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Authors
Hsia, Renee Y
Sarkar, Nandita
Shen, Yu-Chu

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Is Inpatient or Emergency Department Crowding a Greater Driver to Ambulance Diversion?

Renee Y. Hsia, MD, MSc[1], **Nandita Sarkar, PhD**[2], and **Yu-Chu Shen, PhD**[2,3]

[1]Department of Emergency Medicine and Philip R. Lee Institute for Health Policy Studies, University of California at San Francisco

[2]National Bureau of Economic Research

[3]Graduate School of Business and Public Policy, Naval Postgraduate School

Abstract

Inpatient volume has been long believed to be a contributing factor to ambulance diversion, which can lead to delayed treatment and poorer outcomes. We examined the extent to which both daily inpatient and emergency department volumes as well as diversion levels of neighboring hospitals were associated with hospital diversion levels from 2005–2012. We found that patient volume was associated with a 7-fold increase in diversion hours when the volume increase occurred in the inpatient ward (5%) than in the emergency department (0.7%). When the next geographically closest emergency department experienced mild, moderate, and severe diversion, diversion hours of the study hospital increased by 8%, 23%, and 44%. Our results suggest that efforts focused on managing inpatient volume and flow could more effectively reduce diversion than solely emergency department-focused interventions.

INTRODUCTION

Ambulance diversion is defined as when an emergency department (ED) closes its doors to incoming ambulances because the ED does not have the capacity to take on more patients. Diverted ambulances must drive to the next available ED, which increases the time required to reach the ED, potentially delaying ambulance turnaround(1) and treatment,(2) increasing both short- and long-term patient mortality rates by up to 10%,(3, 4) as well as lost hospital revenues(5) and medical costs that may incur from increased need for more intensive treatment that otherwise may have been unnecessary.(6) Inpatient volume has long been anecdotally cited by physicians as a main contributing factor to crowding in the ED and the subsequent trigger of diversion.(7–11) Identifying whether inpatient volume is associated with diversion could prove critically important to formulating more effective interventions to decrease diversion, many of which currently focus on ED dynamics rather than overall hospital systems and resources.(12, 13)

Corresponding author: Renee Y. Hsia, MD, MSc, Department of Emergency Medicine, University of California, San Francisco, 1001 Potrero Ave., 1E21, San Francisco General Hospital, San Francisco, CA 94110, Tel: (415) 206-4612, Fax: (415) 206-5818, renee.hsia@ucsf.edu.

Disclosures

The authors have no further conflicts of interest to disclose.

Previous studies examining the relationship between patient volume and diversion use average or annual volumes instead of daily volumes,(14) limited sample sizes,(15–17) or are simulation-based,(18) all of which do not most accurately quantify the association between diversion and both inpatient and ED volumes as in our study. While some literature describes the relationship between inpatient boarding and ambulance diversion,(19–21) most studies citing the contribution of inpatient boarding and/or volume to diversion are based on cross-sectional surveys or anecdotal reports.(22–25) Quantifying the empirical relationship between diversion and both daily inpatient and ED volumes is critical to provide insight into where "bottlenecks" occur, specifically if diversion might be more sensitive to "input" factors such as demand for ED care, or "output" factors such as lack of available staffed inpatient beds.(24) Furthermore, it is important to know if these relationships between both inpatient and ED volumes and diversion are magnified in hospitals with fewer available beds ("high-occupancy") compared to hospitals with more available beds ("low-occupancy"), which is possible given that high-occupancy has been associated with crowding and increased lengths of stay for ED patients,(26) and how these relationships change if there is a close proximity hospital with an ED.

To determine whether or not inpatient volume may be a bigger driver of ambulance diversion than ED volume, we use a combination of large datasets containing daily inpatient and ED volumes and diversion hours in California to longitudinally investigate: [1] how diversion hours fluctuate with a hospital's inpatient and ED volumes; [2] how diversion hours fluctuate with the level of crowding experienced by its next geographically closest ("nearby") ED as measured by diversion level; and [3] whether or not the relationships between both inpatient and ED volumes and diversion hours differ by the hospital's occupancy rate and whether there was another ("close proximity") ED within a 10-minute driving time. We hypothesize a strong positive association between the number of diversion hours a hospital experiences and its own patient volumes and nearby ED diversion level, and that the magnitude of the association would be stronger for hospitals with high occupancy rates but weaker for hospitals with a close proximity ED.

METHODS

Data

We extracted daily diversion data from ambulance diversion logs maintained by 17 emergency medical services (EMS) agencies in California that did not ban ambulance diversion during the study period (2005–2012), covering roughly 88% of the population in California.

We constructed daily volume information using patient-level data and hospital occupancy information from the Hospital Annual Utilization Data obtained through the California Office of Statewide Health Planning and Development.(27) The non-public inpatient and ED discharge data and vital statistics contained all inpatient admissions and ED visits from every non-federal, general, acute-care hospital in California between 2005–2012.

Our daily inpatient volume included all inpatients, regardless of source of admission (direct inpatient admission or from the ED), because once a patient is under inpatient care, the patient effectively reduces available resources during his or her stay (which might include days with no diversion). Oftentimes, an ED may reach capacity due to boarding inpatients as a result of unavailability of inpatient beds or transfer delays.(21, 28) Our daily ED volume included all patients either discharged from the ED after treatment (i.e., “treat-and-release” patients) or admitted to the hospital from the ED.

Study Design

Our empirical analysis included two sets of key independent variables: daily patient volumes, which allowed us to examine the correlations and sizes of effect between number of diversion hours experienced and both a hospital’s inpatient volume and ED volume; and diversion levels experienced by the nearby ED, defined as the next geographically closest ED, which allowed us to analyze spillover effects of nearby ED diversion levels on number of diversion hours experienced. We identified nearby EDs using automated Google map queries(29) based on longitudinal and latitudinal information from each hospital’s physical address or heliport.(30) As in previous literature,(9, 11) we classified nearby ED diversion levels into four categories based on the total hours of diversion experienced on the given day: 0 hours, <6 hours (mild), 6 to <12 hours (moderate), and ≥12 hours (severe).

We linked the above information with additional hospital characteristics obtained from the American Hospital Association annual surveys and Healthcare Cost Report Information System, including ownership, teaching status, system membership, total beds, occupancy rates, and market competition (defined using the Herfindahl-Hirschman index (HHI), commonly used to measure market concentration in the hospital industry) using unique hospital identification numbers. The Institutional Board of Review approved this study.

Statistical Analysis

We used hospital days as our unit of analysis and showed trends of daily patient volumes between days when hospitals experienced diversion and no diversion. We used a multivariate fixed-effects linear regression model, which took into account the nested days within each hospital and the unobserved heterogeneity across hospitals, to explore the relationship between patient volumes and diversion. For our main results, we estimated two models: the first model explored the “extensive margin,” where the sample contained all hospitals days and the dependent variable indicated whether a hospital had any diversion hours on a given day (i.e., a binary indicator), and the second model explored the intensity of the relationship between volume and diversion, where the sample contained hospital days with positive diversion hours and the dependent variable was log-transformed daily diversion hours.

Our model included hospital fixed-effects to remove baseline differences, such as differences in the underlying patient population and across hospitals (equivalent to the case-crossover design, where a hospital serves as its own control when comparing fluctuations in diversion hours due to patient volume changes), and additional time-varying hospital characteristics, including year, month, and day of the week indicators as well as other hospital characteristics in order to capture macro trends (i.e., normal fluctuations in diversion hours over time not related to patient volumes). In the second model, for ease of interpretation, we log-transformed the dependent variable, daily diversion hours, so that coefficients for inpatient and ED volumes could be interpreted as a percent change. Our key variables of interest included log-transformed inpatient and ED volumes, and 3 indicators for nearby ED diversion level with no diversion as the reference group. We performed all analyses using Stata 14 (StataCorp, College Station, Texas).

The hospital fixed-effects model was advantageous over traditional hierarchical models for our analysis because it removed unobserved time-invariant differences across hospitals, critical to our estimation (i.e., the hospital fixed effects approach allows us to rule out the possibility that the relationship we observed is due to managerial style or care culture in that hospital). Hierarchical models, on the other hand, would assume that hospital-level variation follows a random effects model and would not be able to remove the unobserved time-invariances across hospitals.(31)

We implemented two additional interaction models, stratified by whether or not the hospital was high-occupancy and whether or not there was another operating ED within a 10-minute driving time in order to explore how the association between key independent variables and diversion hours varied between these classifications. We classified a hospital as "high-occupancy" if the hospital had a mean annual occupancy rate greater than 65% (the median in our sample). We defined close proximity EDs as those where the driving time to the next closest ED from the hospital was less than 10 minutes. We added interaction terms between the indicators for each stratification and the five key independent variables included in our main model.

Limitations

Our study has several limitations. First, hospitals self-report the occupancy rates used in our study, which may potentially include discrepancies between the number of staffed versus licensed beds. Because OSHPD data reports licensed beds rather than staffed beds, occupancy rates in our study could be underestimates.

Second, there may be some measurement error or reporting bias in self-reported diversion data; however, the potential errors are likely minimal as we obtained the diversion data directly from EMS online reporting systems, where in all counties, hospitals on diversion notify the base hospital, and the time and date of each diversion episode is automatically logged into the system. In addition, we found a high degree of concurrence when comparing aggregated daily data to yearly levels of diversion using several years of our diversion data and the data reported to the state.

Third, we did not observe the underlying reasons for each diversion episode. In California, local EMS agencies provide guidance to hospitals regarding diversion policies.(32, 33) Most local EMS agencies have similar bypass request categories for reasons such as ED saturation, internal disruptions (e.g., fire or bomb threat causing facility shutdown), or unavailability of critical equipment. However, in general, there are no specific thresholds for the number of inpatients or ED patients that will trigger diversion. The unobserved variation in specific reasons triggering diversion may likely inflate our standard errors.

Fourth, while fixed effects remove time-invariant unobserved differences across EDs, there may be unobserved time-varying hospital characteristics associated with hospital overcrowding and diversion not captured in the data. Our results were robust when we estimated our parameters using hierarchical models.

Fifth, we included all inpatients and ED patients, whom have a wide range of conditions with varying acuity levels, and the distribution of patient health may vary from hospital to hospital. However, our fixed-effects models ensured that we identified our estimated relationship using hospitals as their own case controls, so our results were not driven by differences in the underlying patient population across hospitals.

Lastly, our data only contained information for urban areas in California, and although California represents 12% of the U.S. population, our results may not be generalizable to the rest of the U.S., especially not to rural areas.

RESULTS

Our sample included 248,128 hospital days, representing 208 hospitals in California that reported having diversion on at least one day between 2005–2012. Hospitals reported diversions on 81,802 days, making up 33% of all hospital days. We generated daily patient volumes from 5,875,979 inpatient stays and 18,784,196 ED discharged visits ("treat-and-release"). On average, a hospital treated approximately 133 inpatients and 81 ED patients per day. Approximately 46% of hospitals had fewer than 200 beds (small hospitals), with varying ownership (20% for-profit, 18% government-owned, and 14% teaching hospitals, Exhibit 1).

As seen in Exhibit 2, average daily inpatient volumes were consistently higher on days with diversion compared to days without during the study period (top two trend lines). In other words, days without diversion had lower average daily inpatient volumes (mean of 105 patients), which was notably different on days with diversion (mean of 161 patients). Similarly, daily ED volumes were higher on days with diversion (mean of 87 patients) compared to days without (mean of 70 patients). The only exception was year 2012, where days with and without diversion had similar average daily ED volumes (bottom two lines of Exhibit 2). We compared each pair of trends (using "no diversion" as the reference group) using the nonparametric Kolmogorov-Smirnov test for equality of distribution and found that the trends do not follow the same distribution ($P<0.0001$). In other words, daily patient volume trends between days with and without diversion were statistically significantly different from each other.

Main Results

The first column of Exhibit 3 shows the results of the "extensive margin" where we examined if a hospital goes on diversion at all: for every 10% increase in inpatient and ED volume, the probability of diversion occurring on a given day increased by 0.9 (95% confidence interval [CI]: 0.2 to 1.6) and 1.0 percentage points (95% CI: 0.7 to 1.4), respectively (full results are available in Appendix Exhibit A1). To put this into perspective, diversion occurred in 33% of hospital days; a 1.0 percentage point increase is equivalent to a

3.0% increase in the probability of having any diversion. The probability that a hospital experienced any diversion also increased proportionally with the amount of diversion experienced by its nearby ED, defined as the next geographically closest ED: by 10.0 (95% CI: 8.0 to 12.0), 19.0 (95% CI: 15.0 to 22.0), and 21.0 (95% CI: 17.0 to 25.0) percentage points when the nearby ED experienced mild, moderate, and severe diversion, respectively, on the same day.

The second column of Exhibit 3 shows that, conditional on diversion occurring, a 10% increase in inpatient volume was associated with a 5.0% increase in diversion hours (95% CI: 3.8% to 6.3%), while a 10% increase in ED volume was associated with a 0.7% (95% CI: 0.2% to 1.2%) increase in diversion hours. When the nearby ED experienced moderate and severe diversion, hospitals experienced a 23.0% (95% CI: 18.0% to 27.0%) and 44.0% (95% CI: 37.0% to 51.0%) increase in diversion hours, respectively. However, when the nearby ED experienced mild diversion, compared to days with no diversion, there was only an 8% (95% CI: 5.0% to 11.0%) increase in diversion hours. Full results can be found in Appendix Exhibit A2.

Results from Interaction Models

Exhibit 4 shows the results from our examination of the intensity of the relationship between patient volume and diversion based on two dimensions. When stratifying the analysis by occupancy rate, the relationships between patient volume (both inpatient and ED) and diversion were statistically similar between high- and low-occupancy hospitals. However, high-occupancy hospitals experienced longer diversion hours relative to low-occupancy hospitals when the nearby ED was also on diversion. Specifically, compared to days when the nearby ED experienced no diversion, during nearby mild and moderate diversion, high-occupancy hospitals had an additional 6.0% (95% CI: 0.0% to 11.0%) and 13.0% (95% CI: 4.0% to 21.0%) increase in diversion hours, respectively.

Second, stratifying the analysis by the presence of a close proximity ED, defined as having another ED within a 10-minute driving distance, showed that the presence of a close proximity ED can relieve a hospital's diversion burden when its ED volume is high: specifically, a 10% increase in ED volume was associated with a 2.0% increase in diversion hours among hospitals without another ED within 10 minutes but just 0.5% among hospitals with another ED within a 10-minute drive (difference of 1.5%, $P < 0.05$, 95% CI: −2.7% to −0.4%). However, when the nearby ED experienced severe diversion, hospitals with a close proximity ED had substantially higher diversion hours relative to hospitals whose next ED was more than 10 minutes away: diversion hours for hospitals with a close proximity ED rose by an additional 15.0% (95% CI: 2.0% to 27%) relative to hospitals without a close proximity ED.

DISCUSSION

Our findings indicate that both inpatient and ED volumes are associated with a higher probability of an ED going on diversion. Conditional on a hospital experiencing diversion, our findings also show that a 10% increase in patient volume is associated with a 7-fold increase in diversion hours when the volume increase occurs in the inpatient ward than in

ED (5% vs. 0.7%). Additionally, nearby ED diversion may increase diversion hours anywhere from 8% to as much as 44%.

Theoretically, our findings of an association between both inpatient and ED volumes with diversion could be interpreted in two ways: increased inpatient volume could cause a backlog of patients in the ED, who are then boarded, leading to ED crowding and the subsequent diversion; however, ED crowding could also be a cause of both inpatient volume increases (through increased admissions) and diversion. Previous literature show that inpatient boarding is a key contributor to crowding, and that managing inpatient flow can decrease boarding in the ED, which suggests that the former relationship is more likely to be the case.(34–36)

Why would inpatient and ED volumes have a similar effect on diversion status in a binary fashion but have such different associations when evaluated conditional on diversion (meaning inpatient volumes played a much larger role in influencing the amount of diversion)? Given that diversion is a temporary state of the ED and can be easily switched on and off, it is likely that high inpatient and ED volumes can prompt administrators to temporarily go on divert, but that inpatient volumes have a more lasting effect on the duration of diversion, since it is difficult to create more inpatient capacity in a short amount of time compared with ED visits, which are calculated more often in hours as opposed to days.

Our analysis comparing high-occupancy hospitals, defined as hospitals with a mean annual occupancy rate greater than 65%, to other hospitals reveal two interesting insights. On the one hand, the relationship between patient volume and diversion is similar regardless of a hospital's occupancy status. Given some literature showing that hospitals with low-occupancy rates are associated with low performance,(37) it is possible that low-occupancy hospitals may have less efficient operations (e.g., fewer protocols to expedite movement from the ED to the inpatient ward), and these inefficiencies could be amplified during times of higher volume. On the other hand, our findings show that high-occupancy hospitals experience longer diversion hours relative to low-occupancy hospitals when the nearby ED of both types of hospitals also experienced mild and moderate diversion hours (up to 12 hours), and that two EDs within close proximity can influence each other's diversion status. Although having a close proximity ED can relieve the burden of an ED on diversion, all else being equal, when the nearby ED experiences prolonged diversion, it significantly increases the diversion hours (by another 15%) of its neighboring ED. These findings could either illustrate that there is a domino effect, or be a result of "pre-emptive" or "defensive" diversion.(38) It could also simply reflect that all EDs within a certain proximity are likely affected by similar factors (e.g., time of day, referral practices, flu season). Our findings from these stratified analyses shed light on the importance of accounting for community and hospital characteristics in evaluating solutions for managing patient volume.

This study provides empirical evidence identifying factors that may play a significant role in ambulance diversion. One potential implication of these findings is that initiatives to better manage patient volume in inpatient wards may be important in reducing diversion, thereby improving outcomes, especially in communities that experience high diversion and in patients with time-sensitive conditions. At first glance, hospital volume may appear to be a difficult-to-change factor and outside the scope of policy influence; however, studies have shown that certain practices (e.g., bed control meetings, bed crisis and/or surge models, and more restrictive diversion policies) could result in decreased diversion(33, 39) but have not been widely adopted.(40) Other possibilities include better utilization of licensed beds; there is literature showing that a significant proportion of licensed beds are often not staffed (a.k.a., "phantom beds"), thereby decreasing the number of usable beds.(41) Taken together with other literature, our findings suggest that addressing system-wide hospital factors to better manage inpatient volume could potentially have a larger effect on reducing diversion compared with initiatives focused solely on the ED.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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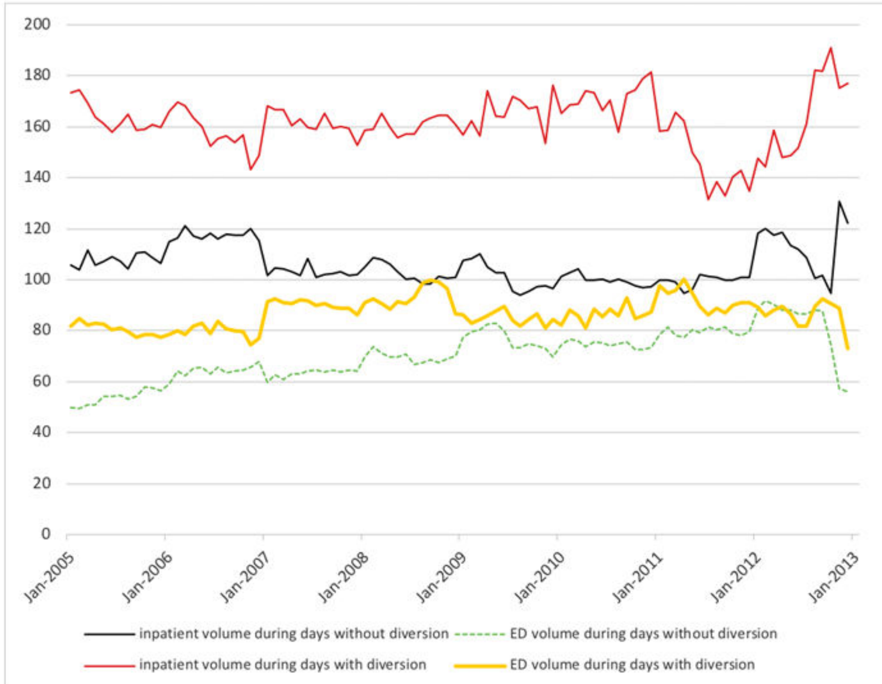

Exhibit 2.

Inpatient and Emergency Department Volume by Diversion Status, 2005–2012

Source: Authors' tabulation of data from CA daily ambulance diversion logs and the Office of Statewide Health Planning and Development.

Exhibit 1

Descriptive Hospital Characteristics of Hospital-Day Study Sample

	Whole sample			
	N	**Mean**	**%**	**SD**
Daily patient volume				
Daily inpatient volume		133.21		87.40
Daily ED volume		81.27		41.60
Ownership				
For-profit	49777		20.06	
Non-profit	153836		62.00	
Government hospital	44515		17.94	
Teaching status				
Teaching hospital	33991		13.70	
Non-teaching hospital	214137		86.30	
Hospital size				
Bed size <100	30428		12.26	
Bed size 100 to <200	83914		33.82	
Bed size 200 to <300	75254		30.33	
Bed size ≥300	58532		23.59	
Other hospital characteristics				
Hospital is part of a system	180116		72.59	
Case mix index		1.46		0.21
Occupancy rate		0.64		0.15
Herfindahl-Hirschman Index		0.16		0.15
Mean Wage index		1.32		0.18
Mean Share of Medicare		0.26		0.14
N	248,128			

Source: Authors' description of data from CA daily ambulance diversion logs, American Hospital Association annual surveys, the Healthcare Cost Report Information System, and the Office of Statewide Health Planning and Development.

Notes: Abbreviations - SD, Standard Deviation; ED, Emergency Department.

Exhibit 3

Regression Results of Inpatient Volume, ED Volume, and Diversion Status of Nearby ED on Hospital Diversion Hours

Dependent variable =	***Whether a hospital-day has positive diversion hours***	***Diversion Hours (log-transformed)***
Sample=	**All Hospital Days**	**Hospital Days with Positive Diversion Hours**
	Percentage point changes in the probability that a hospital is on divert on a given day when:	*Percent change in diversion hours when:*
Total inpatient volume increased by 10%	0.9 *	5.0% **
Total ED volume increased by 10%	1.0 **	0.7% **
Nearby ED's diversion status changed from no diversion to:		
<6 hours	10 **	8% **
6 to <12 hours	19 **	23% **
≥12 hours	21 **	44% **
N	248,128	81,802

* $p<0.05$

** $p<0.01$

Source: Authors' analysis of data from CA daily ambulance diversion logs and the Office of Statewide Health Planning and Development.

Notes: Abbreviations - CI, Confidence Interval; ED, Emergency Department. The sample included only days where hospitals experienced diversion. These regressions include all hospital controls as shown in Exhibit 1, as well as year, month, and day of week controls. Full results shown in Appendix Exhibit A1 and A2.

Exhibit 4

Regression Results of Inpatient Volume, ED Volume, and Nearby ED Diversion Level on Hospital Diversion Hours: Compared by Occupancy Rate and Proximity of Next Closest ED

	High Occupancy Hospital	**Next Closest ED within 10 minutes**
	Percent change in diversion hours when:	Percent change in diversion hours when:
General hospitals:		
Total inpatient volume increased by 10%	4.3%**	6.1%**
Total ED volume increased by 10%	0.8%**	2.0%**
Nearby ED's diversion status changed from no diversion to:		
<6 hours	5%**	5%**
6 to >12 hours	16%**	19%**
≥12 hours	38%**	35%**
Additional change for hospital in header relative to general hospitals when:		
Total inpatient volume increased by 10%	2.0%	−1.7%
Total ED volume increased by 10%	−0.3%	−1.5%**
Nearby ED's diversion status changed from no diversion to:		
<6 hours	6%*	4%
6 to <12 hours	13%**	6%
≥12 hours	10%	15%*
N	81,802	81,802

+ $p < 0.1$

* $p < 0.05$

** $p < 0.01$

Source: Authors' analysis of data from CA daily ambulance diversion logs, American Hospital Association annual surveys, and the Office of Statewide Health Planning and Development.

Notes: Abbreviations - CI, Confidence Interval; ED, Emergency Department. The sample included only days where hospitals experienced diversion. These regressions include all hospital controls as shown in Exhibit 1, as well as year, month, and day of week controls. Full results shown in Appendix Exhibit A2.