Hospital Staffing and Inpatient Mortality

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Abstract

Staff-to-patient ratios are a current policy concern in hospitals nationwide. Legislators in California and New York have imposed staffing requirements on hospitals that are estimated to cost hundreds of millions of dollars per year. These reforms were motivated by the presumption of a causal link between lower hospital staffing levels and adverse patient outcomes. However, the cited empirical evidence is based almost entirely on across-hospital comparisons, which is problematic if the nonrandom selection of patients into hospitals leads to unobservable differences across hospitals in patient characteristics and illness severity. By contrast, this paper uses the significant reduction in the number of doctors on staff on the weekend to estimate the effects of staffing on mortality rates. Within-hospital comparisons in outcome differences between weekday and weekend admissions have two advantages over previous research. First, the observable differences in patient characteristics are much smaller within hospitals than across hospitals. More importantly, it is possible to construct an index that corrects for biases due to unobservable selection into staffing regimes that is based on the excess share of admissions that occur on weekdays. Consistent with previous research, there is a robust association between excess mortality and weekend admission even after regression-adjustment. However, correcting for nonrandom selection in favor of weekday admissions leads to a finding of no excess mortality among patients admitted on the weekend. This suggests that despite a significant reduction in the number of doctors and services provided on the weekend, hospitals are effective in triaging patients with less severe conditions.

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1. Introduction

Medical errors are currently a major concern to medical professionals and the public at large. A 1999 Institute of Medicine Report, *To Err is Human: Building a Safer Health System,* estimated that 44,000 to 98,000 hospital patients in the US are killed by medical errors each year. The reaction to this study was rapid. Within two weeks Congress held hearings to explore the feasibility of implementing the study's suggestions.

The California legislature has also taken up this issue by passing legislation that mandates minimum nurse-to-patient ratios. These rules, which go into effect in July 2003, make California the first state to set hospital-wide minimum nurse-to-patient ratios. The California Healthcare Association estimates that these changes will cost at least $400 million to implement. A similar reform in New York State mandated changes in staffing rates and work hours for doctors, with one goal being to increase both the number and seniority of doctors on site at hospitals on the weekend. The estimated cost of implementing these changes was $358 million per year in 1989 dollars (Thorpe 1990).

These reforms mandating increased staff-to-patient ratios have been motivated by the presumption of a causal link between hospital staffing levels and adverse patient outcomes. Although there have been several recent papers on this question, the existing empirical evidence is somewhat limited. Most research has examined the across-hospital association between staffing levels and inpatient mortality and morbidity – for example, Aiken, et al. (JAMA 2002), Needelman, et al. (N England J Med 2002), and Pronovost, et al. (JAMA 1999). However, these comparisons will lead to biased estimates if nonrandom selection of patients into hospitals leads to unobservable differences across hospitals in patient characteristics and illness severity. For example, patients with planned admissions tend to be lower risk than patients admitted through the emergency room. Thus, hospitals with established reputations and higher staffing levels will have a disproportionate share of low risk admissions if patients with planned admissions sort to better-known hospitals. In this case, the cross-sectional correlation between staffing levels and patient outcomes may be spurious.

By contrast, Bell and Redelmeier (N England J Med, 2001) provide evidence on the effects of reduced staffing within the same hospital over the weekly cycle. In particular, they find that patients admitted to hospitals during the weekend have significantly higher mortality rates than patients admitted on weekdays in Canada, even after adjustment for observable patient characteristics. Since staffing levels within a hospital are lower during the weekend, they conclude that the reduced staffing has negative effects. However, if patients admitted on the weekend have more severe conditions than those admitted during the week, then these estimates will be biased due to the unobservable sorting of patients across the days of the week. This type of selection bias is plausible as the Canadian data show that a disproportionate number of patients are admitted to hospitals on weekdays relative to the weekend.

I use microdata on the universe of discharges from California hospitals between 1995 and 1999 to examine two questions: 1) "Is there a direct relationship between the number of doctors on staff in a hospital and the probability that an error will occur that results in a patient's death?"; and 2) "Does a temporary reduction in the services hospitals provide result in worse outcomes for patients admitted on the weekend?" In response to the higher social cost of working on the weekend, California hospitals significantly reduce both their staffing and available procedures on the weekend. This study examines whether this reduction in staffing results in excess mortality among patients admitted to hospitals on the weekend relative to those admitted on weekdays.

The data include detailed information on patient characteristics, the patient's medical condition, the reported severity of the condition, and the procedures performed on the patient. I document that the observable differences in patient characteristics are much smaller within hospitals than across hospitals. This suggests that within-hospital comparisons in patient outcome differences between weekday and weekend admissions may suffer from less omitted variables bias than between-hospital comparisons. Even so, and in contrast to previous research, I also derive and implement a method that attempts to correct for unobservable selection biases in hospital admissions over the days of the week. In particular, focusing on the top 100 causes of death, I use the weekend-to-weekday admissions ratios for each cause to correct for the potential selection of patients with less severe conditions in favor of a weekday admission.

My selection correction method is based on the following insight: as long as the incidence of (non-accidental) health conditions is uniform over the week, one should see a weekend-weekday ratio of hospital admissions of 0.4 (2/5) for each condition. In the California data, however, almost all patient conditions have weekend-weekday admission ratios well below 0.4 – that is, a disproportionate share of hospital admissions in California occur on weekdays, Monday in particular. Further, it is likely that in response to reduced staffing on weekends hospitals will "triage" those patients presenting less severe conditions on the weekend to a weekday admission. In this situation, the association between weekend admission and excess mortality, even conditional on observed patient characteristics, may be severely biased by this nonrandom sorting on the severity of the condition.

To address this issue, I derive a model in which the condition-specific weekday-weekend admissions ratios provide an index that corrects for this unobservable selection bias into staffing regimes under fairly plausible assumptions. The selection model allows for two groups of patients with medical conditions that develop on the weekend: those with a serious form of the condition that requires immediate medical attention and those with a less severe form of the condition. Patients with the serious form of the condition present themselves at the Emergency Department and get admitted to the hospital immediately, while patients with the less serious form choose between coming to the Emergency Department on the weekend and facing a long wait or deferring admission until a weekday.[1]

This selection rule by the patient (or the hospital) implies that weekday admissions will be disproportionately composed of lower risk patients. In addition, the excess share of weekday admissions for a condition provides a measure of the excess fraction of weekday admissions that are for the low mortality risk patients. For identification, the model also assumes that the mortality risk for patients who defer entering the hospital on a weekend relative to the risk for those who cannot defer admission is constant across conditions. Here, the coefficient on the selection correction term measures the relative mortality rate of those patients presenting less severe conditions on the weekend who were moved to a weekday admission – that is, the hospital (patient) triage effect.

I use two different approaches that incorporate this "admissions ratio" selection index. First, I identify a subsample of California patients who have weekend-weekday hospital admissions ratios close to 0.4 – that is, they appear to enter the hospital at random. The subsample addresses three types of nonrandom selection: 1) doctors schedule admissions on weekdays, 2) individuals engage in high risk behavior on the weekend, and 3) hospitals are more likely to engage in triage on the weekend. This analysis examines patients

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[1] Emergency Departments typically have more patients with traumatic injuries and more patients seeking primary care on the weekend. Waits of up to 8 hours are not uncommon.

that are admitted to the hospital through the Emergency Department and eliminates patients admitted for accidental causes of death from the sample.[2] This results in a sample with daily admissions proportions that are close to the 1/7 one would expect in the absence of selection.

In the second approach, I include a selection index, based on the weekend-weekday admissions ratio for each condition, as a control variable in regressions using the entire population of patients admitted to California hospitals. This provides a direct estimate of the amount of selection on unobservable illness severity that occurs on the weekend. If the excess patients who enter the hospital on weekdays are no different from the patients admitted on the weekend, then the estimated coefficient on the selection variable will be small and statistically insignificant. However, I find that this selection index is a highly significant predictor of the inpatient mortality rate.

Consistent with previous research, there is a large and robust association between excess mortality and weekend admission even after regression-adjustment for patient characteristics. However, both methods that correct for nonrandom selection in favor of weekday admissions lead to a finding of no excess mortality among patients admitted on the weekend. Including the single selection-index control variable has a striking effect on the estimated excess mortality rate on the weekend. This suggests that despite a significant reduction in the number of doctors and services provided on the weekend, hospitals are effective in triaging patients with less severe conditions.

These findings contradict those of Bell and Redelmeier (N Engl J Med 2001), who found evidence of excess mortality among weekend admissions in Canada for 23 of the top 100 causes of death. To reconcile these differences, I apply my selection model to the condition-specific data available in their published paper. I find that emergency room admissions in Canada for the top 100 causes of death are heavily selected in favor of a weekday admission, much more than in California. Also, the conditions with the greatest excess mortality on the weekend also have the greatest excess share of admissions on a weekday. I use three different methods to adjust for selection bias based on the condition-specific weekend-weekday admission ratios. All three lead to a finding of no excess mortality among weekend admissions in Canadian hospitals.

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[2] These are all conditions due to traumatic injury. They include head injuries and damage to internal organs their ICD-9 codes are 800, 801, 803, 808, 820, 851, 852, 853, 854, 861, 863, and 864.

The results appear to be both internally and externally consistent, and the selection model provides a good fit to the diverse data patterns in both California and Canada. The finding of no excess mortality among patients admitted on the weekend suggests that hospitals are reducing their staffing levels and the numbers of procedures preformed on the weekend without negatively impacting patient care. This successful short-term reduction in staffing to minimize social costs cannot be applied to weekday scheduling. It would not be possible to catch up on procedures for the patients admitted on the weekend and provide the current level of service to the patients admitted on weekdays if staffing levels were permanently reduced. Further, the research design used in this paper does not reveal what would happen to inpatient mortality rates if there were a permanent reduction in the number of doctors and the services they provide. However these results do suggest that the rate of medical errors is not directly connected to the doctor-to-patient ratio since during a period when the ratio is significantly reduced I am finding no evidence of elevated mortality rates.

The next section describes the recent literature on the relationship between hospital staffing and patient outcomes. The third section of the paper develops a simple model that motivates the bias correction term that I include in my regressions. The fourth section describes the California hospital discharge data used in the analysis. The fifth section presents the empirical results on excess mortality during the weekend correcting for selection bias. In the sixth and final section of the paper I interpret my findings.

2. Background and Previous Literature

The ideal way to measure the relationship between staffing levels and patient outcomes would be to run an experiment where patients are randomly assigned to hospitals with different staff-to-patient ratios. This experiment would probably be unethical and would certainly be almost impossible to implement due to the enormous number of subjects that would be needed. An alternative is to use the changes in staffing levels induced by legislation. The direct impact of the legislated changes in California is an area for future research as the new legislation takes effect and outcome data become available.

In the absence of experimental or legislatively-induced variation in the staffing levels of doctors, there are two non-experimental ways to compare mortality rates under different staffing regimes. The across-hospital approach compares patient outcomes across hospitals with different staffing levels. The within-hospital approach compares mortality rates under different staffing levels within a hospital or hospitals. Almost all of the studies of the relationship between staffing and mortality use the across-hospital approach.

2.1 Across-hospital studies

The studies that use the across-hospital approach are all fairly similar. They typically measure the staff-to-patient ratio at the hospital level and then compare mortality rates or some measure of morbidity across hospitals. These studies use observable measures of patient characteristics to adjust for differences in the populations of patients entering the different hospitals. The design and findings of the three following studies are typical of the literature. Aiken et al (JAMA 2002) examine the outcomes of patients admitted to 168 Pennsylvania hospitals. They adjust for patient and hospital characteristics and find that hospitals with higher nurse to patient ratios have higher thirty day mortality rates among surgical patients and higher nurse burn out rates. Needleman et al (N England J Med 2002) look across 799 hospitals and find a significant negative association between the proportion of total nursing hours provided by RNs and complications suffered by patients. Pronovost et al (JAMA 1999) examine 46 hospitals and focus on a single condition: abdominal aortic surgery. They find that hospitals with daily rounds by an ICU physician have lower mortality rates.

There are a number of problems with the across-hospital methodology that should temper our belief in these results. The main problems are that staffing is not easy to measure, the fixed differences in technology at the hospitals are difficult to take into account and the severity of patient illness is hard to adjust for.

With regard to staffing measurement, in most of the across-hospital comparisons, the only measure of staffing is the total hospital staffing for the year. It is often impossible to determine how much patient contact the nurses and doctors have. Their levels of training are also often unmeasured and likely to differ systematically by hospital type. Measuring staffing levels is further complicated by the fact that the adequacy of staffing is determined by the difference between the number of nurses and doctors on staff and how severely ill the patients in their care are. In addition a study that focuses on nurses without adjusting for the number of doctors and other staff members may be picking up the contributions of the other staff members.

Fixed differences in the technology available at the hospital are another potential source of bias in estimating the effect of staffing on mortality. It is likely that hospitals that have expended resources to increase the staff-to-patient ratio have also taken other measures, such as purchasing additional diagnostic and therapeutic technology, to improve the quality of the care that they provide patients. The regressions in the studies described above at best include a few variables intended to measure the differences in the technology available at different hospitals. Differences in mortality rates that are due to differences in available technology will confound the analysis if they are unadjusted for.

The difficulty in accurately measuring the severity of a patient's illness is probably the most severe of the three problems. Patient characteristics including severity of illness are much better predictors of patient's outcomes than variables measurable at the hospital level. Silber et al find that for simple surgeries "patient characteristics were 315 times more important than hospital characteristics in predicting mortality." (Silber et al 1997) Patients entering different hospitals are very different in their observable characteristics. Table 1a shows just how different patients are across hospitals even when the hospitals are of the same type. The first two columns show the demographics for patients admitted through the Emergency Department for the two largest private proprietary hospitals in California. There are large differences in the racial composition and the insurance coverage of the populations these hospitals serve. Comparing across hospital types, such as comparing the private with the county hospitals, reveals even more pronounced differences in patient characteristics. These differences in the observable characteristics indirectly suggest that selection is occurring. There is also direct evidence patients are selecting into hospitals. Patients are much more likely to travel past the hospital nearest their house for non-emergency admissions than for emergency admissions. For all California hospital admissions from home 31% of emergency admissions occur at the hospital nearest the persons residence but only 22% of non-emergency admissions occur at the nearest hospital. This pattern persists across race and insurance type as can be seen in table 1c.

If non-emergency patients are seeking out hospitals that they feel are superior it can create significant problems for across hospital comparisons. Since non-emergency admissions are much lower risk then emergency admissions any failure of risk adjustment will produce the spurious result that the hospitals patients are seeking out have lower mortality rates. Risk adjustment is likely to be difficult if the unobservable characteristics of patients are as dissimilar across hospital types as their observable characteristics. These three significant problems with across hospital comparisons argue in favor of seeking out alternate ways of estimating the relationship between staffing and patient outcomes.

2.2 Within hospital studies

There are a couple of studies that implicitly use a within-hospital approach by taking advantage of the variation in staffing levels within a hospital over time. A recent study of within-hospital mortality analyzes the death rate in a single Intensive Care Unit (ICU) over a four year period (Tarnow-Mordi et al 2000). They find that patients are significantly more likely to die during periods when the ICU has a higher than average number of patients. Another recent study (Bell and Redelmeier 2001) examines the relationship between the day of admission and adult mortality. Their study takes advantage of the variation in hospital staffing on the weekly cycle. Bell and Redelmeier look at data on Canadian Emergency Department admissions and compare the mortality rates for people admitted on weekdays with the mortality rates for people admitted on the weekend. Bell and Redelmeier show that there is statistically significant excess mortality for people admitted on the weekend for 23 of the 100 most common causes of death and no evidence of excess mortality among weekday admissions for any cause of death.

The studies that look within hospitals suffer from fewer problems than the cross-sectional studies. Though staffing is still hard to measure correctly, fixed differences in the technology available at different hospitals is implicitly differenced out. Even more important the patients entering one hospital at different times have much more similar observable characteristics than patients entering different hospitals. It is likely that patients with more similar observable characteristics also have more similar unobservable characteristics. Since the initial differences in the populations being compared are small this research design is much less prone to confounding due to selection than the across-hospital comparisons.

3. Methodology

The first question to answer is "What health outcomes should researchers be focusing on when making comparisons across staffing regimes?" The obvious endpoint to focus on is mortality. It is an outcome of intrinsic interest, it has an agreed upon definition and it is very unlikely to be miscoded. Many researchers, particularly in studies involving smaller samples of patients, focus on intermediate outcomes such as infections, falls or length of hospital stay.

Intermediate outcomes such as the ones above are not as clearly defined as mortality and there may be systematic differences in how they are recorded across hospitals. There are several studies that document intentionally and unintentionally that the complication rate and the mortality rate are often uncorrelated or inversely correlated (Silber 1995, Pronovost 1999). In cases where there is an inverse correlation between mortality and the complication rate it appears to be because certain hospitals more completely document their patient's complications (Silber 1995). The positive correlation between complications and mortality rates disappears almost completely when the outcomes are adjusted for patient risk (Silber 1997). For the reasons given above the outcome I will focus on is inpatient mortality. I focus on deaths in the first day after admission because if I look at deaths over a longer period the patients will have been exposed to both the weekday and the weekend staffing regimes. For the conditions that I analyze, 23% of the deaths occur in the first day.

I am making the comparison of different staffing regimes within hospital because it avoids many of the problems with comparing staffing across hospitals. Comparing mortality rates within hospital on a weekly cycle is motivated by three observations: there is a pronounced weekly cycle in hospital staffing, there is very little difference in the observable characteristics of patients coming into the hospital on different days of the week, and if there is any selection in favor of either weekend or weekday admissions it will be reflected in the admissions ratios. These three facts make this a better research design on which to base causal inferences about the relationship between staffing and inpatient mortality than the across-hospital research design.

There are many different medical conditions with very different biological causes. I want to focus on a limited number of medical conditions because this will let me examine them individually to determine if they are occurring at random. Because it is not practical to examine all of the five digit International Classification of Disease-9 (ICD-9) codes separately, I am focusing on a reduced number of ICD-9 codes. Following Bell and Redelmeier (2001) I have selected the 100 three digit ICD-9 codes that were the leading causes of death. These 100 top causes of death account for 63% of the 5,556,301 hospital admissions through the ER between 1995 and 1999, and 91% of the 259,595 within-hospital deaths that occur to people admitted through the ER.

For the within-hospital comparison to be reasonable the patients examined under the different staffing regimes need to have the same risk characteristics. This will be the case if the conditions strike at random and people don't selectively delay when they come into the hospital. As I will document below, I find evidence that both of these assumptions are incorrect. One approach to dealing with this problem is to find a subsample of patients for which these assumptions hold. This is one method that I implement. To do this I measure the amount of selection that is occurring by using the admissions rate for each day. Any deviation of daily admissions from a ratio of 1/7 is evidence of sorting. I identify a number of different factors that are likely to result in sorting and search for routes into the hospital and conditions for which there is very little evidence of sorting. I then focus on the subsample of patients that meet the above criteria in my analysis.

An alternative to searching for a subsample with little evidence of selection is to work with the entire population of admissions and correct for the bias introduced by non-random admissions. I develop a model below that shows how even a relatively small numbers of patients with nonrandom admissions can create significant bias in estimates of the weekend mortality effect. The model is consistent with the empirical facts and motivates the structure of the bias correction term I will include in my regressions.

I make a few simplifying assumptions to make the model tractable. First I assume that for each condition there are two types of patients: those with the serious form of the condition that requires immediate treatment and those with a milder form of the condition for which treatment can be delayed. Clearly some conditions will have no mild form and for these conditions admissions occur in even proportions on each day of the week. I also make the assumption that the serious form of the condition has a higher mortality rate than the milder form of the condition.

When a patient feels ill they present themselves at the Emergency Department. Based on the patient's signs and symptoms, the triage nurse successfully identifies the patients with the serious form of the condition and admits them. The patients with the milder form of the condition are faced with a long wait and may choose to return the next day. This triage effect is most pronounced on the weekend due to the increased demand on the Emergency Department staff due to accidents and non-urgent visits[3]. The patients that have a weekend onset of the condition and defer coming in until a weekday are crossing over to the weekday. The definitions of the symbols I will use in the model are included below.

τ = This is the treatment effect of a weekend admission for all conditions

α_c = Is the percent of patients with the mild form of condition c

M_{ec} = Is the mortality rate for people with the serious form of condition c

Mnec = Is the mortality rate for people with the mild form of condition c

$M_{we,c}$ = Is the mortality rate among weekend admissions for condition c

$M_{wd,c}$ = Is the mortality rate among weekday admissions for condition c

d_{ci} = This is equal to 1 if person i with condition c dies

n = The number of people admitted for a given condition

n_{cWD} = The number of people admitted on weekdays

n_{cWE} = The number of people admitted on weekends

D = Is an indicator function that takes on a value of 0 if patients admitted on the weekend with the mild form of the condition are defering coming to the hospital until a weekday.

The mortality rate among weekday admissions is the weighted sum of the mortality rate among patients that have a weekday onset of their illness and the patients that have a weekend onset of the mild form of the condition and are not admitted until a weekday.

$$M_{wd,c} = \textit{Mortality rate among weekday admissions for condition c}$$

$$M_{wd,c} = \frac{1}{n_{cWD}}\Big[\sum_{\substack{\text{Serious}\\ \text{Weekdday}\\ \text{Onset}}} d_{ci} + \sum_{\substack{\text{Mild}\\ \text{Weekday}\\ \text{Onset}}} d_{ci} + \sum_{\substack{\text{Mild}\\ \text{Weekend}\\ \text{Onset}}} d_{ci}\Big]$$

$$E[M_{wd,c}] = \frac{1}{(\frac{5}{7})n + \mathrm{D}\alpha_c(\frac{2}{7})n}\Big[E[\sum_{\substack{\text{Serious}\\ \text{Weekdday}\\ \text{Onse}}} d_{ci}] + E[\sum_{\substack{\text{Mild}\\ \text{Weekday}\\ \text{Onset}}} d_{ci}] + E[\sum_{\substack{\text{Mild}\\ \text{Weekend}\\ \text{Onset}}} d_{ci}]\Big]$$

$$E[M_{wd,c}] = \frac{1}{(\frac{5}{7})n + (1-\mathrm{D})\alpha_c(\frac{2}{7})n}\Big[(1-\alpha_c)(\tfrac{5}{7})n(\mathrm{M}_{\mathrm{ec}}) + (\alpha_c)(\tfrac{5}{7})n(\mathrm{M}_{\mathrm{nec}}) + (1-\mathrm{D})\alpha_c(\tfrac{2}{7})n(\mathrm{M}_{\mathrm{nec}})\Big]$$

$$E[M_{wd,c}] = \frac{5(1-\alpha_c)(\mathrm{M}_{\mathrm{ec}}) + (5\alpha_c + 2(1-\mathrm{D})\alpha_c)(\mathrm{M}_{\mathrm{nec}})}{5 + 2(1-\mathrm{D})\alpha_c}$$

[3] The empirical evidence in favor of this triage effect is presented in the results section

With no crossover D = 1 and only the patients that have the onset of their illness on a weekday come to the hospital on a weekday. The mortality rate is the weighted sum of the mortality rates for the serious and the mild form of the condition.

$$E[M_{wd,c} \mid \text{no crossover}] = (1-\alpha_c)(\mathrm{M_{ec}}) + \alpha_c \mathrm{M_{nec}}$$

With crossover D=0 and the patients with the weekend onset of the mild form of the condition defer entering the hospital until a weekday and only the patients with the serious form of the condition are admitted on the weekend. The weekday mortality rate is a weighted sum of the mortality rate of patients with the serious form of the condition with a weekday onset, the patients with the mild form of the condition with a weekday onset and the patients with the mild form of the condition of the condition that defer coming in until a weekday.

$$E[M_{wd,c} \mid \text{crossover}] = \frac{5(1-\alpha_c)(\mathrm{M_{ec}}) + (7\alpha_c)(\mathrm{M_{nec}})}{5+2\alpha_c}$$

The mortality rate on the weekend for condition c is the weighted sum of the mortality rate of the patients with the serious form of the condition and of the patients with the mild form of the condition.

$$M_{we,c} = \textit{Mortality rate among weekend admissions for condition c}$$

$$M_{we,c} = \frac{1}{n_{cWE}}\Big[\sum_{\substack{\text{Serious}\\ \text{Weekend}\\ \text{Onset}}} d_{ci} + \sum_{\substack{\text{Mild}\\ \text{Weekend}\\ \text{Onset}}} d_{ci}\Big]$$

$$E[\,M_{we,c}\,] = \frac{1}{\frac{2}{7}n}\Big[E[\sum_{\substack{\text{Serious}\\ \text{Weekend}\\ \text{Onset}}} d_{ci}] + E[\sum_{\substack{\text{Mild}\\ \text{Weekend}\\ \text{Onset}}} d_{ci}]\Big]$$

$$E[\,M_{we,c}\,] = \frac{1}{\frac{2}{7}n}\Big[(1-\mathrm{D}\alpha_c)\tfrac{2}{7}n(\mathrm{M_{ec}}+\tau) + \mathrm{D}\alpha_c\tfrac{2}{7}n(\mathrm{M_{nec}}+\tau)\Big]$$

$$E[\,M_{we,c}\,] = (1-\mathrm{D}\alpha_c)(\mathrm{M_{ec}}+\tau) + \mathrm{D}\alpha_c(\mathrm{M_{nec}}+\tau)$$

With no crossover D = 1 and both the patients with the serious form of the condition and the patients with the mild form of the condition are admitted on the weekend. The mortality rate on the weekend is the weighted average of the mortality rate for the two forms of the condition

$$E[\,M_{we,c} \mid \text{no crossover}] = (1-\alpha_c)(\mathrm{M_{ec}}+\tau) + \alpha_c(\mathrm{M_{nec}}+\tau)$$

With crossover D = 0 and the patients with the mild form of the condition defer entering the hospital until a weekday and only the patients with the serious form of the condition are admitted on the weekend. The weekend mortality rate is the mortality rate for the serious form of the condition.

$$E[\,M_{we,c} \mid \text{crossover}] = \mathrm{M}_{\mathrm{ec}} + \tau$$

When I estimate τ by comparing mortality rates on the weekend with mortality rates during the week:

$$T_c = \textit{Weekend - Weekday mortality condition c}$$

$$E[T_c] = E[\,M_{we,c}] - E[M_{wd,c}]$$

$$E[T_c \mid \text{no crossover}] = \tau$$

$$E[T_c \mid \text{crossover}] = \tau + \frac{7\alpha_c \mathrm{M_{ec}}}{5+2\alpha_c} - \frac{7\alpha_c \mathrm{M_{nec}}}{5+2\alpha_c}$$

If some of the patients are crossing over from the weekends to the weekday then my estimate of τ will be biased. Since the mortality rate for patients with the serious version of the condition is greater than the mortality rate for patients with the less severe form of the condition, if there is any crossover then even a partial failure of risk adjustment will result in estimates of τ that are biased upwards.

I can estimate most of the terms in this equation. I can estimate α_c by measuring the cross over rate and $\mathrm{M_{ec}}$ by calculating the weekend mortality rate but I do not observe $\mathrm{M_{nec}}$. If I want to run the regression above to correct for the bias I need to make additional assumptions about the form of $\mathrm{M_{nec}}$. The simplest assumption is that the mortality rate for patients with mild conditions, $\mathrm{M_{nec}}$, is a fraction of $\mathrm{M_{ec}}$ that is constant across all conditions. This last assumption is necessary because without it or a similar assumption I would need to estimate more parameters than I have degrees of freedom.

4. Data

The dataset that I am working with is built from the California hospital discharge records. I am working with a subset that contains a record for every person discharged from a hospital in California between 1995 and 1999. The dataset contains demographic information on the patient including age, race, gender and insurance provider. It also contains information on comorbid conditions, a measure of the severity of illness and a list of procedures preformed during the hospital stay. The ICD-9 code for the disease or condition that is primarily responsible for the patient's admission to the hospital is also included. One nice feature of the dataset is that it includes the route through which the patient entered the hospital, where they came from and an indicator of if the visit was planned. This makes it possible to look for a subset of the patients who are entering nearly at random. The dataset also includes a scrambled Social Security Number. This turns out to be important as patients are sometimes discharged from the unit of the hospital they were admitted to and transferred to another hospital or another department of the same hospital. The scrambled social security number makes it possible to track them through there entire hospital stay.

5. Results

In the first part of the results section I document the reduction in hospital staffing on the weekend. I then document that this reduction in staffing results in a reduction in the number of procedures performed on patients who enter the hospital on the weekend. I then make a series of comparisons of the mortality rates for patients admitted on the weekend with the mortality rates for patients admitted on weekdays to determine if this reduction in service is adversely affecting the patients admitted on the weekend.

I start by making the naïve comparison of mortality rates for all patients admitted on the weekend with all patients admitted on weekdays. There are three reasons that this is not a fair comparison. The first is that there are many more planned admissions during the week. Including lower-risk planned admissions in the comparisons biases the results in favor of finding a weekend mortality effect because planned admissions are a much larger fraction of weekday admissions. The second is that people behave differently on different days of the week. In particular there are more accidents on Friday and Saturday nights than on other nights. If these accidents are not only more prevalent but also more severe on the weekend this will create the false impression that the reduction in service on the weekend is resulting in excess mortality. The third problem is that hospitals appear to be engaging in triage on the weekend. If only the most ill patients are able to enter the hospital on the weekend and my regression does not completely correct for the differences in the severity of illness this will create the appearance of excess mortality on the weekend.

There are several ways to assess how serious these three problems are. One approach is to compare the observable characteristics of the weekday and weekend admissions. This turns out not to be very effective because though the demographics are very similar there appear to be significant differences in unobservable characteristics between weekend and weekday admissions. An alternative approach is to compare the number of weekday admissions to the number of weekend admissions. I can use the ratio of weekend to weekday admissions to determine if a particular subsample of patients are coming to the hospital at random.

I will try two different ways of dealing with the three forms of selection described above. One is to carefully select a subsample of patients that shows very little evidence of selection. For this approach I measure the amount of selection by using the admissions ratios. The other method is to measure the amount of selection that I observe for each condition and correct for it directly in my regressions. For each of the 100 medical conditions that I am including in my sample I determine how much higher or lower the admissions during the week are than I would expect if patients were coming in at random. I use this measure to create a variable that I will include in my regression that is intended to remove the bias introduced by patients selectively deferring when they enter the hospital. If the excess patients with a given condition who come in during the week are not systematically different then adding this variable to the regression will have no impact on my estimate of the difference between weekday and weekend mortality. If even after correcting for observable differences the additional patients admitted during the week are systematically less ill this variable will reduced the bias in my estimates. I use methods similar to the ones described above to reconcile my findings with the contradictory findings from the literature.

5.1 Documenting the reduction in staffing and service on the weekend

There is a large reduction in the number of personnel at a hospital on the weekend. However, some of this reduction in staffing levels is due to a reduction in administrative personnel. Daily staffing levels of essential personnel are not readily available. Gathering this information is difficult because it varies both across hospitals and across different services of a single hospital. Given the difficulty in gathering accurate information on staffing I am focusing on personnel that are essential for the preservation of life and the delivery of urgent and emergent medical care. Rather than trying to measure staffing levels for a large number of hospitals and doing so inaccurately I am focusing on four representative hospitals.

The staff that I am defining as essential and collecting staffing numbers on are doctors, nurses, and respiratory therapists. The doctors, nurses and respiratory therapists are clearly an essential part of the hospital staff because they provide lifesaving therapies. I am also measuring how long it takes to get diagnostic tests run because they facilitate medical decision making. I will focus on the Internal medicine departments, the Intensive Care Unit (ICU) and the Rehabilitation Service. Because I am focusing on adults with serious medical conditions the majority of patients I am examining will be in one of these units.

There are significant differences in how different hospitals arrange the staffing of physicians, nurses, and X-ray technicians. There are also differences in how different services within a single hospital handle the weekend. I will focus on four different hospitals representing different hospital types and measure staffing levels department-by-department. The four hospital types are Staff Model HMOs, County Hospitals, Church Hospitals and Private Nonprofit Hospitals. These hospital types treat 12%, 7%, 15% and 38% of the sample I am examining, respectively.

The number of nurses – including RNs LVNs and CNAs – does not change on the weekend in the four hospitals that I examined. However the seniority and source of the nurses does change. On the weekend nurses provided by temporary services cover more shifts. There are also reductions in the number of respiratory technicians in two of the four hospitals. There is also an increase in how long it takes to get tests run. CAT scans and MRIs take much longer to run on the weekend and in some cases require a transfer to another hospital. Physicians attest that it is much more difficult to get even urgent X rays or CAT scans done quickly on the weekend. "Any physician who has been on call at a busy hospital on the weekend can attest to the aggravation of obtaining even the most obviously emergent study." [4] Estimates of the number of respiratory technicians, X-ray technicians and the time it takes to get different tests run by hospital are presented in table 2.

The drop on the weekend in the number of doctors on site varies by hospital and unit. In the Staff Model HMO Hospital I examined the reduction in the number of doctors at the hospital on the weekend is smaller than at the other hospitals because the doctors are

[4] Personal communication Paul Ware M.D.

working in shifts. The main difference between the weekday and the weekend in this hospital is that on the weekend the doctors tend to leave early. Since on the weekend the doctors may stay at the hospital only half of a day this can represent a significant reduction in the total services provided.

In the County Hospitals, Church Hospitals and Private Nonprofit Hospitals physicians typically do not work in shifts; they work until all their patients have been seen and cared for. They have other physicians cover their patients when they are not either at the hospital or on call. For these three hospitals on the weekend I am finding a reduction in the number of doctors in the Intensive Care Unit and the General Medical and Rehabilitation units. The reduction is the result of both fewer doctors coming in on the weekend and many of them leaving early. In some units there are 30% fewer doctors in the hospital on the weekend. All hospitals and all units show a significant reduction in the number of doctors. The exact size of the drops is presented in table 2. This reduction in the number of doctors is not a response to a reduction in the number of patients. There are only 7% fewer patients in the hospital on the weekend. In the ICU and the Medicine ward the patient's needs are fairly constant across the week so the large reduction in the number of doctors represents a significant reduction in the doctor-to-patient ratio.

This reduction in staffing results in a measurable reduction in the intensity of treatment that patients receive immediately upon entering the hospital. When I compare patients admitted through the Emergency Department on the weekend with those admitted during the week there is a significant difference in the number of both diagnostic and medical procedures preformed. Patients admitted on weekdays on average undergo 6.7% more diagnostic tests and 8.6% more procedures in the first day after admission than patients admitted on the weekend. When tests and procedures preformed in the first two days after admissions are considered the reduction in service on the weekend is even more pronounced. Patients admitted on weekdays receive on average 9.7% more diagnostic procedures and 12.3% more total procedures in their first two days after admissions than patients admitted on the weekend. The number of procedures preformed in the first day, the first two days and the entire hospitalization are broken out by hospital type in table 3. It is worth noting that the reduction in the number of diagnostic procedures and total procedures is very similar across hospital types.

Most of this reduction in service is not permanent. When the total number of procedures is compared for the entire length of stay the differences between patients admitted on weekdays and patients admitted on weekends are much smaller. There is only a 0.3% difference in the number of diagnostic procedures and a 1.31% reduction in the total number of procedures. The total reduction in service for patients admitted on the weekend is much smaller than the temporary reduction in service. Hospitals are deferring diagnostic work and treatment for patients admitted on the weekend until the rest of the staff returns to the hospital during the week. In the next section I will determine if deferring treatment results in higher mortality for patients admitted on the weekend.

5.2 Comparing mortality rates for patients admitted on the week and the weekend

Does the temporary reduction in staff on the weekend and the delay in service to patients admitted on the weekend result in higher mortality? One possible approach to answering this question is to compare patients admitted on the weekend with patients admitted on weekdays. When I make this naïve comparison I find an enormous difference in mortality rates between the weekday and the weekend admissions. For patients admitted on weekdays there are 1,111 deaths in the first day after admission per 100,000 admissions. For patients admitted on the weekend there are 1,563 deaths per 100,000 admissions[5]. This large statistically significant difference in mortality rates between weekday and weekend admissions persists even when the comparison is made using a logistic regression that includes both demographic information about the patient and a measure of the severity of their illness (Table 4).

This difference is implausibly large and is due in part at least to the large number of patients with planned admissions to the hospital on weekdays. As can be seen in the first two columns of table 1b the characteristics of the patients being compared are very similar other than their route into the hospital. A comparison of the proportion of patients admitted on each day reveals that there are a disproportionate number of patients being admitted on weekdays. In figure 1 I have plotted the proportion of the total admissions occurring on different days of the week. It is immediately clear that there are a disproportionate number

[5] If death during hospitalization is the outcome there are 6,676 deaths per 100,000 admissions on the weekend and 5,381 deaths per 100,000 admissions on weekdays. This difference is robust to the inclusion of covariates.

of admissions on weekdays. This pattern of disproportionate admissions during the week is not caused by a few peculiar conditions. To examine this, I plot the weekend-to-weekday admissions ratios for each of the top 100 causes of death. If there were no selection, for every two patients entering the hospital on the weekend on average there would be five patients entering the hospital on weekdays and we would expect the distributions should be centered at 0.4. The admissions ratios for the top 100 causes of death are plotted in Figure 2. The dotted line on the left of figure 2 is a kernel density estimate of the admissions ratios for each of these causes of death. In examining the plots, it is immediately clear that all conditions are showing a disproportionate number of weekday admissions.

Removing the voluntary hospital admissions by restricting the sample to patients with unplanned admissions through the Emergency Department is the simplest way of dealing with this problem. Dropping patients with voluntary admissions reduces my sample size by 37.3%. Dropping these patients yields patients that have more similar demographics as can be seen by comparing the first and second columns of table 1b with the third and fourth. It also improves the admissions ratios. In figure 2 the kernel density estimate for patients admitted through the Emergency Department is the solid line on the right. It is centered just a little below the ratio 2:5 that we would expect if patients were entering the hospital at random, showing that there are still slightly more weekday admissions for most medical conditions. The improvement in the admissions ratios can also be seen by comparing the proportions of patients admitted on different days. As can be seen in figure 1 the Emergency Department admissions are occurring much more randomly than the non-emergency admissions.

When I make the weekday to weekend comparison using only patients with unplanned admissions through the Emergency Department I find a small but statistically significant difference in mortality rates between weekday and weekend admissions. The mortality rate in the first day for weekday admissions is 1,611 per 100,000 patient days. The mortality rate for weekend admissions is 1,650 per 100,000 patients days[6]. This difference of 39 deaths per 100,000 admissions is robust to the inclusion of covariates. As can be seen in table 5 the inclusion of covariates in a logistic regression has almost no impact on the estimate of the mortality differential between weekday and weekend admissions.

[6] For all deaths within hospital there are 6,833 deaths per 100,000 admissions on the weekend and 6,766 deaths per 100,000 admissions on the weekend. This difference is robust to the inclusion of covariates.

However, there is a problem, as we can see in figure 2 there is a bump at the far right of the kernel density estimate of California Emergency Department admissions ratios. This bump is the result of twelve conditions that occur disproportionately on the weekend. These twelve conditions, which include head injuries and internal injuries, are typically caused by car accidents and are much more common and possibly also more severe on the weekend[7]. These conditions may be biasing my results so I drop them. Dropping these conditions from my analysis reduces the sample size by only 5%.

When I drop these twelve conditions from the analysis I find 1,595 deaths per 100,000 patient days for weekday admissions and 1,608 deaths per 100,000 patient days for weekend admissions[8]. This is a difference of 13 deaths per 100,000 patient days and is no longer significantly different from zero. When I compare the differences in a regression the inclusion of the demographic variables, insurance type and the risk variables halves the coefficient on the mortality estimate (table 6). In a logistic regression with all the covariates included the difference in the mortality rates between the two groups is 6.3 deaths per 100,000 patient days and is not statistically significantly different from zero. When the patients being compared on the weekday and the weekend are reduced to a sample that appears to be entering almost at random there is no evidence of excess mortality among the weekend admissions even without using a regression to adjust for the slight differences in the covariates.

An alternate to dealing with the selection issue by looking for a subsample with no evidence of selection is to adjust for the selection directly in my regressions. To do this I start with all the patients admitted to the hospital from home and try to correct for the selection directly. The unadjusted mortality differential between weekday and the weekend admissions in this population was very large, 452 deaths per 100,000 admissions. The inclusion of patient covariates in a logistic regression reduced the point estimates of the excess mortality on the weekend by only 24%.

To correct for the selection directly I run the same regressions I did with all the patients admitted to the hospital from home but now I include one additional variable that is intended to measure the amount of selection. This selection variable is computed separately

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[7] The twelve conditions are ICD-9 codes 800, 801, 803, 808, 820, 851, 852, 853, 854, 861, 863, and 864.

[8] For deaths within the hospital there are 6,859 deaths per 100,000 weekend admissions and 6,797 deaths per 100,000 weekday admissions. This difference shrinks with the inclusion of covariates and the difference in the mortality rates for weekday and weekend admissions is no longer statistically significant.

for each condition. For each condition I calculate how far above 5/7 the proportion of weekday admissions is. I do the same thing for weekend admissions. This gives me a variable that characterizes the selection that takes on 200 different values, one for the weekend and one for the weekdays for each of the 100 conditions included in the analysis. If the excess patients admitted during the week are no different from the patients admitted on the weekend then this variable should be orthogonal to the mortality rate and be indistinguishable from zero.

When I run regressions with this selection variable included the strong evidence in favor of excess mortality on the weekend disappears. Though the inclusion of all the demographic variables has very little impact on the estimate of the mortality differential, the inclusion of the selection variable in the regressions reduces the estimate of the mortality differential by a factor of more than ten. As can be seen in last three columns of table 7, when the selection variable is included in the regressions the large mortality difference on the weekend shrinks to a number that is not distinguishable from zero. This is particularly striking because as can be seen by looking at the first three columns of table 7 including patient level covariates has very little impact on these estimates.

5.3 Reconciling my results with contradictory results from the literature

The two very different approaches to dealing with the selection problem – working with a reduced subsample with little evidence of selection and correcting for the selection directly – give us the same finding of no difference in mortality between the weekday and the weekend. This finding is in contradiction with the findings of Bell and Redelmeier's paper from the New England Journal of Medicine (2001). They look at a Canadian dataset and find that for 23 of the top 100 causes of death there is excess mortality for patients admitted through the Emergency Department on the weekend and there are no conditions for which they find excess mortality for patients admitted on weekdays. There are a number of reasons to be skeptical about their findings. Thirteen of the conditions for which they are finding evidence of excess mortality are cancers; it is surprising that outcomes for these conditions are so sensitive to short term variation in the quality of care. Their data also shows significant evidence of selection. As can be seen in figure 2 the kernel density estimate of the admissions ratios for the Canadian dataset (denoted by the long dashed line) shows that for almost every condition there are far more admissions occurring on weekdays than we would expect if people were entering the hospital at random. In the Canadian dataset all but one of the conditions has a disproportionate share of admissions during the week. This bias in favor of weekday admissions needs to be examined closely. If there are systematic differences between patients entering the hospital on different days Bell and Redelmeier's results may reflect selection rather than a reduction in the quality of care people are receiving on the weekend.

Since the Canadian study is focused on just Emergency Department admissions and none of the conditions with excess mortality are accidental admissions, neither of the two types of selection I discussed above could be driving the result. This leads me to look for evidence of the third kind of selection mentioned above: hospital triage. Though I cannot examine the Canadian data directly, I can look for evidence of hospital triage in California.

When we examine the kernel density estimates of hospital admissions in figure 2 it is clear that the estimate for California Emergency Department admissions lies a little to the left of the 0.4 ratio, indicating that most conditions have a disproportionate number of admissions on weekdays. The excess admissions on weekdays in California for patients admitted through the Emergency Department are due almost entirely to a surge in admissions on Monday. As can be seen in figure 1 there are 7.3% more admissions on Monday than we would expect if people were coming in at random.

5.4 The evidence of hospital triage in California

The surge in heart attacks reported on Mondays is well documented in the medical literature but the mechanism is unclear. A recent study by Evans et al (British Medical Journal 2000) suggests that increased alcohol consumption on the weekend is a possible cause. Chenet et al observe that the surge in Monday heart attacks does not occur for people with a previous admission for coronary heart disease and suggest that it is possible that either they are protected by their existing therapy plan or they are more likely to seek treatment on the weekend. Peters et al (Circulation 1996) find a pattern in heart attacks for all population subtypes except patients on Beta-Blockers.

There is little evidence on septadian patterns for medical conditions other than heart attacks. In California there is a surge in Monday admissions for almost every cause of admission. In figure 3 I have plotted the day-by-day Emergency Department admission rates for the 20 most common causes of admission. These 20 conditions have very different biological causes and some of them are chronic conditions such as cancer. All but two of them show a pronounced spike in admissions on Monday. As can be seen in figure 4, this Monday spike exists for all age groups. People over 75, who are unlikely to be on a strict weekly cycle, show a surge in admissions that is very similar to the pattern for people under 65.

When the weekly pattern in admissions is broken out by hospital type it is most pronounced in the California County Hospitals (See figure 5). County hospitals have weekend-to-weekday admission ratios that are similar to those found in the Canadian dataset. That the pattern is so similar across medical conditions with different biological causes and age groups with different risk characteristics and so dissimilar across hospital type suggests that at least part of the Monday spike in admissions is due to something occurring at the hospital.

In California the county hospitals primarily serve a poor population that typically does not have access to private doctors. These hospitals tend to have a huge surge in use for primary care on the weekend. These same ERs also have to handle an increased number of traumatic injuries on the weekend. On a crowded day in the ER not everyone can be admitted. In the Emergency Departments of some county hospitals on a busy weekend, waits of up to eight hours are not uncommon. It is possible that less ill people entering the ER on the weekend who are faced with a long wait leave the ER and return to the hospital on Monday or Tuesday. There is some indirect evidence that the patients admitted on the weekend in the county hospital are more ill. The county hospitals are the only hospital type where by the end of their stay weekend admissions on average get more diagnostic tests than weekday admissions (table 3).

When looking at data for all hospitals one can see that when there are an above average number of emergency admissions on a Sunday there are an above average number of emergency admissions on the following Monday (table 8). The fitted value of this regression is about 0.1, indicating that when there are ten more admissions than typical on a Sunday I see one additional admission on the following Monday. This relationship persists even when I include the total number of patients in the hospital on Sunday and hospital and month fixed effects in the regressions.

5.5 The relationship between triage and excess mortality on the weekend

It is important to determine if the amount of triage evident for a given condition is related to the mortality rate for that condition. When the conditions are broken out into three groups based on the mortality differential between the weekday and weekend admissions there is a clear pattern. Figure 6 shows the weekly pattern in admissions for conditions by how much evidence of excess mortality there is for the condition. The more evidence of excess mortality there is for the condition the more pronounced the spike in Monday admissions. For the 30 conditions with the least evidence of excess mortality there are a 6.3% more admissions than we would expect on Monday than if the admissions were occurring at random. For the 30 conditions with the most evidence of excess mortality on the weekend there are 11.8% more admissions on Monday than we would expect if they were occurring at random. This clear association between the Monday spike and the amount of excess mortality on the weekend is probably driving the slight and statistically insignificant difference in the mortality rates between the weekday and the weekend that I am finding in the California hospitals.

The patients entering the Emergency Department in Canada are more ill and are in general more likely to enter the hospital on a weekday than the patients entering California Emergency Departments. Canadian Emergency Departments have higher mortality rates for every condition. In figure 7 I have plotted the mortality rate for Emergency Department admissions in Canada against the mortality rate in California condition by condition. The patients entering the hospital through the Emergency Department in Canada are clearly higher risk than the patients entering the hospital through the Emergency Department in California. Figure 8 plots the admissions ratios in California against the admissions ratios in Canada. Conditions that have more weekday admissions than we would expect in California also have more weekday admissions than we would expect in Canada. The mechanism that is causing the excess weekday admissions in Canada appears to be operating in a fashion similar to the mechanism in California. However in Canada for most conditions the selection is much more pronounced.

When I examine the relationship between the admissions ratios and the evidence of excess mortality on the weekend in the Canadian dataset the results are striking. Figure 9 plots the ratio of weekend to weekday admissions against the differences the mortality rates for the Canadian dataset. The solid circles denote individual conditions for which Bell and Redelmeier found significant evidence of excess mortality on the weekend. The relationship between the amount of sorting and the amount of mortality on the weekend is striking. Conditions with the most excess admissions on weekdays have the most evidence of excess mortality on the weekend. This significant relationship between the amount of sorting and the mortality rates probably reflects triage in the Emergency Department. If only the sickest patients are admitted to the hospital on the weekend the patients admitted on the weekend will have a higher mortality rate than the patient population in general. For a given condition the more triage there is the greater the difference in mortality rates between the weekday and the weekend admissions. In the next section I will try three ways of dealing with the bias introduced by the disproportionate number of weekday admissions in the Canadian dataset. Since the patient level data is unavailable I will work with the data at the level of the condition.

5.6 Three ways of correcting for the selection in the Canadian data

In this section I implement three different ways of correcting for the association between the admissions rate and the mortality rate documented above. I do not have access to the patient level data so I am unable to estimate models with covariates. Instead I take advantage of the admissions ratios which provide me with a direct measure of the amount of selection that is occurring.

The most conservative way to proceed is to assume that all the additional people appearing during the week are surviving and to re-estimate the odds ratios under this assumption. From an estimation perspective this is the worst case scenario and would create a large bias in estimates of the excess mortality on the weekend in Canada. I can put a lower bound on the mortality estimates by assuming none of the people who deferred coming in until a weekday died and reassign them back to the weekend. When I do this not one of the 23 conditions that showed evidence of excess mortality on the weekend in the Canadian dataset still does. This is probably overly pessimistic as some of the people that defer entering the hospital probably die.

An alternative is to estimate the mortality rate for conditions that show no evidence of selection. There are nine conditions that have weekend-to-weekday admissions ratios that are not statistically different from 2/7. These nine conditions account for 267,775 admissions. The weekday mortality rate in this group is 4.83%. The weekend mortality rate is 4.63%. This approach reveals no evidence in favor of excess mortality on the weekend but is limited in power due to the reduced sample size.

An alternate approach that works with the entire sample and corrects for the bias instead of estimating a lower bound is to run a regression that corrects for the bias using the method developed above. I start with an estimate of the difference in the mortality rate between the weekend and weekdays.

$$\textit{Weekend - Weekday mortality condition c} = \tau$$

This gives me an estimate τ of .00534 which is statistically significantly different from zero (Column 1 of table 9). This is equivalent to an additional 524 deaths per 100,000 admissions. If there were no selection this would be an unbiased estimate of the weekend treatment effect.

Since I am finding clear evidence of selection in figure 9 I need to take steps to correct for it. I implement two different strategies. In the first approach I assume that the patients who defer coming in until a weekday are dying at a constant fraction B of the mortality rate for people admitted on the weekend. This makes it possible to estimate τ while adjusting for the bias. In this equation α_c is the percent of patients that defer coming in and M_{ec} is the weekend mortality rate for condition c.[9]

$$\textit{Weekend - Weekday mortality condition c} = \tau + (1-B)\frac{7\alpha_c M_{ec}}{5+2\alpha_c}$$

When I run this regression I get an estimate of B and τ of and .59 and -0.00121 respectively. The estimate of τ is not statistically different from zero (Column 2 of table 9). This suggests that even if the patients who deferred coming in were dying at only 60% of the rate of patients that came in on the weekend it would explain away the entire difference in mortality between the weekend and the weekdays. An alternative way of correcting for the selection that makes no assumptions about the mortality rate of the additional patients that are deferring entering the hospital would be to compare the mortality rate of weekend admissions with the mortality rate of weekday admissions, adjusting for the cross over rate,

[9] The motivation for this equation was presented in the methods section

α_c, and the square of the cross over rate α_c^2. If the mortality difference between the weekend and weekdays is not being driven by some characteristic of the patients who are deferring entering the hospital then it should be unaffected by including a measure of the number of patients crossing over for each condition. The equation that I estimate is.

$$\textit{Weekend - Weekday mortality condition } c = \tau + \alpha_c + \alpha_c^2$$

This regression reveals a mortality differential between the weekday and the weekend of –0.00015 which is not significantly different from zero (Column 3 of table 9).

Though the patients admitted during the weekday and the weekend in the Canadian dataset have very similar observable characteristics and Bell and Redelmeier's results were robust to the inclusion of covariates, there is a serious problem with selection on unobservable characteristics. The four different approaches above all found no evidence in support of excess mortality on the weekend. There appears to be a significantly less ill subpopulation that is deferring entering the hospital until a weekday. This subpopulation appears to be driving the differences in the mortality rate documented in the paper by Bell and Redelmeier.[10]

6. Conclusions

I find no evidence of excess mortality on the weekend in the California hospital system for people admitted through the Emergency Department. This is despite a significant delay in diagnostic and treatment procedures for patients admitted on the weekend. The research design I implemented above has the rare property that the selection is observable. This makes it possible to examine the impact of relatively small amounts of selection on the results. I find that even a small amount of selection can generate statistically significant spurious results that are robust to the inclusion of covariates that are typically available in hospital discharge datasets. The one published study that found evidence of excess mortality

[10] Bell and Redelmeier also find evidence of excess mortality for three conditions they expect to be particularly vulnerable to a reduction in care. These conditions are abdominal aortic aneurysm, acute epiglottitis and pulmonary embolism. There is no evidence of excess mortality on the weekend for these conditions in California even without adjusting for covariates. The admissions ratios for these three conditions in the Canadian dataset are .322, .462 and .292 respectively. The ratios in California are much closer to .4 they are .365, .439 and .365 respectively. (Table available on request)

among patients admitted through the Emergency Department on the weekend appears to be documenting a spurious result due to selection caused by hospital triage.

This study reveals that, even when the covariates of the patients being compared are much closer than in the across-hospital comparisons typical in the literature, selection can still be a serious problem. Even when the comparison is being made within-hospital so that fixed differences between hospitals are not a problem, doctor's and patient's responses to scarce resources can have a confounding effect. The patients who have the scarce resources available on the weekend allocated to them are more ill on average than the patients entering the hospital on other days of the week. In a setting where the allocation of scarce resources results in a significant amount of selection and the selection is unrecognized, it can create the appearance of a positive relationship between the resources available and patient's outcomes.

Hospitals have rational motives to reduce staffing on the weekend. The social cost of maintaining a constant staffing level is higher on the weekend. Hospital staff that is required to work on the weekend is forced to give up time they could spend with their families. The hospitals have responded by reducing the staffing and services provided on the weekend. This reduction in staffing has two effects. Some patients, particularly at county hospitals, are unable to enter the hospital on the weekend and have to defer coming in until Monday. The patients who are admitted to the hospital on the weekend are receiving fewer services in the first few days after they enter the hospital. The hospital staff appears to be doing a good job of allocating the relatively scarce resources on the weekend because there is no evidence that the temporary reduction in services is resulting in a higher probability of dying for patients admitted on the weekend.

What this study tells us about the relationship between staffing and mortality is more limited. That a short term reduction in the ratio of doctors to patients is not resulting in a higher mortality rate among patients suggests that there is no strong relationship between the number of doctors on site and the probability that an error that will results in a patients dying will occur. However this does not tell us what would occur if staffing levels were permanently reduced. A permanent reduction in staff to the weekend level would be unable to handle the influx of additional patients that occurs on Monday and also would not be able to provide all the additional procedures that were deferred for patients that entered the hospital on the weekend.

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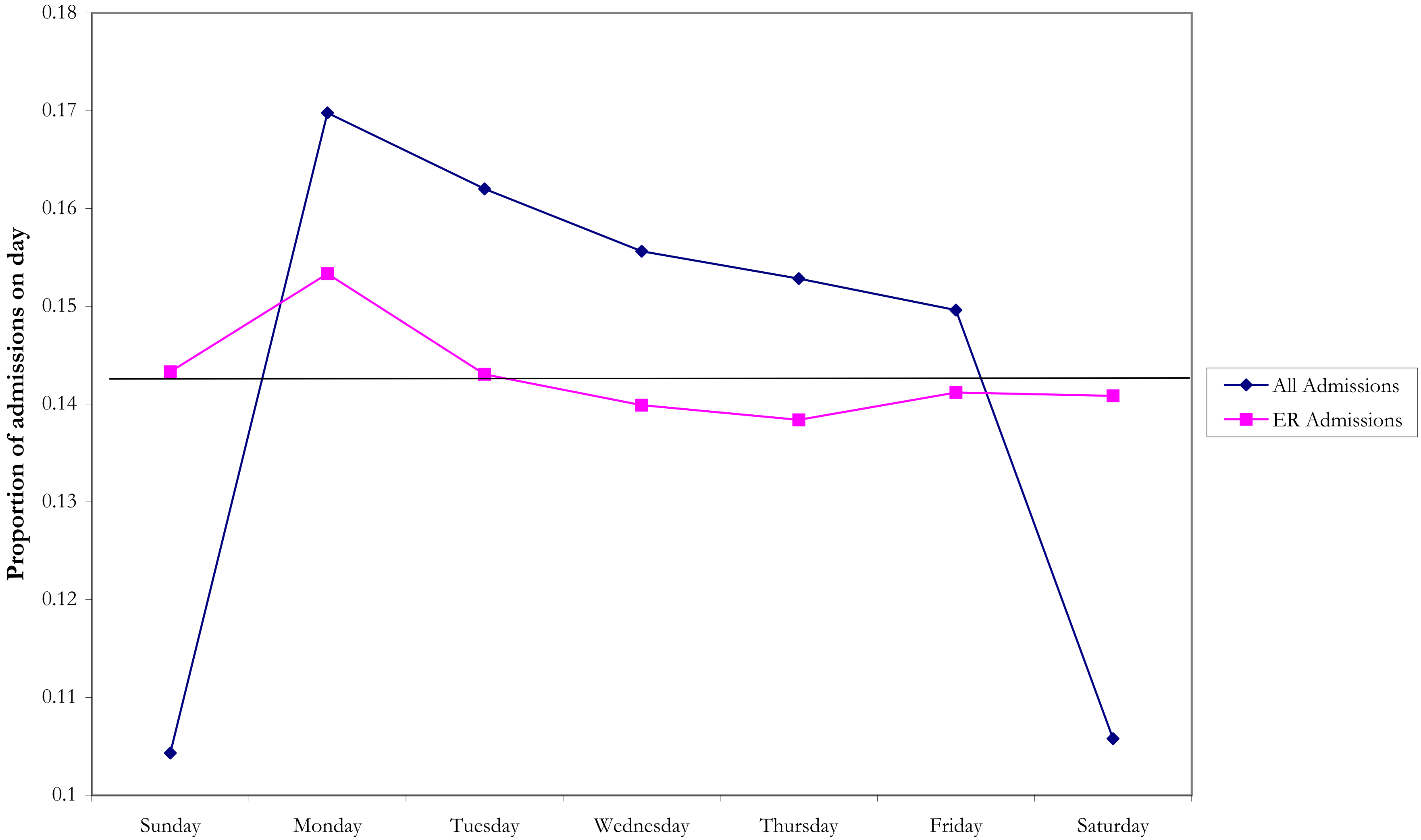
Figure 1: Comparing ER Admissions With All Hospital Admissions



*Note this figure is not scaled to 0

**The horizontal line denotes the admissions we would expect if patients were entering the hospital at random

Figure 2: Hospital Admission Ratios California vs Canada (Top 100 Causes of Death)

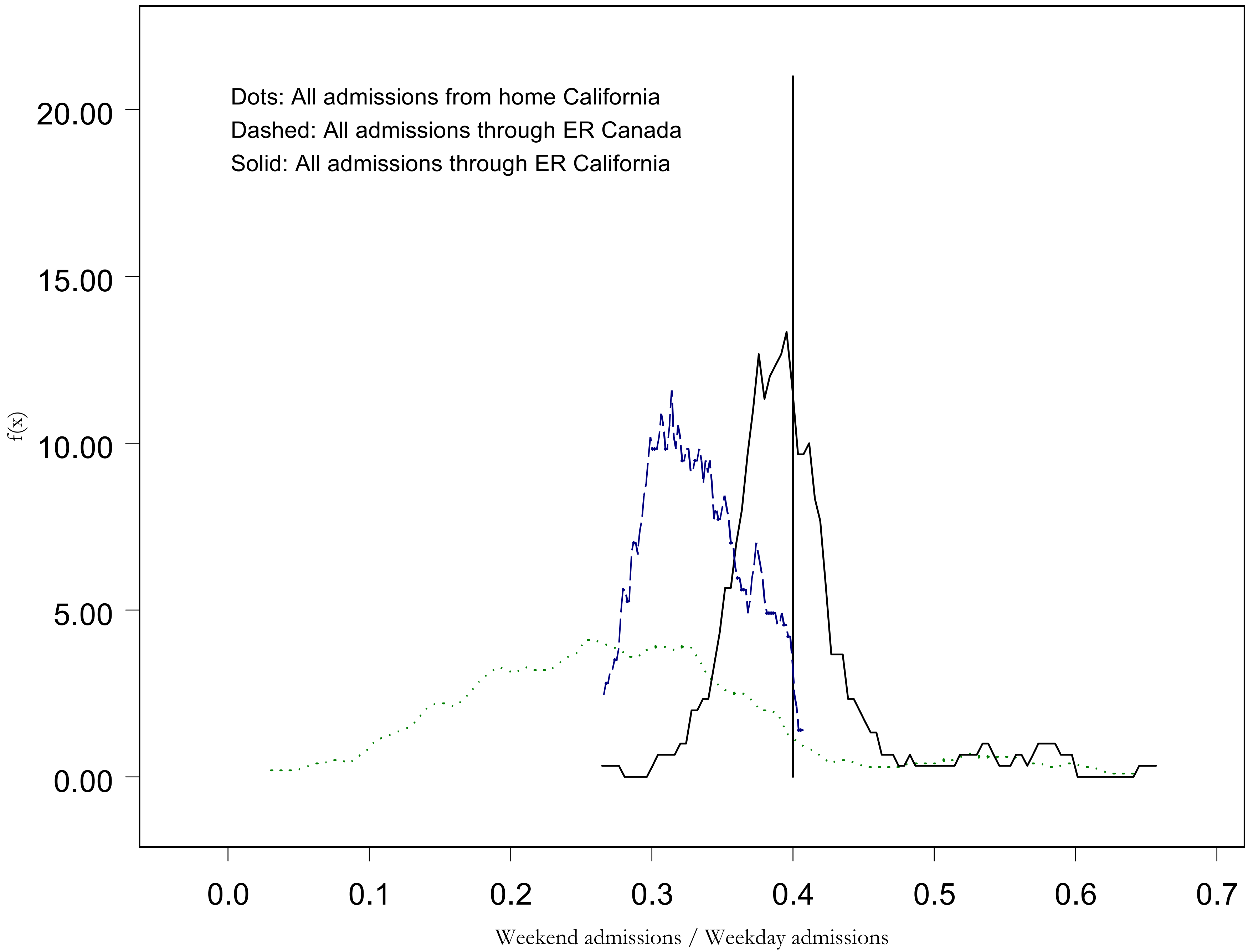
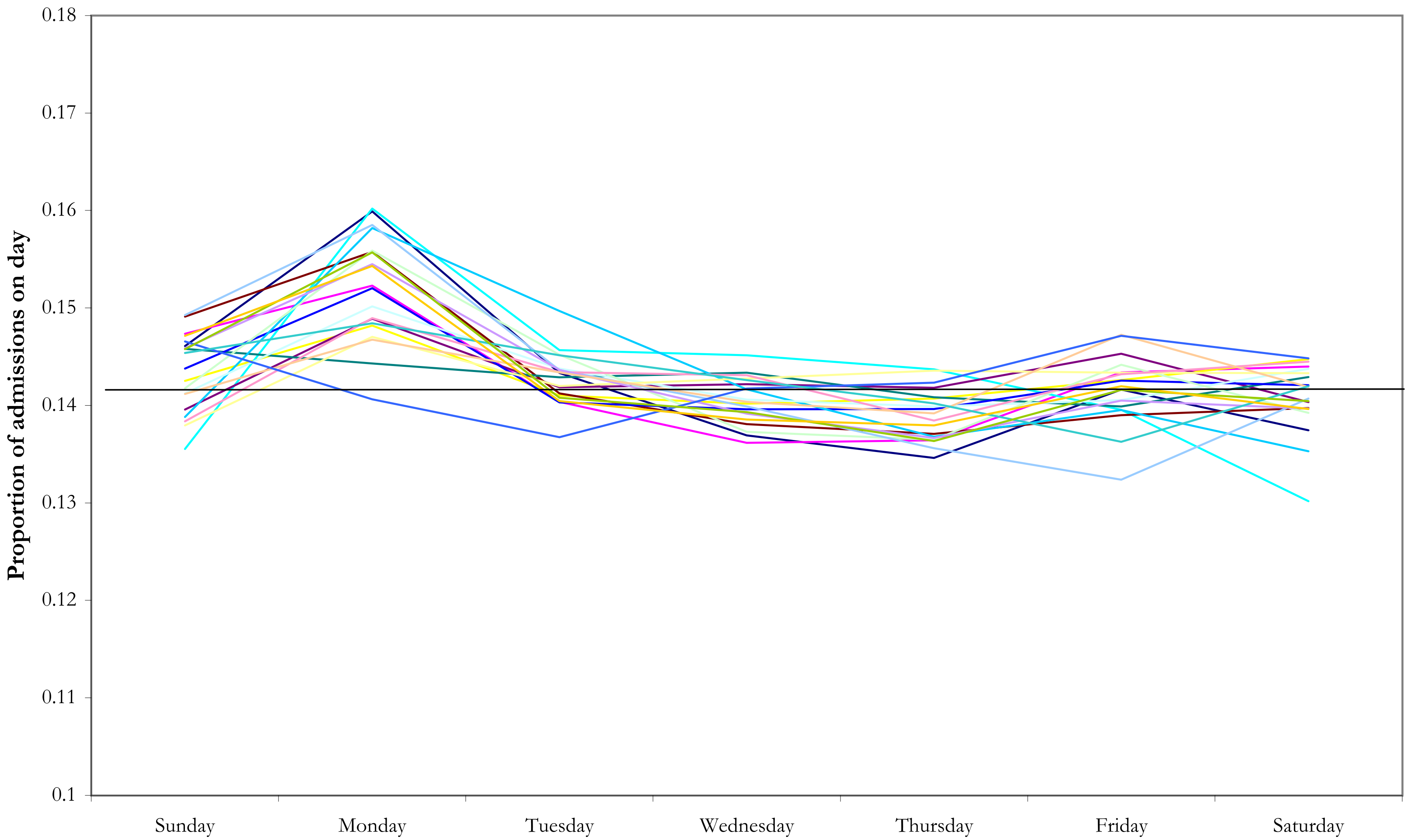


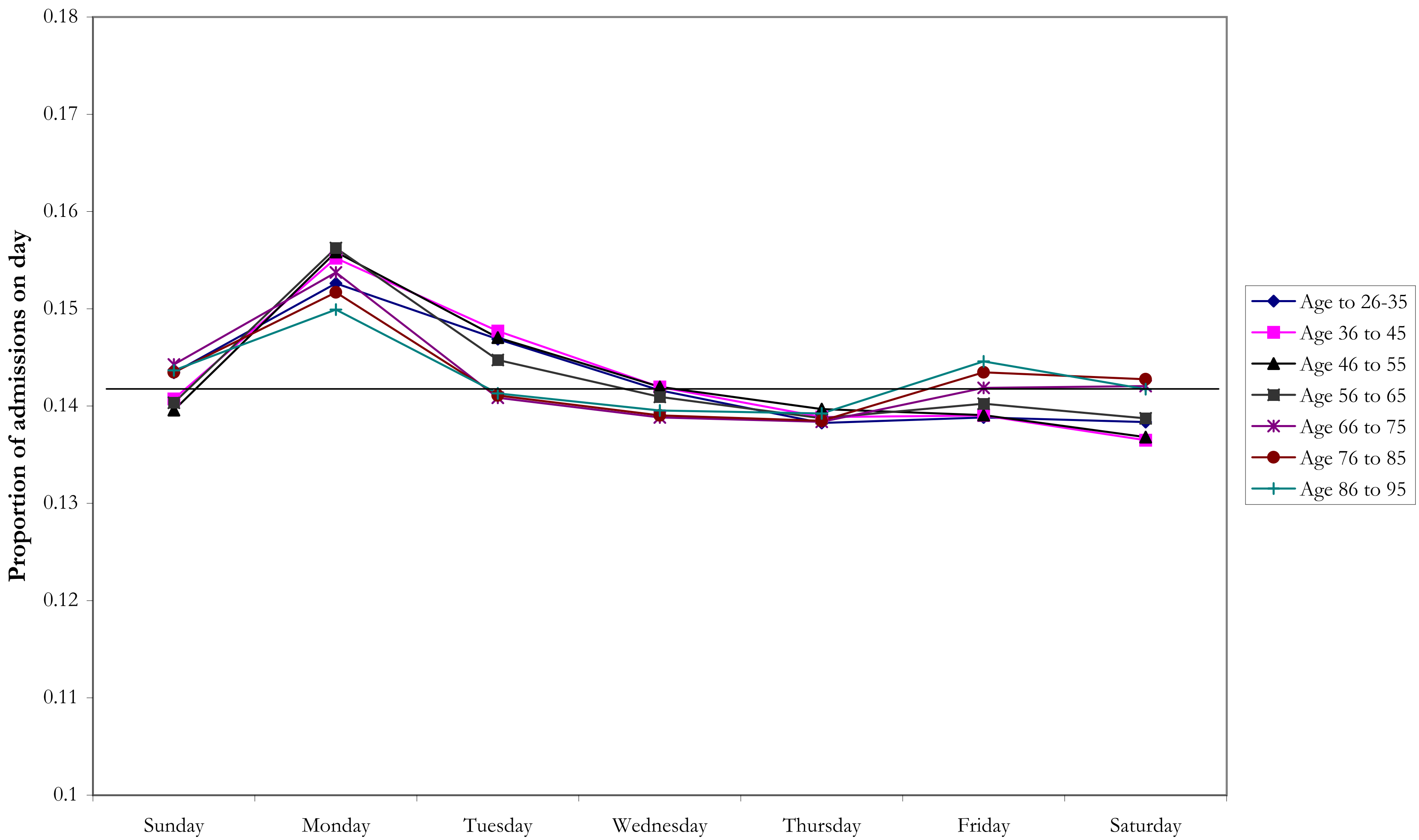
Figure 3: Weekly Patterns for the Top 20 Causes of Hospital Admission



*Note this figure is not scaled to 0

**Most other causes of admissions show a similar spike on Mondays with the exception of external causes which peak on the weekend.

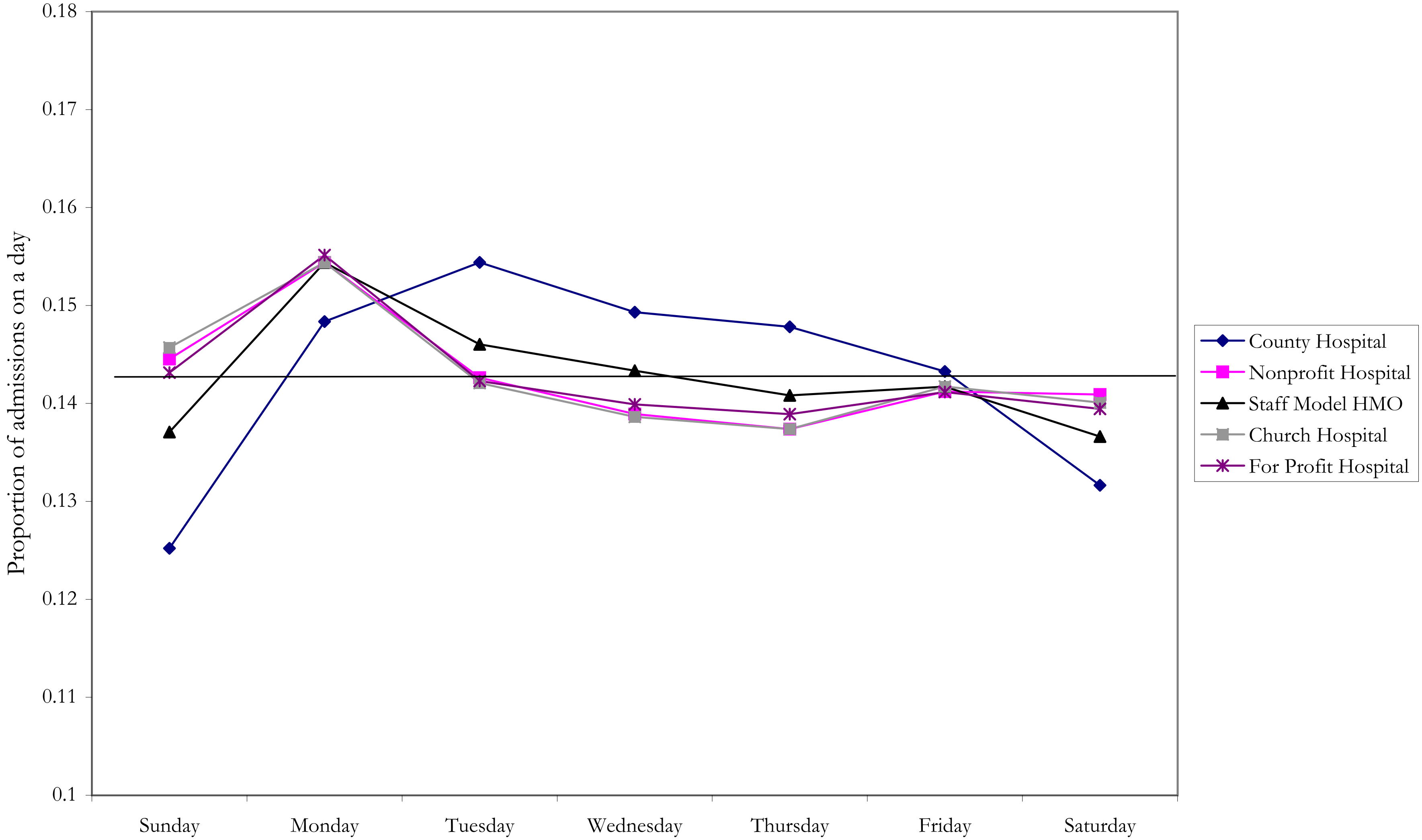
Figure 4: Daily Admission Cycle by Age



*Note this figure is not scaled to 0

**These admission patterns are for the emergency room admissions that are the 100 top causes of death

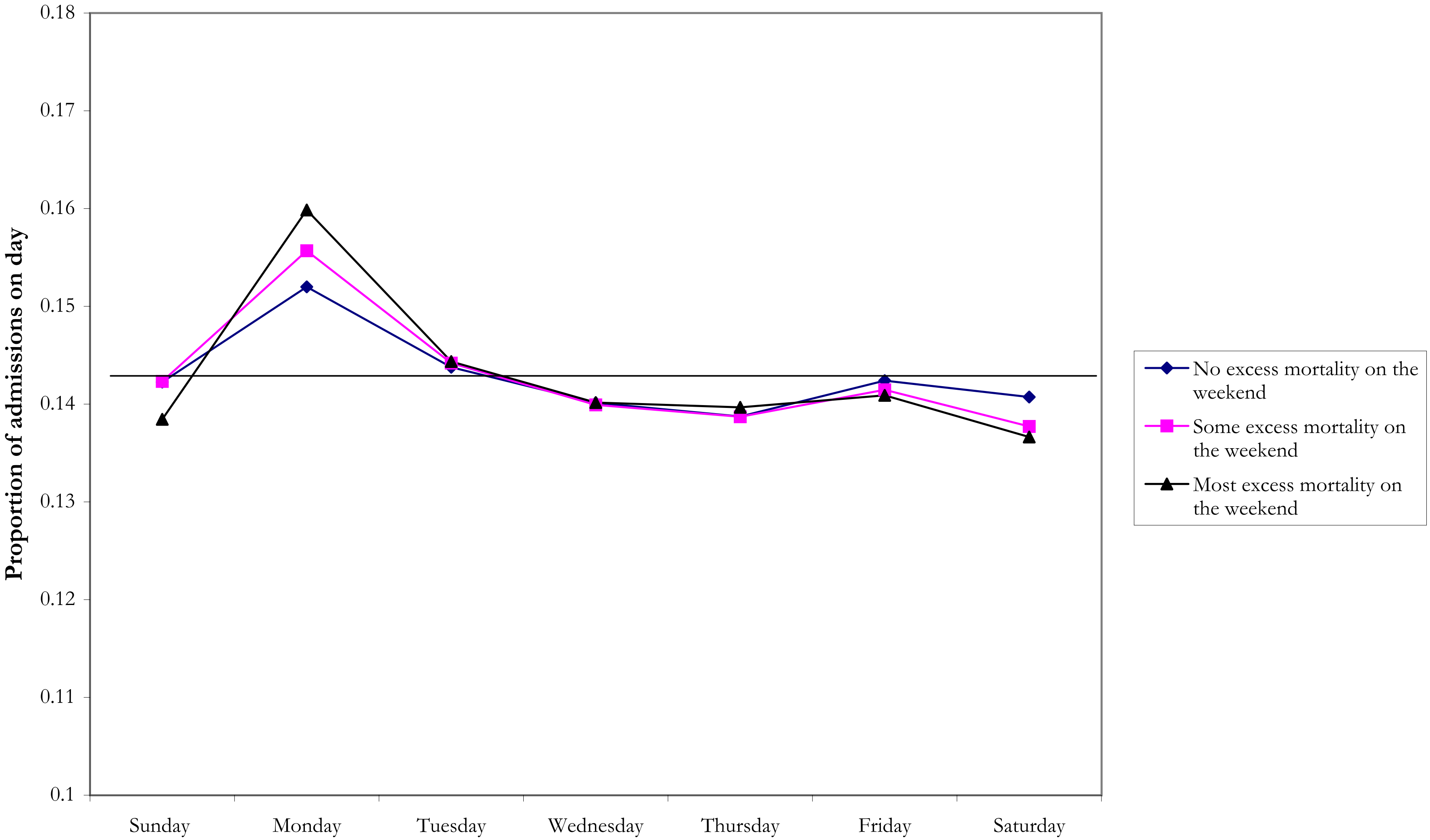
Figure 5: Hospital Admissions by Hospital Type



*Note the chart is not scaled to 0

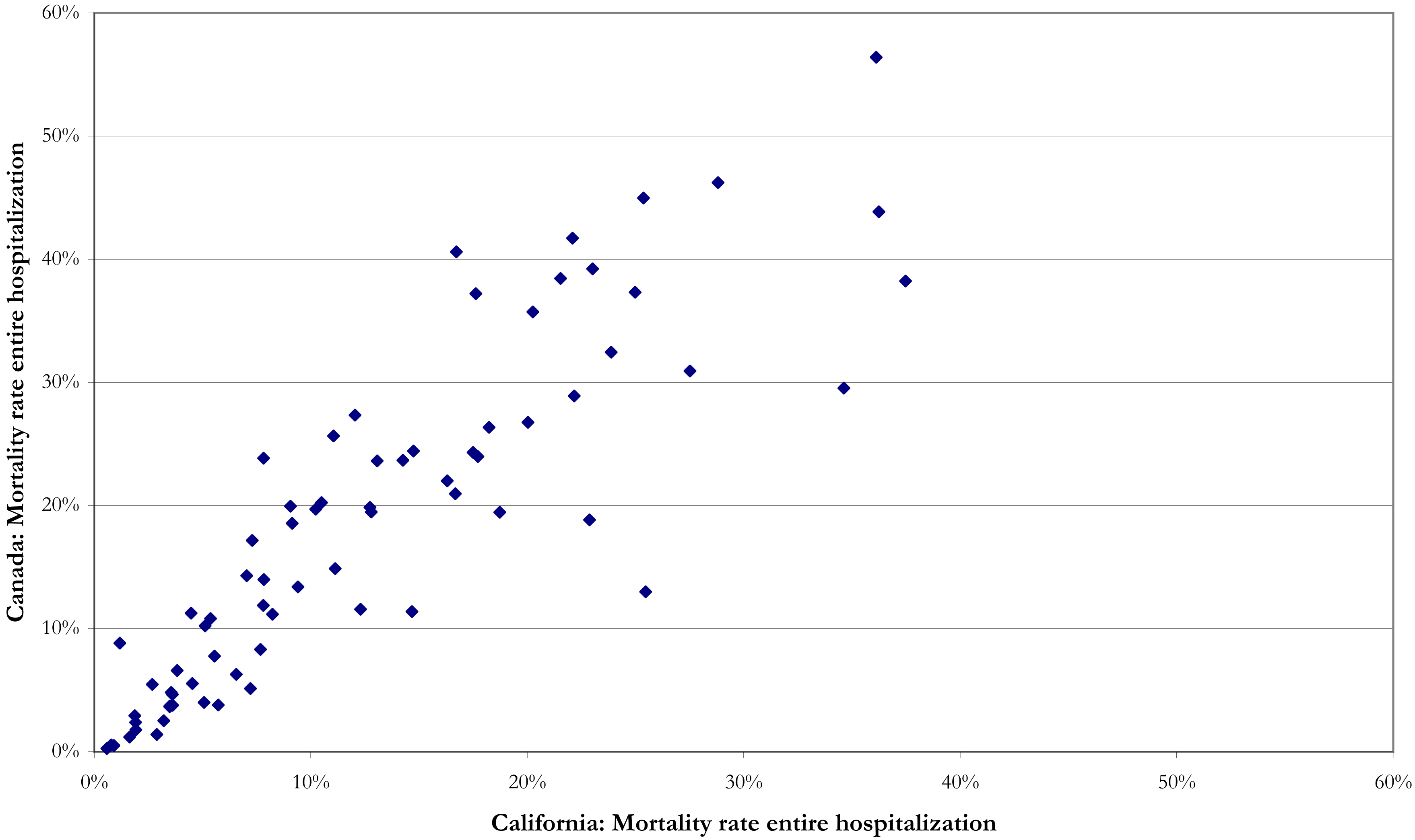
**These charts are generated using all California Emergency Room admissions for each hospital type

Figure 6: California ER Daily Admission Rates by Excess Mortality Rate



*The top 100 Causes of death are broken up into three even groups based on how much evidence of excess mortality there is among weekend admissions.

Figure 7: Mortality Rates for Californian vs Canadian ER Admissions



*Mortality rates are for the entire hospitalization

**The mortality rates are for the 73 conditions that are among the top 100 causes of death in both datasets

Figure 8: Differences in Admission Ratios

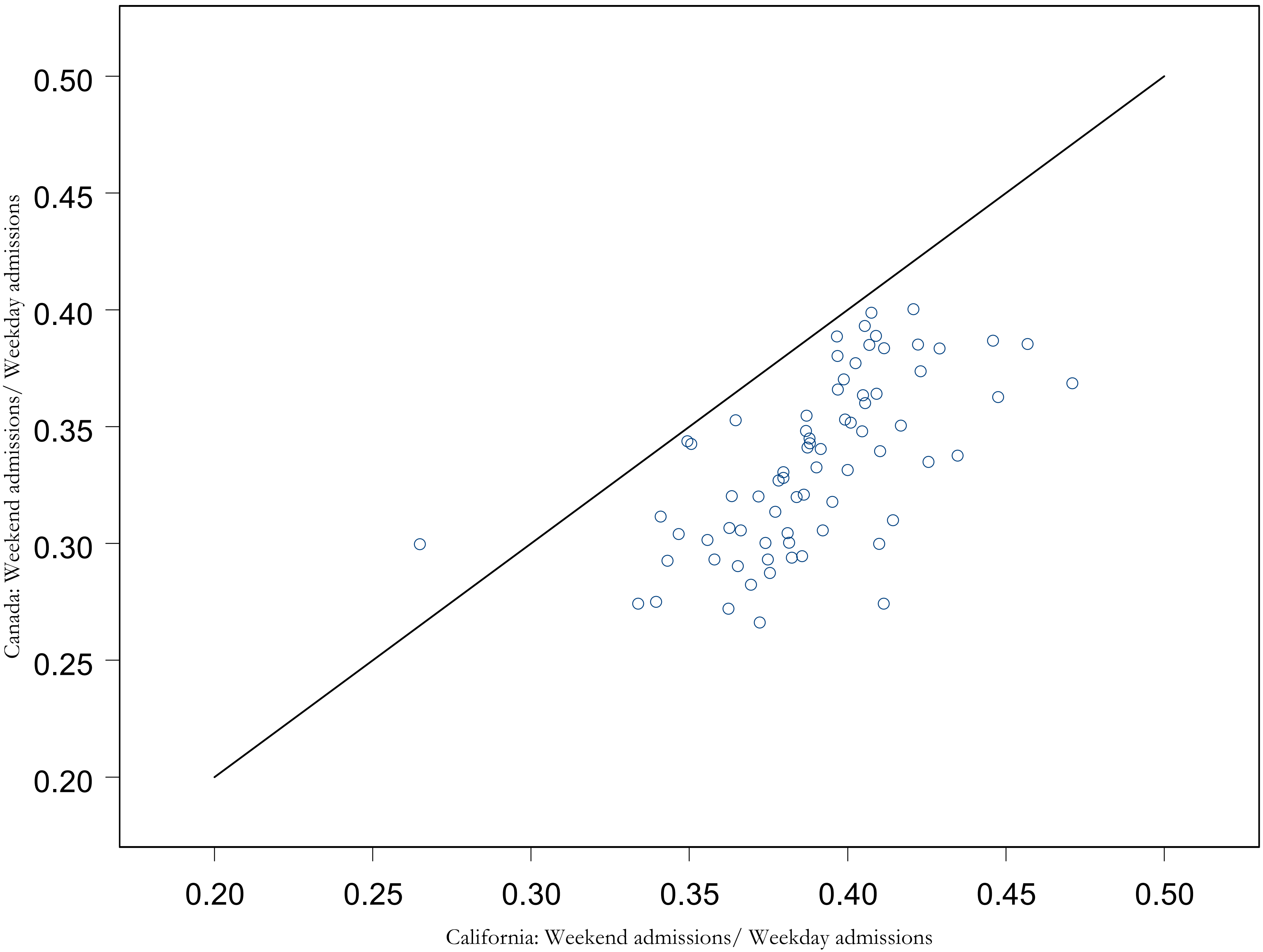


Figure 9: Bell and Redelmeier Results Top 95 Non-Trauma Conditions

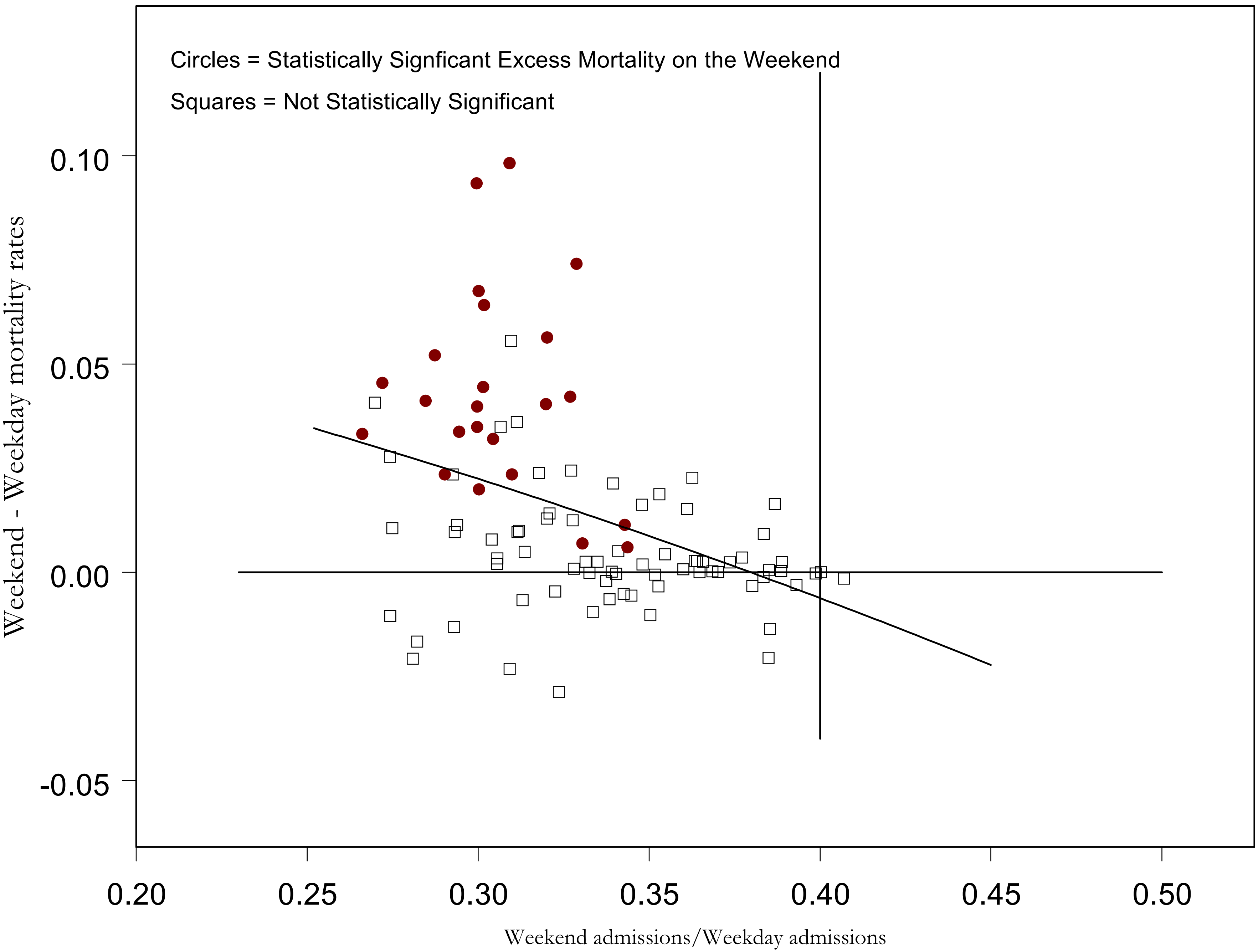


Table 1a: Patient Demographics for the Two Largest Hospitals of Each Type in California

	Private Proprietary		Private Nonprofit		District		County	
	Largest	Second Largest	Largest	Second Largest	Largest	Second Largest	Largest	Second Largest
Length of Stay (first admission)	5.50	4.37	6.14	4.54	3.96	4.40	5.73	5.35
Age of Patient	58.70	61.40	61.79	65.58	66.69	60.88	39.80	41.39
Percent male	49.19%	49.24%	48.15%	44.16%	44.12%	44.50%	52.57%	46.42%
Percent White	88.24%	95.01%	75.20%	90.90%	89.84%	91.77%	35.11%	26.39%
Percent Black	3.26%	1.11%	16.27%	4.12%	1.47%	4.39%	15.28%	22.11%
Percent Asian	1.63%	3.05%	2.97%	3.06%	0.31%	2.12%	5.70%	7.95%
Percent Hispanic	13.67%	7.86%	6.25%	12.47%	7.39%	6.10%	66.76%	57.05%
Description of condition								
Counts of diagnosis	5.69	4.86	4.83	5.76	4.04	5.46	2.55	2.50
Counts of procedures	1.69	1.79	0.71	0.93	1.25	0.66	0.67	0.57
Injury due to external causes	23.34%	23.41%	17.20%	15.42%	13.16%	17.97%	25.06%	13.06%
Insurance type								
Medicare	45.90%	38.34%	49.12%	64.83%	72.07%	51.36%	4.90%	8.24%
HMO	12.61%	31.75%	13.11%	7.42%	5.83%	11.14%	0.53%	0.20%
Medi-Cal	17.03%	4.21%	11.07%	10.07%	11.76%	16.38%	48.29%	44.87%
PPO	12.52%	15.31%	13.68%	11.55%	2.01%	4.56%	0.01%	0.11%
Private	4.36%	2.68%	3.19%	3.36%	3.20%	6.31%	1.28%	2.87%
Self Pay	2.69%	2.91%	7.97%	2.13%	2.94%	4.29%	17.66%	0.18%
County Indigent	3.73%	3.81%	0.01%	0.03%	1.19%	4.86%	19.22%	38.74%
Other Government	0.20%	0.38%	1.21%	0.03%	0.11%	0.55%	7.49%	4.33%
Workers comp	0.91%	0.53%	0.43%	0.59%	0.89%	0.53%	0.59%	0.43%
Other payer	0.05%	0.06%	0.16%	0.00%	0.00%	0.00%	0.02%	0.02%
Unknown	0.00%	0.00%	0.04%	0.00%	0.01%	0.01%	0.00%	0.00%
Total admissions	26,445	26,662	58,675	41,238	42,593	37,366	176,133	78,771

*The demographics are for all admissions for the top 100 causes of death between 1995 and 1999

Table 1b: Patient Demographics by Route Into the Hospital

	All admissions		All unscheduled admissions from home through ER	
Admission type	**Weekend**	**Weekday**	**Weekend**	**Weekday**
From Home	86.82%	83.04%	**100.00%**	**100.00%**
Through ER	78.38%	50.49%	**100.00%**	**100.00%**
Unscheduled	93.26%	77.49%	**100.00%**	**100.00%**
Length of Stay (first admission)	5.83	6.79	5.13	5.18
Age of Patient	64.67	64.59	63.92	63.97
Percent male	47.83%	48.06%	**48.44%**	**48.49%**
Race				
Percent White	76.86%	77.95%	76.29%	75.75%
Percent Black	9.78%	9.07%	10.13%	10.60%
Percent Asian	5.96%	5.84%	**5.90%**	**5.93%**
Percent Hispanic	15.86%	15.37%	16.70%	17.02%
Description of condition				
Counts of diagnosis	5.46	5.31	5.34	5.39
Counts of procedures	1.27	1.39	**1.25**	**1.25**
Injury due to external causes	13.99%	11.19%	14.68%	13.95%
Insurance type				
Medicare	54.96%	54.82%	53.26%	52.98%
HMO	15.43%	15.84%	15.11%	14.70%
Medi-Cal	12.60%	12.06%	13.62%	14.58%
PPO	6.10%	7.10%	6.05%	5.63%
Private	3.62%	3.74%	3.70%	3.38%
Self Pay	3.20%	2.44%	**3.78%**	**3.76%**
County Indigent	2.48%	2.23%	2.99%	3.36%
Other Government	**0.75%**	**0.75%**	0.65%	0.71%
Workers comp	0.29%	0.49%	0.28%	0.35%
Other payer	0.42%	0.39%	**0.43%**	**0.43%**
Unknown	**0.13%**	**0.13%**	**0.12%**	**0.13%**
Total admissions	1,167,399	4,388,902	989,127	2,491,867
Ratio		0.265988851		0.396942132

*If the differences between the weekday and weekend admissions are not significant they are presented in bold

**The demographics are for admissions for the top 100 causes of death between 1995 and 1999

Table 1c: Percent of Patients Admitted to Nearest Hospital

	Planned Admissions	Emergency Room Admissions
All Admissions	21.95%	31.35%
Race		
Black	14.45%	21.31%
White	23.39%	33.88%
Insurance type		
Medi-Cal	19.07%	27.62%
Medicare	25.35%	35.49%
HMO	16.80%	24.13%
PPO	19.25%	30.93%
Private	21.10%	33.38%

*Distance from residence to hospital to is calculated using the population centroid of the residential zip code and the exact location of the hospital. It was not possible to calculate a distance for 2% of the admissions due to missing residential zip code. The numbers presented above are for all admissions from home between 1995-1999

Table 2: Staffing of Doctors and Support Staff on Weekends and Weekdays

Staffing of doctors

	Staff Model HMO		County Hospital		Church Hospital		Private Nonprofit	
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
ICU Medical Attendings	1	1	1	1	1	1	2 [1]	3
ICU Medical Residents	3 [2]	4	4-5 [2-3]	7 [2]	3-4	5	4-6 [2-4]	6
General Medical Attendings	7	8	1 [1]*	1*	3 [2]	3	3-4 [3-4]	4
General Medical Residents	12 [9]	14	4-5 [1-2]*	6*	7-8 [5]	8-9	8-10 [5-7]	10-12
Rehabilitation Attendings	NA	NA	1 [1]	5	1 [1]	2	1 [1]	2
Rehabilitation Residents	NA	NA	1	4	0	2	1 [1]	3

[ ] Indicates that this number of doctors may leave early

*For these observations the numbers are for a single team

NA Not Available

Other Staff and Tests

	Staff Model HMO		County Hospital		Church Hospital		Private Nonprofit	
	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday
Respiratory therapists	5-6	5-6	7-9	8-10	3-4	4	8	8
X-ray technicians	5	10	5	12	3	7	4	15
How long to get MRI**	Transfer	0-8 hrs	On call	0-4 hrs	Transfer	0-12 hrs	1-8 hrs	0-4 hrs
How long to get CAT Scan**	0-2 hrs	0-1 hrs	1-3 hrs	0-2 hrs	1-2 hrs	0-2 hrs	0-4 hrs	0-1 hrs

**The time needed to get tests run are estimates made by doctors working at the hospitals. The actual times vary from week to week depending on caseload

***The staffing numbers above are for one representative hospital of each type, nurses are not included because their staffing levels don't vary on the weekly cycle

****The times to get tests run are for emergent studies

Table 3: Procedures Performed After Admission Through the ER

	All Hospitals*		
	Weekend	Weekday	Difference
Diagnostic Procedures			
First Day	0.513	0.547	6.68%
First Two days	0.723	0.793	9.70%
During admission	1.183	1.188	0.39%
All Procedures			
First Day	0.664	0.721	8.62%
First Two days	0.996	1.119	12.37%
During admission	1.838	1.862	1.32%
Observations	967,034	2,450,087	

*This is for inpatient admissions for internal causes in California 1995-1999

	Staff Model HMO**			County Hospitals**		
	Weekend	Weekday	Difference	Weekend	Weekday	Difference
Diagnostic Procedures						
First Day	0.504	0.546	8.33%	0.544	0.550	0.97%
First Two days	0.722	0.816	13.06%	0.696	0.725	4.26%
During admission	1.221	1.224	0.28%	1.100	1.080	-1.82%
All Procedures						
First Day	0.637	0.699	9.81%	0.702	0.726	3.34%
First Two days	0.961	1.103	14.77%	0.949	1.019	7.40%
During admission	1.725	1.749	1.38%	1.716	1.720	0.25%
Observations	109,401	288,956		64,590	185,518	

	Church Hospitals**			Private Nonprofit**		
	Weekend	Weekday	Difference	Weekend	Weekday	Difference
Diagnostic Procedures						
First Day	0.409	0.447	9.20%	0.506	0.542	7.27%
First Two days	0.608	0.686	12.70%	0.725	0.798	10.09%
During admission	1.073	1.079	0.56%	1.195	1.205	0.82%
All Procedures						
First Day	0.556	0.620	11.65%	0.653	0.714	9.33%
First Two days	0.890	1.027	15.38%	0.999	1.131	13.17%
During admission	1.792	1.818	1.46%	1.876	1.908	1.67%
Observations	142,434	353,742		374,825	930,233	

**These are for admissions due to internal causes for all hospitals each type

Table 4: All Patients Admitted From Home*

	(1)	(2)	(3)
Weekend Admission	0.346	0.269	0.262
	[0.009]	[0.009]	[0.009]
Male		0.173	0.165
		[0.008]	[0.008]
Age 18-40		0.167	0.144
		[0.042]	[0.042]
Age 40-50		0.122	0.127
		[0.042]	[0.042]
Age 50-60		0.154	0.173
		[0.041]	[0.041]
Age 60-70		0.265	0.345
		[0.040]	[0.041]
Age 70-80		0.421	0.552
		[0.040]	[0.041]
Age > 80		0.863	0.998
		[0.040]	[0.040]
Black		-0.195	-0.187
		[0.016]	[0.016]
Asian		0.062	0.047
		[0.016]	[0.017]
Hispanic		-0.074	-0.087
		[0.012]	[0.012]
External		-0.261	-0.273
		[0.013]	[0.013]
1996		0.193	0.196
		[0.013]	[0.013]
1997		0.093	0.096
		[0.013]	[0.013]
1998		0.053	0.055
		[0.013]	[0.013]
1999		0.023	0.029
		[0.013]	[0.013]
Severity		1.76	1.759
		[0.006]	[0.006]
Constant	-4.489	-5.87	-6.023
	[0.005]	[0.040]	[0.041]
Dummies for Insurance type	No	No	Yes
Observations	5,556,301	5,556,301	5,556,301

Robust standard errors in brackets, the dependent variable is mortality in the first day after admission

*These are logistic regression run on all patients who arrived from home including 2,075,307 planned admissions

Table 5: Emergency Room Admissions*

	(1)	(2)	(3)
Weekend Admission	0.024	0.025	0.022
	[0.009]	[0.010]	[0.010]
Male		0.171	0.161
		[0.009]	[0.009]
Age 18-40		0.046	0.030
		[0.047]	[0.047]
Age 40-50		-0.016	-0.010
		[0.047]	[0.047]
Age 50-60		0.010	0.020
		[0.046]	[0.046]
Age 60-70		0.118	0.179
		[0.045]	[0.045]
Age 70-80		0.268	0.376
		[0.045]	[0.045]
Age > 80		0.655	0.769
		[0.044]	[0.045]
Black		-0.266	-0.244
		[0.017]	[0.017]
Asian		0.067	0.069
		[0.018]	[0.018]
Hispanic		-0.095	-0.091
		[0.013]	[0.013]
External		-0.300	-0.313
		[0.014]	[0.014]
1996		0.167	0.169
		[0.014]	[0.014]
1997		0.055	0.056
		[0.014]	[0.014]
1998		0.007	0.009
		[0.014]	[0.014]
1999		-0.032	-0.026
		[0.014]	[0.014]
Severity		1.681	1.681
		[0.007]	[0.007]
Constant	-4.111	-5.317	-5.450
	[0.005]	[0.045]	[0.046]
Dummies for Insurance type	No	No	Yes
Observations	3,480,994	3,480,994	3,480,994

Robust standard errors in brackets, the dependent variable is mortality in the first day after admission

*These are logistic regression run on all patients who are admitted through the ER and arrived from home

Table 6: All Admissions Through the Emergency Room (Internal Causes)

	(1)	(2)	(3)
Weekend Admission	0.008	0.007	0.004
	[0.010]	[0.010]	[0.010]
Male		0.115	0.108
		[0.009]	[0.009]
Age 18-40		0.795	0.796
		[0.089]	[0.089]
Age 40-50		1.102	1.107
		[0.088]	[0.088]
Age 50-60		1.164	1.163
		[0.088]	[0.088]
Age 60-70		1.294	1.328
		[0.087]	[0.088]
Age 70-80		1.455	1.524
		[0.087]	[0.088]
Age > 80		1.852	1.925
		[0.087]	[0.087]
Black		-0.283	-0.262
		[0.018]	[0.018]
Asian		0.033	0.043
		[0.019]	[0.019]
Hispanic		-0.143	-0.127
		[0.014]	[0.014]
External		-0.762	-0.762
		[0.020]	[0.020]
1996		0.171	0.172
		[0.015]	[0.015]
1997		0.059	0.060
		[0.015]	[0.015]
1998		0.010	0.010
		[0.015]	[0.015]
1999		-0.027	-0.023
		[0.015]	[0.015]
Severity		1.677	1.676
		[0.007]	[0.007]
Constant	-4.122	-6.425	-6.516
	[0.005]	[0.087]	[0.088]
Dummies for Insurance type	No	No	Yes
Observations	3,302,360	3,302,360	3,302,360

Robust standard errors in brackets, the dependent variable is mortality in the first day after admission

*These are logistic regression run on ER admissions due to causes identified as internal based on ICD-9

Table 7: All Patients Admitted From Home

	(1)	(2)	(3)	(4)	(5)	(6)
Weekend Admission	0.346	0.269	0.262	-0.057	-0.021	-0.025
	[0.009]	[0.009]	[0.009]	[0.019]	[0.019]	[0.019]
Male		0.173	0.165		0.174	0.165
		[0.008]	[0.008]		[0.008]	[0.008]
Age 18-40		0.167	0.144		0.168	0.146
		[0.042]	[0.042]		[0.042]	[0.042]
Age 40-50		0.122	0.127		0.122	0.127
		[0.042]	[0.042]		[0.042]	[0.042]
Age 50-60		0.154	0.173		0.156	0.174
		[0.041]	[0.041]		[0.041]	[0.041]
Age 60-70		0.265	0.345		0.267	0.347
		[0.040]	[0.041]		[0.040]	[0.041]
Age 70-80		0.421	0.552		0.422	0.553
		[0.040]	[0.041]		[0.040]	[0.041]
Age > 80		0.863	0.998		0.859	0.994
		[0.040]	[0.040]		[0.040]	[0.041]
Black		-0.195	-0.187		-0.200	-0.191
		[0.016]	[0.016]		[0.016]	[0.016]
Asian		0.062	0.047		0.059	0.045
		[0.016]	[0.017]		[0.016]	[0.017]
Hispanic		-0.074	-0.087		-0.076	-0.088
		[0.012]	[0.012]		[0.012]	[0.012]
External		-0.261	-0.273		-0.262	-0.273
		[0.013]	[0.013]		[0.013]	[0.013]
1996		0.193	0.196		0.191	0.194
		[0.013]	[0.013]		[0.013]	[0.013]
1997		0.093	0.096		0.090	0.093
		[0.013]	[0.013]		[0.013]	[0.013]
1998		0.053	0.055		0.050	0.053
		[0.013]	[0.013]		[0.013]	[0.013]
1999		0.023	0.029		0.020	0.026
		[0.013]	[0.013]		[0.013]	[0.013]
Severity		1.760	1.759		1.755	1.754
		[0.006]	[0.006]		[0.006]	[0.006]
Selection				1.188	0.916	0.911
				[0.039]	[0.043]	[0.042]
Constant	-4.489	-5.870	-6.023	-4.361	-5.772	-5.926
	[0.005]	[0.040]	[0.041]	[0.007]	[0.040]	[0.042]
Dummies for Insurance type	No	No	Yes	No	No	Yes
Observations	5,556,301	5,556,301	5,556,301	5,556,301	5,556,301	5,556,301

Robust standard errors in brackets, the dependent variable is mortality in the first day after admission

*These are logistic regression run on all patients who arrived from home including 2,075,307 planned admissions

Table 8: Monday Admissions Through the Emergency Room 1995-1996

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sunday Admissions	0.14	0.115	0.125	0.122	0.104	0.089	0.096
	[0.006]	[0.006]	[0.006]	[0.006]	[0.006]	[0.006]	[0.006]
Sunday Inpatient Load		0.018	0.005	0.004		0.012	0.004
		[0.001]	[0.002]	[0.002]		[0.001]	[0.002]
Saturday Inpatient Load			0.014	0.013			0.009
			[0.002]	[0.002]			[0.002]
Constant	8.28	6.161	5.635	6.323	8.612	7.112	6.697
	[0.054]	[0.148]	[0.160]	[0.179]	[0.058]	[0.171]	[0.187]
Month Dummies	No	No	No	Yes	No	No	No
Fixed effects	Hospital	Hospital	Hospital	Hospital	Hospital/Month		
Observations	34,953	34,953	34,946	34,946	34,953	34,953	34,946
Number of Groups	406	406	406	406	4,636	4,636	4,635
R-squared	0.02	0.02	0.03	0.03	0.01	0.01	0.01

Standard errors in brackets

*For all models the dependant variable is Monday admissions

*These are OLS regressions on admissions counts at the hospital level

Table 9: Excess Mortality on the Weekend in Canada

	(1)	**(2)**	**(3)**
τ^*	0.00534	-0.00121**	-0.00015**
	[0.00246]	[0.00282]	[0.00701]
1 - B		0.41148	
		[0.00024]	
α_c			-0.01247
			[0.00041]
α_c^2			0.60592
			[0.00197]
Weight	Admissions	Admissions	Admissions
Observations	95	95	95
R-squared	0	0.63	0.3

Standard errors in brackets

The dependent variable in all three regressions is percent mortality for weekend admissions minus percent mortality for weekday admissions.

*This is the estimate of the excess mortality on the weekend.

**When the selection is adjusted for in two different ways the mortality difference is reduced to 121 additional deaths on weekdays per 100,000 by one method and 15 additional deaths per 100,000 admissions on the weekdays by the other method.