

Quality Control Analysis based on Wait Times
and Visit Lengths in Emergency Rooms Across
the United States

Statistical Quality Control

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Introduction

Across the United States, ambulances are on average diverted away from an overcrowded emergency room approximately once every minute. Over the past decade, waiting times at emergency rooms have steadily increased, which often leads to frustration of the patients and their families. Long wait times will generally decrease patient satisfaction, and consequently the quality rating of an emergency room visit. Have you ever wondered how long the average person is waiting in the emergency room? The United States emergency department (ED) recommends an average wait of maximum 15 minutes. Leora Horwitz, Jeremy Green, and Elizabeth Bradley published an article called United States emergency department performance on wait time and length of visit. The following report will be based on their findings, where we will apply quality control processes to see if wait times in emergency rooms are within statistical control or if some adjustments may be necessary to improve the quality of a patient's emergency room visit. Horwitz, Green, and Bradley conducted a cross-sectional study of random sampling of 35,849 patient visits to 364 United States hospital emergency departments in 2006. They did not only measure the median wait times and visit lengths, but also the proportion of patients seen within the recommended time frame. The results are somewhat scary with conclusions that only a small minority of hospitals consistently stayed within the suggested wait times. Additionally, they found that less than half of the hospitals ended up admitting their emergency room patients within 6 hours, meaning that many patients did in fact not necessarily need to visit the emergency room.

Methods Horwitz, Green, and Bradley examined the median ED performance with respect to the wait time, which they defined as the number of minutes between the patient arrived at the ED and the time the patient was seen by a provider. Secondly, they calculated the median length of the visit, defined as the number of minutes between the time the patient arrived at the ED and the time the patient was discharged from the ED. Both of these measures are directly correlated with customer satisfaction, and thus the quality of the emergency room visit. They categorized the wait times into four different triage categories:

- Emergent(0-14 minutes)
- Urgent(15-60 minutes)
- Semi-urgent(61 minutes - 2 hours)
- Non-urgent(121 minutes - 24 hours)

For each of those categories, they calculated the percentage of patients seen within their triage target timeframe. They used standard descriptive statistics to characterize the sample of patients and hospitals. Additionally, they estimated linear models to identify the percent of variation in wait time (log-transformed) and in length of visit (log-transformed) within hospitals and between different hospitals. To perform such analysis, they used Stata 10.0

Table 1: Hospital performance on wait time and length of ED visit

	Mean	Median	Proportion within target
Wait time, all patients (min)	52.4	34.0	78.3%
Emergent (min)	31.8	16.0	48.4%
Urgent (min)	45.2	32.0	80.0%
Semi-urgent (min)	58.6	45.0	91.7%
Non-Urgent (min)	68.6	45.0	100%
Length of visit, patients ultimately admitted (hours)	4.93	4.3	76.3% (6h target) 60.0% (4h target)
Length of visit, patients ultimately discharged (hours)	3.0	2.3	93.0% (6h target) 86.8% (4h target)

and SAS 9.1.2 depending on the analysis. The most important results are summarized in Table 1. As we can see from Table 1, most significant problem seems to be in the emergent triage category, where only 48.4% of the patients are within the target of 0-14 minutes. This can possibly result in more damaging illnesses. This is where we will focus our attention to and use statistical quality control to assess if this process needs adjustments or not. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2830619/>

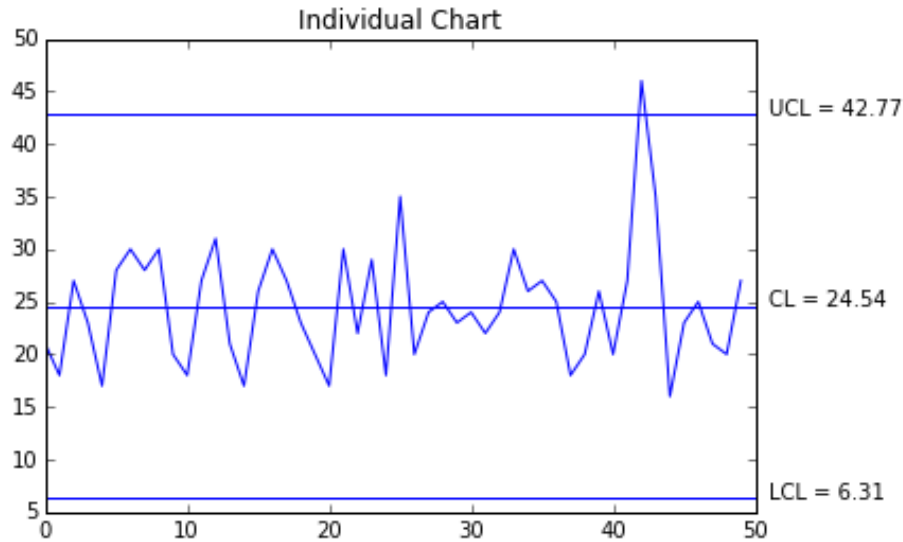
Problem Statement

The central tenet of quality improvement is that quality is a system property. ED wait time and length of visit have been observed to differ systematically according to race, ethnicity, site of care and a variety of other immutable patient-level factors. Using, instead, the quality improvement model, we examine ED wait time at the system (hospital) level. Describing hospital-level rather than patient-level performance allows for benchmarking, characterization of variation, recognition of positive and negative outliers, and assessment of effective care practices: activities necessary for sustainable quality improvement. Let's look at the data from <https://projects.propublica.org/emergency/> which represents state-by-state waiting times for ERs. In Table 2, we chart the time, on average, that patients wait in emergency rooms before being seen by a doctor. To improve productivity of ER we can construct and analyze Control Charts. Control charts have two general uses in an improvement project. The most common application is as a tool to monitor process stability and control. A less common, although some might argue more powerful, use of control charts is as an analysis tool. Since natural subgroup size is unknown, we will construct The Individual (I) and Moving Range (MR) Charts for given data.

Table 2: Average ED wait time by State

State	Average Wait Time (min)	State	Average Wait Time (min)
Alabama	30	Montana	20
Alaska	24	Nebraska	18
Arizona	26	Nevada	21
Arkansas	26	New Hampshire	28
California	26	New Jersey	30
Colorado	17	New Mexico	28
Connecticut	27	New York	27
Delaware	35	North Carolina	30
Florida	23	North Dakota	20
Georgia	30	Ohio	20
Hawaii	20	Oklahoma	23
Idaho	20	Oregon	29
Illinois	25	Pennsylvania	24
Indiana	18	Rhode Island	31
Iowa	20	South Carolina	30
Kansas	17	South Dakota	18
Kentucky	22	Tennessee	23
Louisiana	25	Texas	24
Maine	27	Utah	16
Maryland	46	Vermont	27
Massachusetts	35	Virginia	22
Michigan	21	Washington	21
Minnesota	25	West Virginia	27
Mississippi	27	Wisconsin	18
Missouri	23	Wyoming	17
National Average			24.54

Figure 1: I-Chart



Analysis

The sample size of each of the measurements in Table 2 is unknown, so the \bar{x} -bar and R charts could not be used. This made it a good candidate for an I and MR chart. In Figure 1, you can see the I chart for the data in Table 2. As you can see from the figure, the Upper Control limit is 42.77, the Center Line is 24.54, and the Lower Control Limit is 6.31. Only one data point fell outside of the control limits, and that corresponds to the state of Maryland. This suggests that, except for Maryland, the states are within a three sigma range from the average national ED wait time. The data in Table 2 was collected between 2014 and 2015. Previous data couldn't be found, which made the construction of an MR Chart impossible. The chart in Figure 1 was generated in a custom script written in Python. The code is included in Appendix I.

Appendix I

```
import numpy as np
import matplotlib.pyplot as plt
class IMRChart:
    def __init__(self, data):
        self.d2 = 1.128
        self.D3 = 0
        self.D4 = 3.267
        self.data = data
        self.mean = sum(data)/float(len(data))
        self.mr = self._setMovingRange()
        self.mrave = sum(self.mr)/float(len(self.mr) - 1)
        self.indlcl = self._findIndividualLCL()
        self.inducl = self._findIndividualUCL()
        self.mrlcl = self._findMrLCL()
        self.mrucl = self._findMrUCL()

    def _setMovingRange(self):
        mr = []
        for index, value in enumerate(self.data[1:]):
            mr.append(abs(value - self.data[index - 1]))
        return mr

    def _findIndividualLCL(self):
        return max(0, self.mean - 3*(self.mrave/self.d2))

    def _findIndividualUCL(self):
        return self.mean + 3*(self.mrave/self.d2)

    def _findMrLCL(self):
        return max(0, self.mrave * self.D3)

    def _findMrUCL(self):
        return self.mrave * self.D4

    def showIChart(self, savefig = True, figtype = 'png'):
        chart = plt.plot(range(len(data)), data.values())
        plt.axhline(y = self.indlcl)
        plt.annotate('LCL={:.2f}'.format(self.indlcl),
                    xy=(len(data) + 1, self.indlcl),
                    xycoords='data',
                    annotation_clip = False)
        plt.axhline(y = self.mean)
        plt.annotate('CL={:.2f}'.format(self.mean),
```

```

        xy=(len(data) + 1, self.mean),
        xycoords='data',
        annotation_clip = False)
plt.axhline(y = self.inductl)
plt.annotate('UCL={:.2f}'.format(self.inductl),
            xy=(len(data) + 1, self.inductl),
            xycoords='data',
            annotation_clip = False)
plt.title("Individual_Chart")
if savefig:
    plt.savefig('IChart.{}'.format(figtype), bbox_inches = 'tight')
plt.show()

def showMRChart(self, savefig = True, figtype = 'png'):
    chart = plt.plot(range(len(self.mr)), self.mr)
    plt.axhline(y = self.mrlcl)
    plt.annotate('lcl={:.2f}'.format(self.mrlcl),
                xy=(len(data) + 1, self.mrlcl),
                xycoords='data',
                annotation_clip = False)
    plt.axhline(y = self.mrave)
    plt.annotate('UCL={:.2f}'.format(self.mrave),
                xy=(len(data) + 1, self.mrave),
                xycoords='data',
                annotation_clip = False)
    plt.axhline(y = self.mrucl)
    plt.annotate('UCL={:.2f}'.format(self.mrucl),
                xy=(len(data) + 1, self.mrucl),
                xycoords='data',
                annotation_clip = False)
    plt.title("Moving_Range_Chart")
    if savefig:
        plt.savefig('MRChart.{}'.format(figtype), bbox_inches = 'tight')
    plt.show()

data = {"AL":30, "AK":24, "AZ":26, "AR":26, "CA":26, "CO":17,
        "CT":27,"DE":35, "FL":23, "GA":30, "HI":20, "ID":20,
        "IL":25, "IN":18, "IA":20, "KS":17, "KY":22, "LA":25,
        "ME":27, "MD":46, "MA":35, "MI":21, "MN":25, "MS":27,
        "MO":23, "MT":20, "NE":18, "NV":21, "NH":28, "NJ":30,
        "NM":28, "NY":27, "NC":30, "ND":20, "OH":20, "OK":23,
        "OR":29, "PA":24, "RI":31, "SC":30, "SD":18, "TN":23,
        "TX":24, "UT":16, "VT":27, "VA":22, "WA":21, "WV":27,
        "WI":18, "WY":17}
chart = IMRChart(data.values())
chart.showIChart(savefig = True)

```