the Institutional Review Board of Columbia Presbyterian Medical Center, number AAAA0354.

Setting

The study setting was the city of New York, which is comprised of five boroughs – Manhattan, the Bronx, Brooklyn, Queens, and Staten Island – and a population exceeding eight million. During the study period from January 2, 1999, to December 31, 2000, the New York City Fire Department-operated emergency medical response system included 58 area hospitals, including three on the border of Queens and Long Island. Hospital diversion status is requested by individual emergency departments, and diversion status is granted or denied by the central dispatch, operated by the Fire Department. All diversions granted by the Fire Department are logged in the diversion records. Even if a hospital has diversion status, it cannot turn away ambulances, which may have been directed there either by the patient or by central dispatch if a patient is in extremis.

Methods of Measurement

The two sources of data were summarized by borough and date. Because the myocardial mortality data contain neither time nor specific place of death (e.g., hospital, ambulance, home), we linked the summary mortality data (numbers of deaths per borough per day) to summary diversion data (amount of diversion per borough per day) by borough and date to capture diversions that may have affected the patient's care. The three hospitals on the border of Long Island and Queens were included in the Queens catchment area, as per New York Fire Department protocol.

The main independent variable studied was the borough diversion rate. This variable was defined within boroughs as total hours of emergency department diversion time divided by the number of daily available emergency department hours (i.e., the number of emergency departments in a given borough multiplied by 24 hours). It was then categorized, with strata defined by no diversion, less than 10 percent diversion, 10 to 20 percent diversion, and over 20 percent diversion.

To assess the effect of multiple hospitals being on diversion simultaneously, we defined "gridlock" as the event that more than 25 percent of borough hospitals are on diversion at the same time. Twenty-five percent was chosen as the cut-off so that Staten Island, which had four hospitals during the study period, would be considered in gridlock only when more than one emergency department was on diversion.

Primary Data Analysis

We estimated multivariate regressions using the number of deaths from myocardial infarctions per borough per day as the dependent variable. To account for the known seasonal effect in both the incidence of myocardial infarction mortality and ambulance diversions, and potential weekly and yearly variation, we included day of week, month of year, and year categorical variables as independent controls.[13] Given that our unit of observation is borough-date, we were unable to include individual patient characteristic data to control for potential confounders such as socioeconomic status. In addition, we do not know where or if a patient was treated, and thus cannot control for individual hospital quality. However, to the extent that socioeconomic status and hospital quality varies between boroughs, we address these potential confounders and, more generally, inter-borough variability in death rates, by including a borough categorical variable.

Because the dependent variable, myocardial infarction deaths per day per borough, is a count variable, negative binomial regressions were used to model the predictive effect of ambulance diversion. Negative binomial modeling is the appropriate functional form when the dependent variable follows a distribution in which the variance is larger than the mean, as is the case in our data.[14] The estimated coefficient from a negative binomial regression can be interpreted as a percentage change in the dependent variable given a unit change in the independent variable. In the case of categorical variables, the unit change in the independent variable represents the movement from absence to presence of the marker. The analyses were recalculated assuming a Poisson distribution, but there was no significant difference in standard errors or coefficients on the independent variables. All analyses were carried out using Stata version 8.0.

Sensitivity Analyses

Our multivariate regressions use summary data, with the borough-date as the unit of observation, and thus cannot control for individual patient characteristics. To assess the robustness of our results among different patient groups, we repeated the analysis using patient subgroups by sex, age, and race. All observations with non-missing values for the subgroup variable were included.

In our primary analysis, we assume that the borough in which the patient died, rather than the borough in which the patient lived, is the more relevant link to hospital diversion data. To test whether this assumption affected our results, we repeated the analyses using the borough of residence to link mortality data to ambulance catchment area.

To address the possibility that an external event caused either increased ambulance diversions and myocardial infarction fatalities or both, we employed two strategies: first, subgroup analysis by year, and second, including a week-in-sample categorical variable. These methods serve to control for the possibility that, due to some external event such as influenza season, one week has a greater number of myocardial infarction (or ambulance diversions) than others. This is particularly relevant in our sample period, as the 2000-

2001 flu season, which includes November and December of 2000, was much milder than the flu seasons of 1998-1999 and 1999-2000.[15]

RESULTS

Sample Demographics

A total of 9,743 adults died of myocardial infarctions in New York City over the time period between January 2, 1999, and December 31, 2000. Forty-six percent were men; 65 percent were white, 19 percent were black, and 11 percent were Hispanic. The boroughs' mortality mirrored their populations; Brooklyn accounted for the most myocardial deaths, with 2975, and Staten Island, the least, at 741. Table 1 provides descriptive statistics. We found a seasonal effect in the incidence of myocardial infarction mortality, with more deaths occurring in the winter months, as shown in Graph 1. The mean number of myocardial infarction deaths per borough-day was 2.67 (95 percent confidence interval, 2.60 to 2.74).

Ambulance Diversion

Over the same time period, ambulance diversion was a frequent occurrence in New York City. On average, three hospitals per day city-wide went on critical adult diversion status, with each diverting ambulance admissions for approximately five hours. Diversion was most frequent in the winter months and in Manhattan. The distribution of the variable borough diversion rate is shown in Table 2. Summarizing the mortality data by borough diversion rate strata revealed the following: on the 2239 borough-days with no diversion, the mean number of deaths from myocardial infarction was 2.49 (95 percent confidence interval, 2.41 to 2.57), on the 1354 borough-days with borough diversion rates less than ten percent, the mean number of deaths was 2.96 (95 percent confidence interval, 2.85 to 3.07), during the 50 borough-days with a rate between ten and 20 percent, the mean was 2.56 (95 percent confidence interval, 1.86 to 3.26), and on the seven borough-days with a borough diversion rate greater than or equal to 20 percent, the mean number of deaths from myocardial infarction was 5.86 (95 percent confidence interval, 3.11 to 8.60).

Gridlock

Gridlock occurred on 46 borough-days during the two year study period, with forty-four of the 46 borough-days between the months of October and March. The distribution of the gridlock variable is shown in Table 2. On days in which there was no gridlock in a borough, the mean number of borough deaths from myocardial infarctions was 2.65 (95 percent confidence interval, 2.58 to 2.71). On those days in which over 25 percent of a borough's hospitals had diversion status simultaneously, the mean number of borough deaths was 3.93 (95 percent confidence interval, 3.21 to 4.66).

Primary Regression Analysis

In multivariate regressions of borough diversion rate on myocardial infarction mortality figures, controlling for day of week, month of year, year, and borough, we found a significant association between a borough diversion rate greater or equal to 20 percent and increased mortality (95 percent confidence level, 27 to 67 percent). The coefficient on this variable indicates that borough-days with a greater than 20 percent borough diversion rate were associated with a 47 percent increase in myocardial infarction fatalities, or about 1.25 deaths per borough-day. In contrast, there was no association at lower levels of diversion. Our second independent variable, gridlock, also displayed a significant association with myocardial infarction deaths when regressed with the categorical covariates on deaths per borough-day (95 percent confidence level, 2 to 31 percent). The incidence of gridlock was associated with a 17 percent increase in deaths from myocardial infarction, or about 0.45 deaths per borough-day.

Sensitivity Analysis

Subgroup analysis supported the significant association between high borough diversion rates and cardiac mortality in older patients (greater than or equal to 80 years of age), in both sexes, and in whites. The association did not hold in other races, and there was a non-statistically significant trend toward the association in patients less than 80 years of age (t-statistic, 1.93). The gridlock incidence variable remained a statistically significant predictor of increased myocardial infarction deaths in women, and whites, but not in the separate age groups, men, and the other races.

Repeating the analysis using borough of residence instead of borough of death as the linking variable for the mortality data had no impact on the significance of our results. In contrast to the borough of death variable, in which there were no missing values, there were 497 missing values for the borough of residence variable, of which 225 had missing values for zip code of residence in the dataset, and the remaining 272 were zip codes outside of New York City's five boroughs. These deaths were dropped from the analysis.

Finally, repeating the regressions with a week-in-sample categorical variable had no substantial effect on our main findings, and in the by year analyses, the borough diversion rate over 20 percent was a significant predictor in both 1999 and 2000, and the gridlock variable was significant in 2000 but not 1999.

LIMITATIONS

There are several limitations to our study. Importantly, this is an observational study and so considers only associations and not causal relationships. The mechanism by which an increased number of myocardial infarction deaths occur during periods of significant levels of hospital diversion is unclear, and we cannot test that more ambulance diversions lead to longer time to treatment given the limitations of our data. It is possible that on days with higher rates of myocardial infarctions, more emergency departments are overcrowded, and thus requests for ambulance diversion increase. We believe this to be unlikely, as emergency department visits with the diagnosis of myocardial infarction make up only 0.7 percent of total emergency room visits.[16] It is also possible that a hospital on diversion is a more general marker of an overstressed system, which could have adverse consequences not only on those patients who activated the emergency medical system, but also on those who were hospitalized at the time of the diversion status.

Another significant limitation is that our mortality data lacks a variety of critical information. We know only the borough and not place of death; in short, we cannot know whether the person actually experienced effects of emergency department overcrowding on the day of his death. We may incur large measurement error in linking the two datasets. For example, because the analysis is conducted at the level of the borough, we may be linking a death in Southern Brooklyn to a diversion in Northern Brooklyn. In addition, the temporal linking is not ideal; the mortality data did not include time of death, and we inevitably may link patients to diversions that occurred after their demise. Most generally, we do not know how the cause of death was determined, and it is likely that less than ten percent of the deaths from myocardial infarction were diagnosed by autopsy, the gold standard. However, in one series of patients who died outside of the hospital, forensic pathologists were able to correctly predict ischemic heart disease as the cause of death prior to post-mortem examination in 79.7 percent of cases.[17] Our mortality data should carry a higher percentage of correct diagnoses, as it includes patients who died in an ambulance or in the hospital, on whom there would be greater amounts of ante-mortem data.

Finally, because the regressions utilize borough-date as the unit of observation, there is no way to include individual patient or hospital characteristics, and the results may have been driven by a particular type of patient or a few select hospitals. We have attempted to control for these confounders by including a borough categorical variable and performing subgroup analysis to test for robustness, however, we are constrained by the increasingly small sample sizes within subgroups. Finally, although we attempt to address the possibility of confounding external events by adding a categorical week-in-sample variable, there are many other potential external confounders for which we were unable to control.

DISCUSSION

In summary, the objective of this study was to examine the covariance of emergency department crowding with patient outcomes. Our results show a statistically significant association between increasing myocardial infarction deaths and severe emergency department crowding, as measured by a daily borough diversion rate above 20 percent and the event that more than 25 percent of the borough's emergency departments are on diversion at the same time. In contrast, our analysis showed low levels of ambulance diversion to have no association with mortality.

These findings differ from previously published results, which showed no increase in transport-related deaths over a concomitant period of increasing ambulance diversion.[7] However, unlike the previous study, our primary outcome is deaths from myocardial infarction, a smaller and we believe more sensitive subset of patients. In addition, our analysis includes all deaths within a day, rather than solely those that occurred during transport. This inclusion may capture deaths that occurred after the time of transport but which were nonetheless associated with the amount of emergency department crowding. Finally, the geographical areas of the two studies are different; the previous study looked at ambulance diversion in Northern California, whereas we included only the five boroughs of New York City, a much more densely populated region.

As has been done in previous studies, we used ambulance diversion episodes as our indicator of significant crowding. We quantified diversion levels using two measures: borough diversion rate, and gridlock. Recent studies have demonstrated delays in treatment time during periods of significant simultaneous hospital diversion, and our gridlock variables were designed to model this effect.[9,18] By using predictor variables that were percents of borough emergency department time or borough hospitals, we standardized diversion and gridlock times among boroughs with differing numbers of available hospitals. Finally, in contrast to previous studies, our primary outcome was clinical – daily mortality due to myocardial infarctions – within a subset of patients who have been shown to significantly benefit from rapid initiation of treatment.

In retrospect, our results, while robust in subgroup and other sensitivity analyses, must be interpreted with caution. Because of the observational, retrospective nature of our study, the relatively small time period over which it occurs, and the limited datasets on which it is based, there are many potential confounders for which it is difficult to control. While we included categorical covariates to control for the daily, seasonal, yearly, and inter-borough variability in both death rates and ambulance diversion, we were unable to incorporate individual patient or hospital characteristics into our analysis. Our method of linking mortality data to diversion data is imprecise, as our databases did not contain time of death. Finally, observational analysis can only show associations. Our results can not clearly establish that emergency room overcrowding causes increased myocardial infarction mortality.

Graph 1:

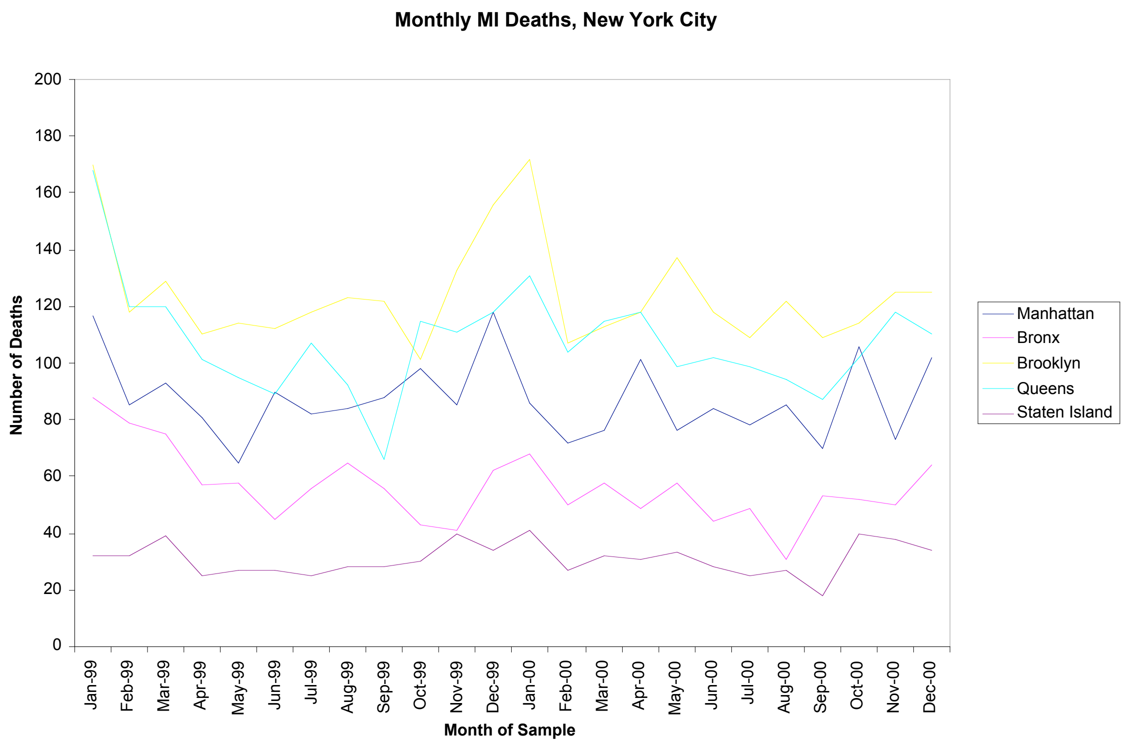
Monthly MI Deaths, New York City
Number of Deaths
0
20
40
60
80
100
120
140
160
180
200
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Apr-00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Month of Sample
Manhattan
Bronx
Brooklyn
Queens
Staten Island

Table 1: Characteristics of the New York City Myocardial Infarction Mortality Data, 1999-2000

Characteristic	**Value***	
	1999	**2000**
Total Number of MI deaths	4986	4757
Mean Age	78.1 ± 12.3	77.9 ± 12.6
Age < 80 (%)	48.0	48.7
Male sex (%)	45.0	47.7
Race (%)		
White	66.0	64.8
Black	18.0	19.1
Hispanic	10.9	10.8
Other	5.1	5.3
Mean MI deaths per day		
Manhattan	3.0 ± 1.7	2.8 ± 1.7
Bronx	2.0 ± 1.5	1.7 ± 1.3
Brooklyn	4.1 ± 2.1	4.0 ± 2.1
Queens	3.6 ± 2.1	3.4 ± 2.0
Staten Island	1.0 ± 1.0	1.0 ± 1.0

*Plus-minus values are ± standard deviation.

Table 2: Distribution of Independent Variables, Borough Diversion Rate (BDR)* and Gridlock**

	Manhattan	**Bronx**	**Brooklyn**	**Queens**	**Staten Island**
BDR strata (in borough-days)					
BDR = 0	328	516	445	402	548
0 < BDR <10%	395	209	279	314	157
10% <= BDR <20%	7	3	4	12	24
BDR >=20%	0	2	2	2	1
Gridlock strata (in borough-days)					
No gridlock present	721	717	723	719	724
Gridlock present	9	13	7	11	6

*Borough Diversion Rate = (Cumulative daily borough emergency department diversion time) /(Number of borough emergency departments x 24 hours)

**Gridlock = Greater than 25 percent of a borough's emergency departments simultaneously on diversion at any point during the day

References:

[1] Burt CW, Schappert SM. Ambulatory care visits to physician offices, hospital outpatient departments, and emergency departments: United States, 1999-2000. *Vital Health Stat. 13* 2004; 157:1-70.

[2] McCaig LF, Ly N. National Hospital Ambulatory Medical Care Survey: 2000 emergency department summary. In: *Advance Data from Vital and Health Statistics.* Hyattsville, MD: National Center for Health Statistics; 2002. No. 326.

[3] Derlet R, Richards J, Kravitz R. Frequent overcrowding in US emergency departments. *Acad Emerg Med.* 2001; 8:151-155.

[4] Schull M, Redelmeier D, Szalai J, *et al*. Trends in ambulance diversion for Toronto emergency departments from 1991 to 1999 [abstract]. *Acad Emerg Med.* 2000; 7:520.

[5] Schneider S, Gallery M, Schafermeyer R, et al. Emergency department crowding: a point in time. *Ann Emerg Med.* 2003; 42:167-172.

[6] United States General Accounting Office. *Hospital emergency departments: Crowded conditions vary among hospitals and communities (GAO-03-460).* Washington, DC: 2003.

[7] Redelmeier DA, Blair PJ, Collins WE. No place to unload: a preliminary analysis of the prevalence, risk factors, and consequences of ambulance diversion. *Ann Emerg Med.* 1994; 23:43-47.

[8] The GUSTO Investigators. An international randomized trial comparing four thrombolytic strategies for myocardial infarction. *N Engl J Med.* 1993; 329: 673-682.

[9] Boersma E, Maas AC, Deckers JW, *et al*. Early thrombolytic treatment in the acute myocardial infarction: reappraisal of the golden hour. *Lancet.* 1996; 348:771-775.

[10] Center for Medicare and Medicaid Services, 7th statement of work. *Quality of care measure specifications: Acute myocardial infarction (AMI).* Baltimore, MD: Center for Medicare and Medicaid Services; 2002.

[11] Schull M, Morrison L, Vermeulen M, et al. Emergency department overcrowding and ambulance transport delays for patients with chest pain. *CMAJ.* 2003; 168:277-283.

[12] Schull M, Vermeulen M, Slaughter G, *et al*. Emergency department crowding and thrombolysis delays in acute myocardial infarction. *Ann Emerg Med.* 2004; 44:577-585.

[13] Sheth T, Nair C, Muller J, *et al*. Increased winter mortality from acute myocardial infarction and stroke: the effect of age. *J Am Coll Cardiol.* 1999; 33:1916-1919.

[14] Cameron AC, Trivedi PK. *Regression analysis of count data*. New York, NY: Cambridge University Press. 1998.

[15] Influenza activity: United States surveillance data: 1997-1998 through 2002-2003 seasons. Center for Disease Control and Prevention Web site. Available at http://www.cdc.gov/flu/weekly/ussurvdata.htm. Accessed May 1, 2004.

[16] Burt CW. Summary statistics for acute cardiac ischemia and chest pain visits to United States EDs, 1995-1996. *Ann J Emerg Med.* 1999; 17:552-559.

[17] Nashelsky M, Lawrence C. Accuracy of cause of death determination without forensic autopsy examination. *Am J Forensic Med Pathol.* 2003;24:313-9.

[18] Schull M, Morrison L, Vermeulen M, *et al*. Emergency department gridlock and out-of-hospital delays for cardiac patients. *Acad Emerg Med.* 2003; 10:709-716.