**Literature Review**

**Definitions**

An emergency department (ED) is the area of a hospital dedicated to providing acute medical and surgical care to patients arriving in need of immediate help. In an emergent situation, a visit to the emergency department, and receipt of proper care upon arrival, can be the difference between a person living and dying. That is why it can be extremely frustrating when a patient arrives at the ED with a painful condition only to be asked to wait. During that time, the injuries that patient came in with worsens, they may start to feel ignored or neglected, and their satisfaction steadily declines. For that reason, wait time is used as an important quality measure when assessing ED outcomes. Among the studies reviewed herein, “wait time” is defined as the difference in minutes between the time a patient arrives and the time of initial patient examination by an emergency department physician (National Center for Health Statistics, 2019).

Another important measure in assessing ED performance is a patient’s emergency department length of stay (LOS). For patients ultimately admitted to the hospital, Pines et al. (2009) define LOS as the difference in minutes between the time a patient arrives at the ED and the time they are admitted to the hospital as an inpatient. For patients not admitted to the hospital, LOS is defined as the difference in minutes between the time a patient arrives at the ED and the time they leave from the visit. Ensuring these measures are as low as possible while still providing quality care to each patient is a critical effort each hospital must constantly strive toward, because the longer a patient stays in the ED, the more likely they are to suffer an adverse health outcome. Research shows for example that extended LOS during an ED visit is associated with increased likelihood of a patient dying in the hospital within 30 days of their visit (Plunket et al., 2011). Based on their observations, the authors recommend a maximum ED stay of 4 and 6 hours for referrals and admissions, respectively. Another study from Australia shows a link between ED overcrowding, as measured by LOS, and an increased likelihood of a patient dying in the hospital within 10 days of their visit. In just one Canberra hospital, the effect of ED overcrowding equated to 13 deaths per year over a three year period (Richardson, 2006).

Closely tied to emergency department wait times is the rate of patients leaving the ED without being seen. Carron et al. (2014) define this “indirect quality indicator” as the proportion of “patients who leave the ED from the waiting room, after having completed their administrative paperwork and usually an initial evaluation by a triage nurse.” These unplanned departures represent a missed opportunity to help a person in need and lead to a higher risk of failing health, hospital readmission and death in the weeks that follow. In the same paper, Carron et al. (2014) examine incidents of patients leaving the emergency department without being seen (LWBS), as well as incidents of patients leaving the emergency department after being seen but against medical advice (LAMA), over a six year period at Lausanne University Hospital in Switzerland. They find that while LWBS patients list a wide range of reasons why they chose to leave before being seen, the majority cite length of stay or waiting time. They also highlight a slight predominance of men in both the LWBS and LAMA groups and point out that these findings are consistent with previous studies.

**Statistical Methods Used by Previous Studies**

Existing literature on emergency department quality measures features a series of mostly rudimentary statistical approaches, with Chi-square tests, T-tests and multiple linear regression being the most common. These methods are often chosen in an effort to strike a balance between statistical rigor and ease of interpretability, with the intended audience (readers of medical journals) in mind. As a result, the most convincing results showing the widest disparities are often stem from very simple analyses. Zhang et al. (2019) use basic Chi-square tests to produce adjusted odds ratios showing the likelihood of hospital admittance for different groups of people. The results show that Black and Hispanic children are 8% less likely and 14% less likely, respectively, than their white counterparts to be admitted to the hospital following a visit to the emergency department. By keeping statistical comparisons simple, the results appear more compelling and are easier to interpret.

That being said, one effect of this simplification is that important statistical considerations are often omitted. Haywood et al. (2013), for example, is a highly cited publication on the impact of race on patients with sickle cell disease. As part their study, the authors use t-tests for all continuous bivariate analyses, such as comparing emergency department wait times between sickle cell crisis patients and patients presenting with long bone fractures, a similarly painful emergent condition. The issue is that the authors provide no evidence of having performed diagnostic tests to see whether t-tests were appropriate. The independent samples t-test is a parametric statistical test that assumes the two samples being compared come from the same population and follow approximately normal distributions. When the normality assumption fails to hold, the non-parametric Mann-Whitney U test is recommended as a replacement because it produces results with more statistical power. The authors, at the very least, fail to mention that appropriate diagnostic tests were performed.

Another statistical issue that arises is the overuse of log transformations. There is a wide-ranging assumption, even among some statisticians, that transforming a right-skewed dataset by taking the natural log of each value will make the data viable for use in tests that assume normally distributed data. That assumption is poorly supported, as it can call into question the relevance of any conclusions reached through statistical analysis. For example, Feng et al. (2014) use Monte Carlo simulations to demonstrate that log transformation, in addition to making model interpretation more difficult, can actually make data even more variable when the intent is the opposite. As we will see later, log transformation of wait times prior to analysis is very common in emergency department wait time literature, because a normalized response allows for use of multiple linear regression, whose results are simple and easier to interpret than those with a non-normal response.

These issues highlight the problems that arise when taking an oversimplified approach to modelling wait time. Clearly, while simple approaches are easier to explain to an audience of medical professionals, their lack of complexity and failure to correct for important variables can render dubious even the most conclusive results. Luckily, there are examples in the literature of authors building a relatively complex model while still retaining easy interpretability. One example is the use of exponentiated model coefficients as odds ratios. Okunseri et al. (2013) use multivariable regression models to assess the individual effect of each of several predictors including race, age, sex, and insurance status on log-transformed emergency department wait times for nontraumatic dental condition visits. These models produce coefficients representing the multiplicative effect of each individual independent variable relative to some reference level. These coefficients, when exponentiated, can be interpreted as fold-changes in waiting time compared to the reference level. For example, relative to patients paying with private insurance (the reference level), Medicare patients experience wait times for nontraumatic dental conditions that are longer by a factor of 1.08, or 8% longer in other words. This technique is useful in situations where a balance between model complexity and ease of interpretation is sought.

Finally, it is important we remember that disparities in important outcome variables may be more noteworthy to a statistician than to a health care worker. For example, in Wilson et al. (2016), patients with health insurance who are admitted to the hospital were found to experience an ED LOS that is actually 8 minutes longer than admitted patients who do not have insurance. This difference was statistically significant (575 vs 567, P<0.01) because of large sample size and low variance. The problem here is the relative significance of those 8 minutes in a clinical setting. Across an emergency department stay lasting nearly 10 hours, a stay that is 8 minutes longer is unlikely to have a measurable effect on patient outcomes or satisfaction, so it would be a misstep to focus on such a disparity. This serves as a reminder that statistical significance does not always indicate practical significance.

**Evidence of Disparities**

In the United States, black and brown minorities consistently receive lower quality health care than whites, even at an early age. This disparity is linked directly to higher rates of mortality and chronic disease among minorities, and in turn to lower life expectancy than whites. It is also true that black and brown minorities receive lower quality care in emergency situations. Numerous studies have shown that, for comparable injuries, minorities are significantly less likely than whites to receive treatment for pain upon presentation to an emergency department (Tamayo-Sarver et al., 2003; Lee, Lewis and McKinney, 2016; Goyal, Kuppermann and Cleary, 2015).Moreover, minorities in the U.S. are consistently underrepresented in well-paying jobs that include private health insurance as a benefit. As a result, minorities disproportionately find themselves on the bottom of a two-tiered health care system that provides quality care to those with private insurance, and relatively mediocre care to those without. Large disparities also exist when it comes to minority representation in the health care profession. Figure 1 shows the proportion of the U.S. population represented by each of three minorities, along with the proportion of physicians represented by each (United States Census Bureau, 2019; Association of American Medical Colleges, 2019). The disparities are stark, especially when coupled with research showing minority patients are most comfortable receiving care from a physician or their own race or ethnic background (Saha et al., 2000). Finally, focus group data reveal that a deep-seated distrust toward the medical community exists due to a series of incidents in which minorities, particularly African-Americans, were victims of medical experimentation (Jacobs et al., 2006). The effect is a reluctance among minorities to trust health care providers and approve of medical interventions they are told they need.

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| **Race/Ethnicity** | **% of U.S. Population** | **% of U.S. Physicians** |
| Black or African-American | 13.4 | 5.0 |
| Hispanic or Latino | 18.5 | 5.8 |
| Native American | 1.3 | 0.3 |

FIGURE 1: U.S. Total Population vs. Physician Population, by Race/Ethnicity

A further persistent fault of the U.S. health care system is the disparity in health outcomes between patients living in rural areas and patients living in urban areas. While the root cause is manyfold, unequal distribution of resources to health care providers in rural areas is often the effect. For example, the numbers of primary care physicians and specialist physicians operating in rural areas are 58% and 89% lower per capita, respectively, than in urban areas (National Rural Health Administration). These limited numbers of physicians are then expected to provide quality care for a rural population that is less likely to be insured, more likely to live below the poverty line, and more likely to engage in risky health behaviors like smoking (Georgetown University Health Policy Institute). Compounding such efforts is the fact that the typical rural hospital offers fewer services. While surgical, obstetric, and swing bed services are standard, provision of quality health care for patients in rural areas usually requires travel for access to the following: intensive care units, skilled nursing facilities, psychiatric care, hospice services, chemotherapy services, dental services, and outpatient drug/alcohol rehabilitation. The result is a mean life expectancy for people in rural areas that is 2.4 years shorter than people in urban areas as of 2009, with that gap expanding over time (Health Policy Institute).This comes despites the fact that individuals in rural areas still pay a higher rate of health care costs out-of-pocket—29% compared to 23% for individuals in urban areas (Singh and Siahpush, 2014). Clearly, patients in rural areas receive worse health care.

**Studies Using NHAMCS Data**

The studies in this section each rely on data from the National Hospital Ambulatory Medical Care Survey (NHAMCS) for their analyses. The NHAMCS is an annual survey administered by the Centers for Disease Control and Prevention to collect data on the provision and utilization of ambulatory care services. Findings are based on a national sample of visits to the emergency departments of U.S. hospitals. Following each visit, a patient record card is completed that collects a myriad of information for the study. Those data include demographic statistics, personal health facts (e.g. smoking status), vital signs, injury details, triage decisions made, diagnoses, tests ordered, services administered, medicines offered, visit duration, provider(s) seen, time spent with provider(s), and follow-up instructions given. These data are collected, compiled, and released to the public every year for research and quality control purposes.

We begin with a study that assess ED wait times for people with mental health and substance abuse disorders. These patients present a unique challenge to emergency department staff because, with only a small number of hospitals properly equipped to accept psychiatric inpatients, it is often difficult to find them a bed at an appropriate a facility. Patients are then forced to wait, sometimes for many hours, while occupying space in the emergency department that could be better utilized. But as Opoku et al. (2018) describe, some groups of people with mental health and substance abuse disorders wait longer than others before being seen. They regressed log-transformed wait times on a host of possible determinants. After correcting for a number of individual- and hospital-level covariates, they found that “ED wait time was 23.4% longer for non-Hispanic Blacks (p<0.05), compared to non-Hispanic Whites.” The authors concluded that implicit provider bias and other latent factors likely play a role. They also found that women, people who did not arrive by ambulance, and people at non-profit and/or government hospitals waited longer.

Wait times also vary widely among patients who present to the emergency department with a nontraumatic dental condition (NTDC). Wait times for such an injury offer us a unique perspective because, unlike with other conditions, NTDC injuries are best handled outside the emergency department and are usually preventable with access to appropriate care. As a result, when an NTDC patient does arrive at the emergency department, they are often prioritized below others and forced to wait longer despite their pain, and as Okunseri et al. (2013) found, these long wait times are even longer for some groups. “Hispanics (aged ≤ 33 years old) and Blacks,” they concluded, “waited longer to receive care for NTDCs in EDs than Whites.” The article highlights how most NTDC-related ED visits are preventable and points to the lingering problem of unequal access to dental care in the U.S. as the likely cause.

Clearly, it is dangerous for a patient to stay in the ED for an extended period of time. That is why it is so troubling that, as with wait time, ED LOS is longer on average for minorities and people in urban areas. Returning to Pines et al., the authors found that, across a sample of 408 U.S. hospitals, Black patients waited 77 minutes longer compared to non-Black patients. The authors also noted that among patients admitted to the ICU, Black patients were 62% more likely than non-Black patients to have a LOS of more than 6 hours *within the same hospital*. In addition, they found that urban hospitals, teaching hospitals, and hospitals in the Northeast U.S. had longer average (median) LOS. While unable to conclude definitively whether such disparities are due to individual-level racial bias or other confounding factors not represented in their model, the authors express concern that bias likely plays a part.

Among the most unsettling effects of health care inequality in the U.S. is its impact on children. Evidence shows that children of color, those from low-income families, and the uninsured are much less likely to receive appropriate care (Flores, 2010). These negative early-life experiences with the health care system, and the economic adversity and the social disadvantages that often accompany them, are linked with increased rates of chronic illness later in life (Braveman and Barclay, 2009). Unsurprisingly, those disparities extend to the emergency department. In a comprehensive 2009 study, Zhang et al. analyzed multiple dimensions of ED care among children, including wait time, length of stay, patient triage score, medical resource utilization (blood work, scans, etc.) and ED disposition (whether the patient was admitted to the hospital and/or operated on). Their sample included data from over 78,000 visits to nearly 3,800 unique U.S. emergency departments between 2005 and 2016. They found pervasive and persistent racial disparities in nearly every study outcome variable they examined. After adjusting for a host of temporal, demographic and socioeconomic factors, including insurance status, compared to whites, Black children waited 21% longer to be seen; had a 15% longer average LOS; and were 28% less likely to be admitted to the hospital, 24% less likely to receive a blood test, and 17% less likely to receive an imaging scan such as X-ray or CT. Likewise, Hispanic children waited 19% longer to be seen; had a 19% longer average LOS; and were 3% less likely to be admitted, 4% less likely to receive a blood test, and 9% less likely to receive an imaging scan than white children. Such disparities compared to whites were not found among Asian children.

**Studies Using Other Data**

As with ED wait times, there is compelling evidence of demographic disparities in the proportion of patients who leave the ED without being seen. Hsia et al. (2011) examined 9.2 million ED visits to 262 hospitals in California in 2007 and found that hospitals serving higher rates of low-income and poorly insured patients are more likely to have a patient leave without being seen. The authors note significant room for improvement in these outcomes, suggesting the need for localized interventions targeted toward under-resourced hospitals. There is also evidence of a time threshold beyond which a majority of patients, particularly young patients, are unwilling or unable to wait. Shaikh et al. (2012) surveyed 340 patients waiting for treatment in the emergency department of a large academic medical center in the U.S. They found that 51% patients were only willing to wait up to two hours, and that, “among social and demographic factors … only age greater than 25 years was independently associated with a willingness to wait longer to be seen.”

Disparities in LOS also exist when it comes to the presence or absence of health insurance coverage. Wilson et al. (2016) examined data from over 95,000 visits to one urban, academic trauma center in the U.S. between 2011 and 2013 and found that among patients transferred to an operating room, insured patients experienced a LOS that was 43 minutes shorter compared to uninsured patients. They also found that insured patients were more likely overall to be admitted to the hospital. While these results do not speak directly to any potential racial bias, since Black and Hispanic Americans are 1.5 times and 2.5 times more likely, respectively, to be uninsured compared to whites (Kaiser Family Foundation, 2020), any disparity that exists based on insurance status likely has a racial component.

**Efforts to Reduce ED Length of Stay**

Some emergency departments have completely overhauled the way they operate in order to reduce wait time and length of stay. Vermeulen et al. (2014) describe a complex, months-long intervention at a series of hospitals across Canada with that exact goal. The strategies implemented all stemmed from lean management principles, a streamlining approach developed by Toyota in the 1960s to eliminate wasteful work processes. Hospital staff were provided with lean coaches and management experts, trained in lean methodology, and given tools to measure and track their efforts. While the conclusions reached were less than compelling—lean intervention was associated with a decrease in length of stay but not when compared to control sites—the project was comprehensive, well-funded and exhaustively planned. This shows the lengths health care systems are willing to go to improve efficiency in the emergency department.

Research also shows the potential of very simple interventions in reducing wait time. Willoughby et al. (2010) document the attempts one Canadian hospital made to reduce the times patients are forced to wait at different stages of their emergency department visit, not just the initial door-to-evaluation wait time as with other studies. The stage that stood out as having the longest, most easily reversible wait time was the time spent waiting for physician reassessment after treatment had been administered. With the help of a trained facilitator, hospital staff proposed their own ideas on how to improve this quality indicator, and then implemented some of them. The modifications that ultimately had the largest impact on wait times were surprisingly simple: a clear visual indicator to help staff identify the physician assigned to each patient, which reduced the time staff spent trying to identify the right physician to perform the reassessment, and implementation of a “Physician Reassessment Worksheet,” which streamlined the reassessment itself. These small changes reduced waits for physician reassessment by 50%.

**Summary**

The immensity these disparities may take a generation or more to reverse, and as statisticians, our efforts focus a deep dive into data collected from the institutions creating disparate outcomes. Given the strength and size of the U.S. healthcare infrastructure, the tools to achieve increased equity of health outcomes are likely in hand, but we cannot know how best to allocate resources in pursuit of that goal without analyzing data. Luckily, the transition from paper to electronic medical records over the past thirty years has made health care data monumentally easier to retrospectively access and analyze. In fact, health care analytics in the U.S. is slated to become a forty-billion-dollar industry by 2025 (Valuates Reports, 2019). So, the infrastructure is in place to make large, systemic changes in the direction of health care equality. Whether or not the willingness to enact such change will be present, is another matter.