Causal Analysis of Emergency Department Delays

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Background: Improvement teams make causal inferences, but the methods they use are based on statistical associations. This article shows how data and statistical models can be used to help improvement teams make causal inferences and find the root causes of problems. **Methods:** This article uses attribution data, competing risk survival analysis, and Bayesian network probabilities to analyze excessive emergency department (ED) stays within one hospital. We use data recorded by ED clinicians that attributed the cause of excessive ED stays to 23 causes for the 70 049 ED visits between March 2011 and April 2014. We use competing risk survival analysis to identify contribution of each cause to the delay. We use Bayesian network models to analyze interaction among different causes of excessive stays and find the root causes of this problem. **Results:** This article shows the utility of causal analysis to help improvement teams focus on the root causes of problems. For the example analyzed in the article, most causes for patients' excessive ED stays were related to the hospital operations *outside* the ED. Therefore, improvement projects *inside* the ED such as expanding ED, increasing staff at the ED, or improving operations are less likely to have a positive impact on reducing excessive ED stays. On the contrary, interventions that improve hospital occupancy (better discharge, expansion of beds, etc) or improve laboratory response times are more likely to result in positive outcomes.

Key words: control charts, emergency department, health care quality improvement, root-cause analysis, run charts, statistics

Health care process improvement teams often have to make implicit assumptions about the cause of the problem they are trying to resolve. In the absence of evidence regarding the root cause of the problem, process improvement teams often attempt multiple improvement projects, hoping to achieve the desired outcome. Traditional process improvement tools such as control charts can be useful in monitoring the process. However, in complex situations when multiple (sometimes overlapping) improvements are attempted, those tools do not necessarily clarify what has caused the changes in the outcomes. Given this complex multi-intervention improvement environment, new data and statistical procedures are needed that would more clearly identify cause and effects. There has been significant progress in causal analysis in recent years. Causal analysis of observational data can be traced to a series of articles by Rubin.[1-4] It also has roots in econometric models,[5,6] probability network models,[7] and philosophy.[8] The goal of this article is to show how improvement teams could use causal analysis to understand the complex interaction among multiple improvement interventions.

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In this article, we demonstrate the application of the new causal analysis tools in gaining insight into what causes patients to experience *excessive* emergency department (ED) stays. This is a common medical care issue in the United States and negatively affects patient safety, quality of care, and patient and provider satisfaction.[9-11] Delays in diagnosis and treatment of time-sensitive conditions such as myocardial infarction, pneumonia, and stroke have been attributed to excessive ED stay.[12] Excessive ED stays has been cited as a contributing factor in 31% of sentinel events.[13]

A PERSISTENT PROBLEM

Figure 1 demonstrates the rate of patients with excessive ED stays over a 3-year period in the Washington DC Veterans Affairs Medical Center (DC VAMC). Excessive ED stay refers to patients spending more than 6 hours from arrival to exit from the ED, whether admitted or discharged. During this 3-year period, many improvements were attempted including:

a. Changing procedures for setting ED priorities;
b. Hiring new staff to support a "fast track" for lower-acuity ED patients;
c. Training the staff on how to set time frames for handoffs and transfers for admitted patients;
d. Improving the ED patient flow using the emergency severity index, the 5-level triage tool was completed by the triage nurses to reinforce the effective use of the emergency severity index and to accurately direct patients to the appropriate level of care;
e. Dynamically adjusting the staffing level and temporarily shifting the staff assignments to ED as needed; and

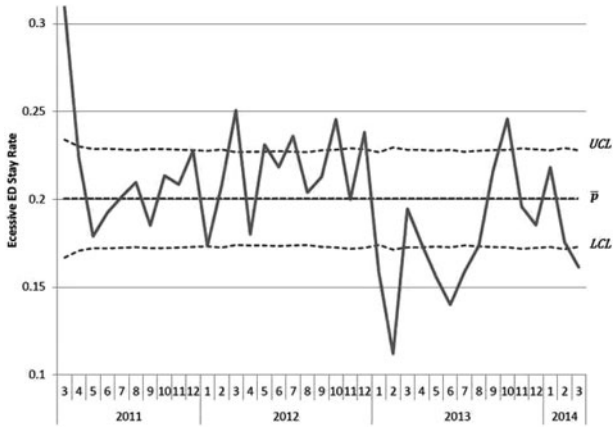

Figure 1. Changes in excessive ED stays. ED indicates emergency department; LCL, lower control limit; UCL, upper control limit.

f. Improving laboratory testing processes using abbreviated laboratory orders to facilitate transfers and reduce delays in test results.

These improvement projects were attempted repeatedly and often simultaneously. These types of comprehensive, multidimensional, and overlapping changes in care processes are common; managers and clinicians seek every possible solution until something works. Although the aforementioned improvement projects were implemented "successfully," Figure 1 shows that the problem persisted. The rate of excessive ED stays remained high in 2011 and 2012 despite these interventions. It declined in 2013, but it was not clear if the decline was associated with any of the improvement projects. Much more menacing is the increase at the end of 2013, suggesting the possibility of returning to higher excessive ED stay rates despite numerous improvement projects in prior years.

ATTRIBUTION DATA

For every patient who had stayed in excess of 6 hours, the ED clinician was asked to indicate the reason for excessive stays. Clinicians were prevented from completing documentation on the ED encounter until they provided a cause. The use of attributional data has been widely studied in the literature.[14-16] These data represented a case-based reasoning regarding the causes of excessive ED stays by the clinician closest to the case. The clinicians attributed the excessive ED stays to one of the following 23 causes:

1. *On call*: Delays caused when the on-call clinicians was not available.
2. *Observation*: Delays caused to observe the patient within the ED.
3. *Physician limit*: Delays caused because of access to physicians within the ED.
4. *ED to bed*: Delays caused in getting the patient from the ED to the hospital bed, such as delays in providing handoffs or other obstacles associated with the receiving unit.
5. *Overcrowding*: Delays caused when there were more patients in the ED than the available beds.
6. *Consult*: Delays caused in the process of obtaining a physician consult.
7. *Supplies*: Delays caused while waiting for the required supplies.
8. *Accepting physician*: Delays caused by the accepting physician, such as delayed evaluations or admission orders.
9. *Image study*: Delays caused as a result of lengthy image studies.
10. *Interfacility*: Delays caused because of interfacility coordination of transfer of the patient.
11. *Staff limit*: Delays caused because of limited availability of ED staff.
12. *Pharmacy*: Delays caused because of waiting for medications.
13. *Transport*: Delays caused because of availability of personnel to transfer the patient within the facility.
14. *Inpatient bed*: Delays caused because inpatient beds were not available.
15. *Image result*: Delays caused because image results were not available.
16. *Surgery*: Delays caused because of waiting for the surgical unit.
17. *Laboratory results*: Delay caused because laboratory results were not available.
18. *Disposition*: Delay caused because of uncertainty about disposition of the patient.
19. *Evaluation*: Delays caused in evaluating the patient.
20. *Home*: Delays caused in the process of discharging the patients to their home.
21. *Ambulance*: Delays caused because the ambulance was not available to transfer patients to another facility.
22. *Escort*: Delays caused because escorts were not available to help transfer patients.
23. *Laboratory study*: Delays caused because of lengthy laboratory studies.

COMMON REASONS FOR EXCESSIVE ED STAYS

Figure 2 shows causes of excessive (>6 hours) ED stays and the changes in the causes over time. The *y*-axis represents the percentage of cases in which the reason was mentioned, and the *x*-axis illustrates the time from 2011 to 2014 shown in months. The shaded areas correspond to delay reasons correspond to delay reasons. A quick glance at the data shows that 2 reasons explain most of the excessive stay incidents: availability of an inpatient bed, and overcrowding in ED.

Problems in bed availability seem to worsen in the last 3 quarters of 2011 and more recently in 2014. Overcrowding of ED seems to be another key reason for excessive stays.

ANALYZING THE ED LENGTH OF STAY

Figure 2 illustrates the *prevalence* of excessive stay reasons but does not indicate the *length* of ED stay.

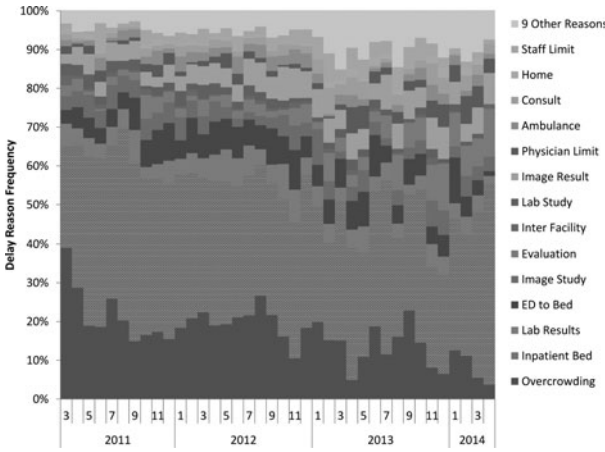

Figure 2. Changes in reasons for excessive ED stays. ED indicates emergency department.

To understand the contribution of each reason to the length of stay in ED, we used the competing risk survival analysis.[17,18] A competing risk survival analysis assumes that delays caused by one reason would exclude (censor) that case for consideration of delays caused by another reason. These cases are censored because one is not sure if the other reason for delay could have also occurred, perhaps a few hours later. For example, in calculating the impact of unavailability of hospital beds on excessive ED stays, one would censor cases that were delayed because of laboratory tests. In these situations, observations are censored and do not affect findings from competing risk survival analysis.

Using the competing risk survival analysis, we indicate the top 5 causes that result in the longest stays in the ED: inpatient bed, ED overcrowding, ED to bed, image study, and laboratory study. The cumulative incident functions for these top 5 causes are illustrated in Figure 3. The *x*-axis corresponds to the hours spent in ED, and the *y*-axis corresponds to the cumulative incidence of each delay reason. The dotted lines around each curve correspond to the 95% confidence bounds.

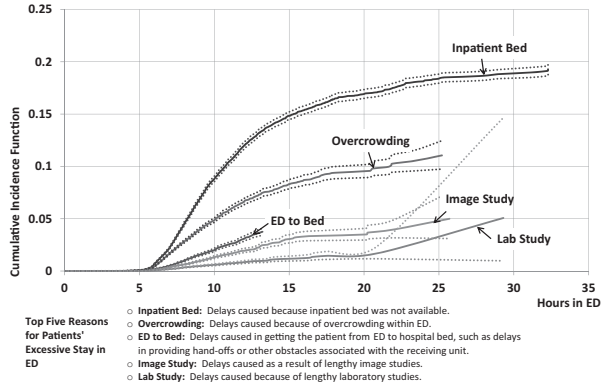

Figure 3. Cumulative incident function for top 5 causes of excessive ED stays. ED indicates emergency department.

For instance, in Figure 3, the vertical gridline that crosses the *x*-axis at hour 10 crosses the curve corresponding to ED overcrowding at 0.05. This indicates that in 5% of cases, with at least 10 hours of ED stays, overcrowding of the ED is given as the reason for the delay. The higher the curve, the more frequently the reason is given. Thus, in Figure 3, the most frequent reason for delay beyond 5 hours is availability of an inpatient bed. The cumulative incidence function enables improvement teams to analyze the length of stay due to each cause and focus on the most critical ones.

RELATIONSHIP AMONG REASONS

The underlying assumption for competing risk survival analysis is the independence of causes. However, in a complex hospital system, causes that result in excessive stays may not be always independent from each other. For example, it is reasonable to expect that overcrowding affects many other reasons for excessive ED stays. Overcrowding may increase the workload of the laboratory and, in turn, cause laboratory delays. Thus, it is possible that under some conditions, laboratory delays are mentioned as the cause of excessive ED stays while those laboratory delays may, in turn, have been caused by overcrowding. To better understand the relationship between delay reasons, we use a Bayesian network approach. To perform such analysis, we create a node for each delay reason; arcs represent the relationship among the nodes. We use ED data from March 2011 to April 2014 to construct the network structure—the results are depicted in Figure 4. In this network, the reasons that directly affect each other are shown as a direct link between the 2 nodes. The data show various direct links among the reasons. The data also show that 3 reasons mediate the impact of various causes on excessive ED stays: count of patients visiting the ED, image results, and inpatient bed availability. Other reasons also matter, but these 3 reasons mediate the effect of other reasons for excessive ED stays.

Many of the relationships identified in the network structure make intuitive sense. For example, the network in Figure 4 shows a direct link between "inpatient bed" and "laboratory results" nodes. That means when the hospital is near occupancy (and thus inpatient beds are not available), the likelihood of delays due to laboratory congestion increases. The link between "pharmacy" and "inpatient bed" indicates that as pharmacy delays increase, the likelihood of delays due to the lack of inpatient beds also increases—since increasing pharmacy's workload delays the discharge process and thus availability of inpatient beds becomes an issue. The on-call delays are also associated with consult-related delays and staff availability. Escort delays affect surgical delays. Delays in getting image results are associated with delays in evaluation of the patient.

One should not assume that the nodes that are not directly linked to "excessive ED stays" do not actually cause excessive ED stays. For example, there is no link in the network between transport and excessive

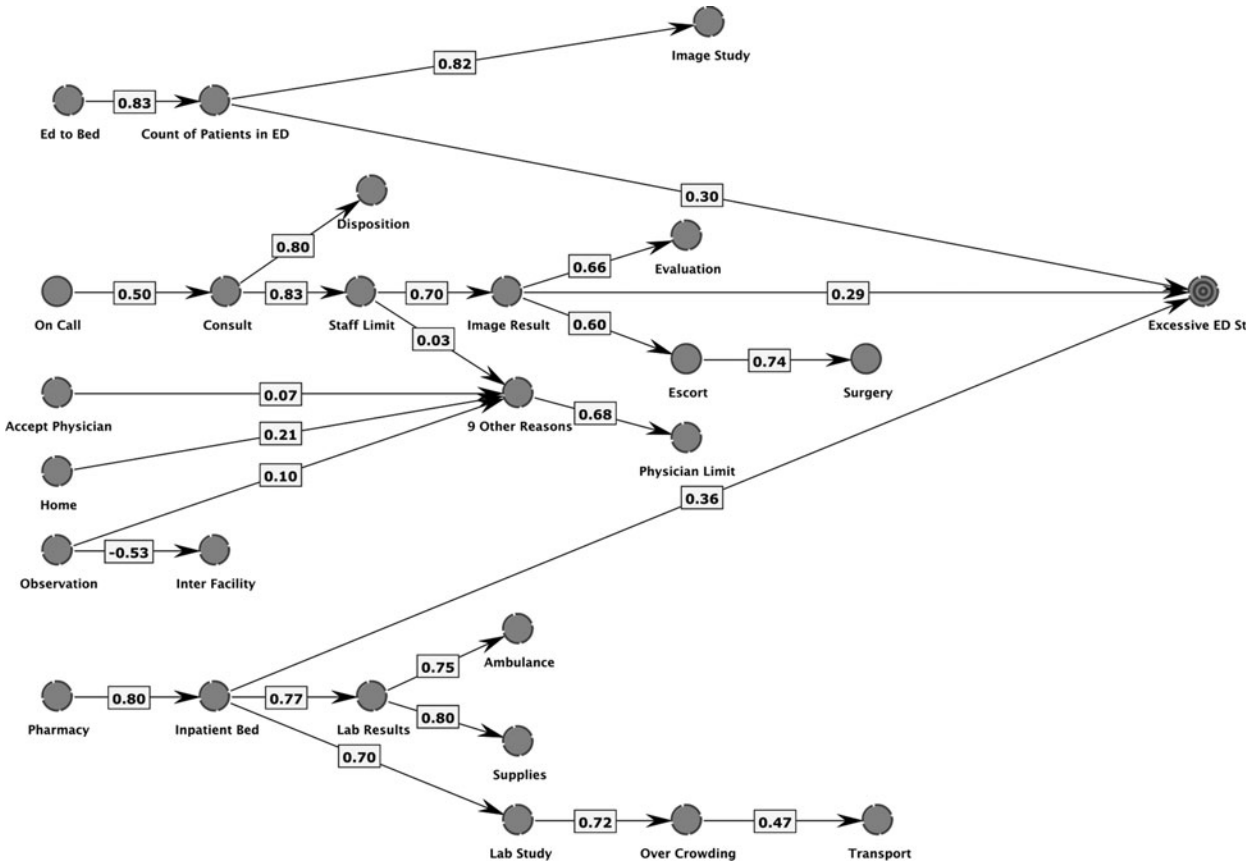

Figure 4. A network of causes of excessive ED stays. ED indicates emergency department.

ED stays. However, removing the common cause of both transport and excessive ED stays (availability of inpatient beds) would lead to the emergence of a new link between these 2 events. In other words, when inpatient beds *are not* available, transfer delays cannot logically happen. For situations where inpatient beds *are* available, transport delays will have a direct causal impact on excessive ED stays.

This type of causal networks can help illustrate the complexities and interrelations of systems and guide improvement teams toward the root cause of the problem. The results of this analysis helped the improvement teams at the DC VAMC focus their efforts on streamlining the inpatient discharge process and also on preventing readmissions.

CONCLUSION

This article demonstrates the value of collecting and analyzing attributional data for understanding relative contribution of different causes of failure. A plot of prevalence of reasons for excessive ED stays identified overcrowding (too many patients in the ED) and the lack of inpatient beds as 2 major reasons for excessive ED stays. A competing risk survival analysis identified the contribution of each of the causes and focused attention on top 5 causes. A Bayesian causal network showed how reasons were interrelated and provided a systems perspective to determine the root causes of excessive ED stays.

Many improvement projects focus on the efficiency of the ED processes. These projects are unlikely to solve excessive ED stays caused by reasons *outside* the ED. For example, consider the effort that the improvement team within our organization put into hiring more ED staff. If there are extended ED stays, it may seem reasonable to hire nurses to address the shortage, expediting assessments, and to initiate protocols to facilitate provider decisions. Our analysis, however, has shown that the main reason for excessive ED stays was related to the availability of hospital beds. Thus, hiring new ED staff would not be as effective in alleviating this problem as making more hospital beds available, reducing the overall length of stay in the hospital units, discharging patients sooner, perhaps before noon.

This analysis also revealed the sheer complexity of the problem. There were numerous interrelated reasons for excessive ED stays, perhaps too many to address through a single improvement project. These reasons also connect the excessive ED stay problem to other ongoing activities within the organization. A problem in one part of the organization affects other parts. It is no surprise that improvement teams are encouraged to take a systems view of their problems.

There are downsides to using attributional data. For instance, it is conceivable that a clinician is more likely

to attribute the delay to external causes than his or her own behavior. One would have more confidence in these attributions if they were also accepted by the unit held responsible for the excessive stay. More research is required to determine how prevalent this issue might be and whether it impacts the outcomes.

The results of this analysis guided the performance improvement team at the DC VAMC toward finding the root causes of excessive ED stays and thus helped them redirect their focus. New improvement projects such streamlining the discharge process and preventing readmissions are initiated as a result.

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