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THESIS

911 AND THE AREA CODE FROM WHICH YOU CALL: HOW TO IMPROVE THE DISPARITY IN CALIFORNIA'S EMERGENCY MEDICAL SERVICES

by

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Thirty-three local emergency medical services (EMS) authority agencies serve the 58 counties in California. A local EMS authority (LEMSA) in California governs either EMS providers in a single county or several counties combined. Each LEMSA dictates widely different treatment and transport protocols for its paramedics. Preliminary data for this thesis substantiate previously published literature, which shows broad disparities in prehospital care and patient outcomes among LEMSA jurisdictions in California. Although previous research has established the problem of geographic EMS disparities, nothing definitively explains their cause. This thesis contends that the decentralized LEMSA system is the chief culprit for EMS disparities in California, based on an analysis of the available California EMS performance-measure data. Regression analysis does not identify a single factor to explain the problem; the only constant across all LEMSAs in California is that their treatment protocols and training standards to maintain local accreditation vary widely. Unfortunately, the striking lack of performance-measure data—a data desert—for EMS throughout the United States limits the scope of research seeking to explain the inconsistency in EMS care.

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911 AND THE AREA CODE FROM WHICH YOU CALL: HOW TO IMPROVE THE DISPARITY IN CALIFORNIA'S EMERGENCY MEDICAL SERVICES

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Submitted in partial fulfillment of the
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ABSTRACT

Thirty-three local emergency medical services (EMS) authority agencies serve the 58 counties in California. A local EMS authority (LEMSA) in California governs either EMS providers in a single county or several counties combined. Each LEMSA dictates widely different treatment and transport protocols for its paramedics. Preliminary data for this thesis substantiate previously published literature, which shows broad disparities in prehospital care and patient outcomes among LEMSA jurisdictions in California. Although previous research has established the problem of geographic EMS disparities, nothing definitively explains their cause. This thesis contends that the decentralized LEMSA system is the chief culprit for EMS disparities in California, based on an analysis of the available California EMS performance-measure data. Regression analysis does not identify a single factor to explain the problem; the only constant across all LEMSAs in California is that their treatment protocols and training standards to maintain local accreditation vary widely. Unfortunately, the striking lack of performance-measure data—a data desert—for EMS throughout the United States limits the scope of research seeking to explain the inconsistency in EMS care.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALS	advanced life support
AHA	American Heart Association
BE-FAST	balance, eyes, face, arms, speech, time (last known well)
BLS	basic life support
CARES	Cardiac Arrest Registry to Enhance Survival
CQI	continuous quality improvement
CT	computed tomography
CVA	cerebral vascular accident
DOT	Department of Transportation
ECG	electrocardiogram
EMS	emergency medical services
EMT	emergency medical technician
ICEMA	Inland Counties Emergency Medical Authority
IV	intravenous
LAS	London Ambulance Service
LEMSA	local emergency medical services authority
NASEMSO	National Association of State Emergency Medical Services Officials
NEMSIS	National Emergency Medical Service Information System
NREMT-P	National Registry of Emergency Medical Technicians–Paramedic
NHS	National Health Service Trust
NHTSA	National Highway Transportation Safety Administration
OTI	oral tracheal intubation
PHTLS	Prehospital Trauma Life Support
REMSA	regional emergency medical service authority
RTCC	regional trauma coordinating committees
STAC	State Trauma Advisory Committee
STEMI	ST-elevation myocardial infarction
UCSF	University of California San Francisco

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EXECUTIVE SUMMARY

There are 33 separate local emergency medical services (EMS) authority agencies serving the 58 counties in California.[1] A local EMS authority (LEMSA) in California governs either EMS providers in a single county or several counties combined. Each LEMSA dictates widely different treatment and transport protocols for its paramedics.[2]

The medical director for each LEMSA has sole authority to change or maintain a local EMS treatment protocol. The only state-regulated requirement for a protocol is it must fall within the accepted scope of practice for basic life support (BLS), emergency medical technicians (EMTs), or advanced life support (ALS) paramedics, according to Title 22, § 100146 of the *California Code of Regulations*.[3] ALS paramedics require a significantly higher level of training and licensure than EMTs.[4]

The preliminary data collected for this thesis substantiates previously published literature that shows a broad disparity in prehospital care and patient outcomes among different LEMSA jurisdictions in California. The literature indicates that this is a national problem and not limited to California. Several possible factors may contribute to the disparity: differences in geography, proximity to specialty hospitals, population size, and socioeconomic differences among each LEMSA area. Although previous research has established the problem of geographic EMS disparities, nothing definitive sufficiently explains its cause. Compounding the problem is a striking lack of performance-measure data for EMS in the United States. The structure of EMS authority, provider standards, and

[1] "Local EMS Agencies," California Emergency Medical Service (EMS) Authority, accessed August 25, 2018, https://emsa.ca.gov/local-ems-agencies/.

[2] Eric C. Silverman et al., "Prehospital Care for the Adult and Pediatric Seizure Patient: Current Evidence-Based Recommendations," *Western Journal of Emergency Medicine* 18, no. 3 (April 2017), https://doi.org/10.5811/westjem.2016.12.32066.

[3] Pre-hospital Emergency Medical Services, 22 Cal. Code Regs. § 100146 (2016), https://emsa.ca.gov/regulations/.

[4] "Regulations," California EMS Authority, accessed April 29, 2018, https://emsa.ca.gov/regulations/.

treatment protocols vary significantly from one U.S. state to another.[5] In California, protocols vary significantly from one county to another.

Arguably, the decentralized LEMSA system is the chief culprit in California's EMS disparities. An analysis of California's available EMS performance-measure data reveals wide disparities. However, the inequities do not always correlate directly with socioeconomic factors, geographical differences, or population size. Thus far, the only constant across all LEMSAs in California is that they have different treatment protocols and a wide variety of training standards for local EMT and paramedic accreditation. If the LEMSA system is the problem in California, how can the state reorganize EMS to improve patient care and outcomes for all Californians? Is there enough data to compare California's EMS performance measures to those of states consolidated under one set of prehospital treatment protocols?

The first step to answer the research questions is to compare and contrast known performance measures from several California LEMSA agencies. To narrow the scope of the thesis, the research focused on the following four quantifiable prehospital performance measures:

1. Percentage of patients meeting trauma triage criteria directly routed to trauma specialty care hospitals;
2. Percentage of stroke patients directly routed to stroke specialty care hospitals;
3. Intubation success rates; and
4. 12-lead electrocardiogram acquisition for patients at risk for acute coronary syndromes.[6]

[5] Douglas F. Kupas et al., "Characteristics of Statewide Protocols for Emergency Medical Services in the United States," *Prehospital Emergency Care* 19, no. 2 (April 2015): 292–301, http://dx.doi.org/10.3109/10903127.2014.964891.

[6] A 12-lead electrocardiogram is a machine that traces the heart's multidimensional electrical activity. When used by paramedics in the field, it can identify the early stages of what is commonly referred to as a heart attack, in medical parlance an ST-elevation myocardial infarction (STEMI), as well as other acute coronary syndromes.

Although EMS is called to treat and transport dozens of different pathologies, California's EMS Authority collects the aforementioned performance-measure data.[7] The four measures are universal to all EMS systems, rural and urban, and are directly related to EMS actions in the field. Unlike other performance measures, they are not affected by external forces outside the control and quality of a field paramedic's training.

Because U.S. EMS data are fragmented and incomplete, it is difficult to compare the performance measures of U.S. states that centralize EMS authority with states that decentralize authority, such as California. To make such a comparison, the scope of the research was broadened to examine centralized EMS systems outside the United States that rigorously collect and openly share performance data.

A. LONDON AMBULANCE SERVICE, U.K. NATIONAL HEALTH SYSTEM TRUST

The London Ambulance Service (LAS) is a subdistrict of the United Kingdom's centralized National Health System (NHS) for emergency medical services. EMS in the United Kingdom has a vertically integrated hierarchy, overseen by the Department of Health, which dictates treatment protocols, transportation guidelines, and dispatch algorithms. There are 11 NHS districts for EMS in the United Kingdom, all operating under the same protocols. In stark contrast to most U.S. EMS systems, the LAS under the NHS collects and openly publishes comprehensive performance-measure data quarterly.

B. SUMMARY OF DATA RESULTS

Despite gaps in the data, the thesis draws several conclusions. The regression analysis of California's core measures report illuminates results that support the hypothesis of this thesis—that the fragmented LEMSA system in California is the root cause of EMS disparity.

[7] California Emergency Medical Service (EMS) Authority, *EMS Core Measures Project, Reporting Capability of EMSA and LEMSA Data Systems and Results from Performance Measures Data Year 2015* (Rancho Cordova: California EMS Authority, 2015), 31.

(1) California Core Measure Performance Data, 2015–2016

There is a borderline statistical relationship between median income and patients who were directly routed to stroke specialty hospitals in California only in 2016 ($p = 0.052$). This is not the case for 2015. It may be assumed that higher data-reporting compliance would show a more significant relationship between median income and stroke routing; however, such a relationship remains speculative. Despite the borderline relationship between stroke care and median income in 2016, there was no statistical relationship between the number of stroke specialty centers and direct-routing. Although the datasets are incomplete, the existing data may suggest that areas with higher incomes get better stroke care in California, regardless of geographic location. This finding does not reject the hypothesis of the thesis; rather, it implies that higher income areas mandate a higher level of stroke care.

There is also a statistical relationship between patients in California who required trauma triage and were directly routed to trauma specialty centers and the number of available trauma centers in a LEMSA jurisdiction in 2016; however, no such relationship is evident for 2015. The 2016 results are not terribly surprising; the more trauma centers available in a geographic area, the more likely EMS transports a patient to one. The lack of a relationship in 2015 is surprising; however, neither result conflicts with the underlying hypothesis.

For all other performance measures examined, there are no statistical relationships among median income, population density, number of specialty hospitals in the LEMSA jurisdiction, or size of a geographic area. The lack of relationships between the variables and the four performance measures supports the hypothesis that the decentralized LEMSA system is the underlying cause of performance disparities. More research is needed to examine all 17 performance measures in California's core measures report.

(2) National EMS Information System Datasets

If the administrators of the National EMS Information System (NEMSIS) identified individual states with high compliance for comparison, someone could undertake meaningful research on this topic using NEMSIS statistics. Unfortunately, the current environment prohibits administrators from sharing information from individual states. The inaccessibility of NEMSIS illustrates how vast the EMS data desert is in the United States.

(3) London Ambulance Service versus California LEMSAs

Despite the limitations of the California data, in almost every comparable measure, the nationally centralized LAS is superior to the decentralized system in California. The t-tests show statistical significance for two of the four original measures—as well as for two additional measures, cardiac arrest survival and STEMI-center direct-routing. Additionally, LAS reporting is superior compared to individual LEMSAs that report data.

C. RECOMMENDATIONS

Although further research is required to support the general hypothesis of the thesis, the broad disparities in California's EMS are obvious, and the current model of EMS authority does not address the problem. Based on the research presented, disparate prehospital care and outcomes may be improved in California with the following proposals.

(1) Establish Statewide EMS Policies and Treatment Protocols for All Basic Life Support and Advanced Life Support Providers

The guidelines shall be rooted in the latest evidence-based recommendations from the National Association of State EMS Officials. Regional medical directors may then amend state protocols to suit the unique operational requirements of their regions. The state medical director shall impanel a committee to review the state protocols on an annual basis to make updates.

(2) Eliminate the Local EMS Authority System and Consolidate All LEMSAs into Five Regional Authorities

The regions shall be based on the preexisting boundaries of the California regional trauma committees. Treatment protocols shall be standardized based on the latest evidence-based research and require that providers offer the same level of care, no matter what geographic area they serve.

(3) Mandate Data Gathering and Reporting by All EMS Agencies

Agencies shall collect and report all 17 performance measures tracked by the annual California *Core Measures* reports. Additionally, all agencies and cardiac-receiving hospitals shall be required to participate in the Cardiac Arrest Registry to Enhance Survival. The results of each agency's performance-measure data shall be public and transparent. Moreover, the regional authority and the state shall administer a schedule of consequences for failure to report data.

(4) Establish a Standard for Continuous Quality Improvement for Every Provider Agency

The state EMS authority shall mandate ratios of continuous quality improvement personnel to field providers in an effort to improve oversight. Establish a universal standard for performance-based accreditation requirements for all paramedics and EMTs in the state. Additionally, all paramedics and EMTs should be mandated to participate in a robust continuing education schedule prescribed by the regional authority.

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The time commitment to complete a program like this requires a particular type of patience from those closest to you. Vacations are postponed, time is spent away from home, and home time is steeped in research, reading, and writing. I am lucky to share my life with someone who can accept the sacrifice required without kicking me out of the apartment. Thank you, Sheera, for tolerating these past 18 months. I love you lots, and the next vacation is going to be off the charts.

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I. EMERGENCY MEDICAL SERVICES IN CALIFORNIA

A. INTRODUCTION—A TALE OF THREE STROKES

At 2030 hours, the San Francisco Division of Emergency Communications receives a 9-1-1 call for a 60-year-old male who has a sudden episode of abnormal behavior, or “altered mental status.” The first advanced life support (ALS) paramedic engine company from the San Francisco Fire Department (SFFD) responds and is on the scene within five minutes of receiving the call. One minute later, an ALS ambulance from the SFFD arrives with two additional paramedics.

Upon entering the residence, the responders find a 60-year-old male, Mr. Jones, sitting in a chair, not speaking, and gazing off to his left. His hysterical wife, who made the 9-1-1 call, states that her husband was completely normal 20 minutes before she had called. She said, “All of a sudden, he slumped over in the chair and has not spoken since.”

Mr. Jones has no significant medical history other than high blood pressure and high cholesterol, for which he takes medication. The paramedics perform their primary assessment. Mr. Jones is not speaking and is gazing to the left. The paramedics give Mr. Jones oxygen. The lead paramedic notes that Mr. Jones’s blood pressure is extremely high. They connect him to the cardiac monitor and perform a 12-lead electrocardiogram (ECG), looking at the various angles of the heart, all of which are normal. They check his blood glucose level, which is slightly elevated. The lead paramedic performs a quick field stroke exam, known as the Cincinnati Prehospital Stroke Scale, and finds that the patient follows commands; however, he cannot speak, and the entire right side of his body is paralyzed.

Recognizing that this patient is likely having a stroke, the paramedic follows the protocol of San Francisco’s local emergency medical services authority (LEMSA) for this condition, protocol 2.14, "Stroke."[1] The protocol dictates that if a stroke is suspected in a

[1] San Francisco Department of Public Health (SFDPH), EMS Authority, *2.14 Stroke*, EMS Protocol (SFDPH, EMS Authority, 2017), https://acidremap.com/sites/files/1/101/214-stroke.pdf.

patient with symptoms starting within the last 4.5 hours, paramedics must transport the patient immediately to a designated stroke-receiving hospital.[2]

In addition to the stroke protocol, Policy 5000, provides a list of designated stroke-receiving hospitals to which paramedics may transport this patient, bypassing non-stroke hospitals along the way.[3] However, Protocol 2.14 offers no guidance to paramedics for treating this patient other than placing the patient in a position of comfort, administering oxygen, establishing an IV, checking the patient's blood glucose level, and treating him with dextrose if the level is below 60mg/dl.[4]

The crew in San Francisco carries Mr. Jones to the ambulance. They transport him, lights and sirens blazing, to the University of California, San Francisco, (UCSF) Medical Center. They bypass two hospitals along the way, one of which does not offer stroke specialty services, and the other is not preferred by the family. The transport time is 12 minutes. Once at UCSF, Mr. Jones immediately receives a computed tomography (CT) scan of his brain, which reveals he is having an ischemic stroke. This type of stroke is caused by a clot blocking blood flow to a section of the left side of the brain. The doctors administer a "clot-busting" medication called a fibrinolytic, which clears the clot from the blocked cerebral artery and restores blood flow to the affected area. Mr. Jones is released from the hospital four days later after regaining full neurologic function.

At the same time, another 9-1-1 call goes out in the city of Hollister, California, in San Benito County. The patient, Mr. Smith, is also 60 years old and presents with the exact signs and symptoms as Mr. Jones does in San Francisco; he suddenly stops speaking and is now gazing off to his left. He has the same vital signs and medical history as Mr. Jones. However, the paramedics responding to Mr. Smith work for a private ambulance service contracted by the country to provide 9-1-1 response and transport. The local fire department in Hollister also responds, but it is staffed not with ALS paramedics but with

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[2] SFDPH, EMS Authority, *2.14 Stroke*.

[3] SFDPH, EMS Authority, *Destination Policy*, Policy No. 5000 (SFDPH, EMS Authority, 2017), https://acidremap.com/sites/files/1/19/5000-destination-policy.pdf.

[4] SFDPH, EMS Authority, *2.14 Stroke*.

basic life support (BLS) emergency medical technicians (EMTs). The privately contracted ambulance paramedic performs a field stroke exam; however, the protocol of the San Benito County Emergency Medical Service (EMS) Authority advises a completely different test, called the BE-FAST (balance, eyes, face, arms, speech, time [last known well]).[5] The Hollister paramedic references the LEMSA protocol for San Benito County, in this case, Protocol 700-N3, and determines Mr. Smith is having a stroke. San Benito County's EMS authority dictates that the paramedic treat this patient as an acute stroke if the patient has had symptoms within the last six hours, unlike the 4.5 hours that protocols in San Francisco dictate.[6]

When deciding where to transport Mr. Smith, the paramedic in Hollister may not bypass the closest hospital to route this patient directly to a stroke specialty-care center as the team in San Francisco does. The San Benito County EMS protocols mandate that paramedics take Mr. Smith to the closest receiving emergency department, which—in this case—does not have the stroke specialty capability to remove the clot that is blocking blood flow to Mr. Smith's brain. The patient has to wait several more hours for a second ambulance to take him to a hospital that offers the stroke specialty care, which Mr. Jones receives immediately in San Francisco. Unfortunately, Mr. Smith arrives at the second hospital a full seven hours after his initial stroke symptoms appear. The clot-busting fibrinolytic medications that Mr. Jones receives in San Francisco are not effective for Mr. Smith because he arrives at the stroke center too late after symptoms begin; the damage to his brain is done.[7] Mr. Smith spends several months in a rehabilitation facility, learning how to speak and eat again, and he must live the rest of his life without the use of the right side of his body.

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[5] San Benito County Office of Emergency Services (OES), *Adult Patient Care: Stroke*, Protocol 700-N3 (Hollister, CA: San Benito County OES, 2017), https://www.acidremap.com/sites/files/168/333/700-n3-stroke.pdf. "Activation" in San Benito County involves notifying the receiving hospital in advance.

[6] San Benito County OES.

[7] William J. Powers et al., "2015 American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the Early Management of Patients with Acute Ischemic Stroke Regarding Endovascular Treatment: A Guideline for Healthcare Professionals from the American Heart Association/American Stroke Association," *Stroke* 46, no. 10 (October 2015): 3031, https://doi.org/10.1161/STR.0000000000000074.

Meanwhile, in rural San Bernardino County in southern California, another 60-year-old man, Mr. Stevens, presents the same way as Mr. Jones and Mr. Smith do. The lone responding paramedic from the private ambulance company responds with her EMT partner along with BLS providers from the local fire department, composed mostly of part-time firefighters who are also EMTs. Mr. Stevens has the same medical history, vital signs, and acute symptoms as Mr. Jones and Mr. Smith.

The paramedic, recognizing that this may be a stroke, operates under Inland Counties Emergency Medical Authority (ICEMA)'s Protocol 11110 for stroke treatment. The policy mandates that a paramedic in San Bernardino County use an entirely different stroke identification exam than the tests used in San Francisco (Cincinnati Prehospital Stroke Scale) and San Benito County (BE-FAST). This one is called the Modified Los Angeles Prehospital Stroke Screen, which mandates she treat the patient as an acute stroke within 12 hours of the start of symptoms, unlike six hours in San Benito County and 4.5 hours in San Francisco.[8] She, too, must obtain a blood glucose reading, but her protocol dictates administration of dextrose by IV with a blood sugar reading below 80mg/dl—unlike San Francisco and San Benito County protocols, which dictate administration of dextrose with a blood sugar readings of 60mg/dl.[9]

Like the paramedic in San Francisco and unlike the one in San Benito, the paramedic in San Bernardino is allowed to bypass closer hospitals to route this stroke patient directly to a stroke specialty-care hospital.[10] However, from her remote location, the closest stroke center is well over an hour away. She contacts her base station and requests an aeromedical helicopter to intercept the ambulance at a nearby baseball field. The local fire department sets up the landing zone, and a helicopter from a private aeromedical provider, contracted by the county, launches with a flight paramedic and flight nurse. The paramedic explains to Mr. Stevens's family that he is likely having a stroke,

[8] Inland Counties Emergency Medical Agency (ICEMA), *Stroke Treatment—Adult*, Protocol 11110 (San Bernardino, CA: ICEMA, 2016), https://www.sbcounty.gov/icema/main/ems_policy_manual.aspx.

[9] ICEMA, *Medication: Standing Orders, Dextrose—Adult*, Protocol 7040 (San Bernardino, CA: ICEMA, 2016), https://www.sbcounty.gov/icema/main/ems_policy_manual.aspx.

[10] ICEMA, *Transportation and Destination*, Policy 8130 (San Bernardino, CA: ICEMA, 2015), https://www.sbcounty.gov/icema/main/ems_policy_manual.aspx.

and it is crucial that he be transported to a stroke center as quickly as possible. The paramedic tells them, "I called in a helicopter to transport him because the faster we get him there, the more of his brain we can save." Mr. Stevens's emotionally distraught wife instructs the paramedic to do whatever necessary.

The helicopter lands at the predetermined landing zone, and the flight paramedic and nurse take over patient care. They load Mr. Stevens into the aircraft and fly him to Loma Linda University Medical Center, the closest stroke specialty-care facility with a helicopter landing pad.

Once at the medical center, Mr. Stevens undergoes an emergency procedure wherein doctors insert a catheter into the artery supplying blood to his brain and manually remove the clot, thereby restoring blood flow to the affected area. Mr. Stevens is left with some decreased function to his right side but regains the ability to speak and eat. He spends four days in the hospital followed by another week in a rehabilitation facility. Several weeks later, Mr. Stevens receives a bill from the private aeromedical provider for $50,200—in addition to the $1,500 bill he receives from the private ambulance provider for the initial paramedic evaluation, treatment, and transport to the landing zone.[11] A separate bill arrives from Loma Linda University Medical Center for his in-hospital emergency treatment and subsequent stay in the Neuro Intensive Care Unit; the bill is well into the tens of thousands of dollars. Mr. Stevens does not have medical insurance.

Although the experiences of the three stroke patients are fictional, the variation in protocols that paramedics are mandated to follow in these three California counties is real. Similar scenarios and outcomes play out all over California every day.

B. RESEARCH QUESTION

The goal of this thesis is to shed light on the following questions:

[11] Donna Rosato, "Air Ambulances: Taking Patients for a Ride," Consumer Reports, April 6, 2017, https://www.consumerreports.org/medical-transportation/air-ambulances-taking-patients-for-a-ride/; and ICEMA, *Ground Based Ambulance Rate Setting Policy*, Ref. 5080 (San Bernardino, CA: ICEMA, 2012), https://www.sbcounty.gov/icema/main/ViewFile.aspx?DocID=1242.

1. Is there consistency or disparity in EMS patient care and patient outcomes in California?

2. If there is a disparity, is the decentralized EMS authority system with 33 separate LEMSA jurisdictions the chief culprit?

3. Does California's system of decentralized EMS authority provide better or worse prehospital emergency care compared to states that centralize EMS authority?

4. How could statewide centralization of EMS protocols and authority be a solution to improve patient outcomes?

C. THE PROBLEM SPACE

There are 33 separate LEMSA agencies serving the 58 counties in California.[12] A LEMSA in California governs either EMS providers in a single county or several counties combined. Each LEMSA dictates widely different treatment and transport protocols for its paramedics and EMTs.[13]

The medical director for each LEMSA has sole authority to change or maintain a local treatment protocol. The only state-regulated requirement for a protocol is that it must fall within the accepted scope of practice for BLS, EMTs, or ALS paramedics per Title 22, § 9 of the *California Code of Regulations*.[14] ALS paramedics require a significantly higher level of training and licensure than EMTs.[15] Although some of these protocols adhere to national standards of care, many other LEMSA medical directors have not updated their local policies to the latest evidence-based standards.

The preliminary data collected substantiate previously published literature showing a broad disparity in prehospital care and patient outcomes among different LEMSA

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[12] "Local EMS Agencies," California Emergency Medical Service (EMS) Authority, 2017, https://emsa.ca.gov/local-ems-agencies/.

[13] Eric Silverman et al., "Prehospital Care for the Adult and Pediatric Seizure Patient: Current Evidence-Based Recommendations," *Western Journal of Emergency Medicine* 18, no. 3 (April 2017): 428, https://doi.org/10.5811/westjem.2016.12.32066.

[14] Pre-hospital Emergency Medical Services, 22 Cal. Code Regs. § 100146 (2016), https://emsa.ca.gov/regulations/.

[15] "Regulations," California EMS Authority, accessed April 29, 2018, https://emsa.ca.gov/regulations/.

jurisdictions in California. As examples, cardiac arrest survival-to-discharge rates range from 6.3 percent to 32 percent.[16] Direct routing of stroke patients to a stroke specialty-care hospital varies wildly from 0 to 100 percent.[17] Finally, yearly intubation success rates range widely from 44 percent to 92 percent.[18] The literature indicates that this is a national problem and not limited to California. Several possible factors may contribute to the disparity—differences in geography, proximity to specialty hospitals, population size, and socioeconomic differences among each LEMSA area. Although previous research has established the problem of geographic EMS disparity, there is nothing definitive that sufficiently explains the cause of it.

Compounding the problem is a striking lack of performance-measure data for EMS throughout the United States.[19] The structure of EMS authority, provider standards, and treatment protocols vary significantly from one U.S. state to another.[20] As demonstrated in the introduction, there are significant variants from one county to another in California.

The EMS "data desert" limits the scope of research, which seeks to explain the inconsistency in EMS care. Although organizations such as the National EMS Information System (NEMSIS) and the Cardiac Arrest Registry to Enhance Survival (CARES) are beginning to collect standardized national data, participation in these programs is still voluntary, and only a fraction of EMS agencies around the country contribute.[21]

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[16] California EMS Authority, *EMS Core Measures Project, Reporting Capability of EMSA and LEMSA Data Systems and Results From Performance Measures Data Year 2015* (Rancho Cordova: California EMS Authority, 2015), 31, http://www.emsa.ca.gov/Media/Default/PDF/Core_Measures_2015_DataYear_Report.pdf.

[17] California EMS Authority, 37.

[18] California EMS Authority, 45.

[19] Ralph Rengar et al., "National Data Collection Efforts Pose Challenges for Many EMS Agencies," *Journal of Emergency Medical Services* (June 2016), http://www.jems.com/ems-insider/articles/2016/06/national-data-collection-efforts-pose-challenges-for-many-ems-agencies.html.

[20] Douglas F. Kupas et al., "Characteristics of Statewide Protocols for Emergency Medical Services in the United States," *Prehospital Emergency Care* 19, no. 2 (April 2015): 292–301, http://dx.doi.org/10.3109/10903127.2014.964891.

[21] "About CARES," Cardiac Arrest Registry to Enhance Survival (CARES), accessed October 15, 2017, https://mycares.net/sitepages/aboutcares.jsp.

D. HYPOTHESIS

Arguably, the decentralized LEMSA system itself is the chief culprit for EMS disparity in California. Analysis of the available California EMS performance-measure data reveals the wide disparity. However, the inequities do not always have a direct correlation to socioeconomic factors, geographical differences, or population size, although further regression analysis is still necessary. Thus far, the only constant across all LEMSAs in California is that they have different treatment protocols and widely varying training standards to maintain local accreditation as EMTs or paramedics.

Twenty-one U.S. states have standardized statewide EMS protocols applying to all providers. Other states have a recommended set of EMS guidelines to which local medical directors voluntarily adhere with slight adjustments based on unique operational needs. In the literature, there is no research comparing performance measures between states with decentralized EMS authority versus states with statewide standardized protocols.[22]

If the LEMSA system is in fact the problem in California, how can the state reorganize EMS to improve patient care and outcomes for all Californians? Is there enough data to compare California's EMS performance measures to those of states that consolidate under one set of prehospital treatment protocols?

[22] Kupas et al., "Characteristics of Statewide Protocols."

II. LITERATURE REVIEW

Multiple studies have identified the scope of the problem for EMS in the United States today—the disparity of care, the variation of training standards, and a lack of performance-measure data. Moreover, where data are available, they are often skewed by unstandardized collection and reporting methods. To put the identified issues into perspective, several studies and articles have established the scope of the problem and the failure to track performance.

A. DISPARITIES IN EMERGENCY MEDICAL SERVICES

In 2009, Micky Eisenberg and Roger White, two well-known medical directors from Washington state, published a scathing article about the state of prehospital cardiac-arrest care in the United States.[23] In the article, they describe a vast disparity in survival-to-discharge rates for patients who suffer out-of-hospital cardiac arrest. The survival-to-discharge rates range from 0 percent in Detroit to 46 percent in Seattle.[24] This is despite over four decades of cardiac-arrest research and the emergence of ALS as an EMS standard throughout the United States since the 1970s. Additionally, Eisenberg and White claim, "Only 50 communities have reported their experience," and they conclude that the nation has no idea whether their local level of cardiac-arrest care is "good, bad or terrible."[25]

Eisenberg and White's article is one of the first to use empirical data to identify what many practitioners in the field have known intuitively for years: there are significant differences in care for critical patients from one area to another. The article is unique because it indicts national prehospital leaders for inconsistency and failure to create a system that accurately evaluates performance. The article identifies the lack of standardization for EMS training and a resource disparity between rural and urban

[23] Micky Eisenberg and Roger White, "The Unacceptable Disparity in Cardiac Arrest Survival in the United States," *Annals of Emergency Medicine* 54, no. 2 (August 2009): 258–260, http://ramaryland.org/Portals/0/Users/002/02/2/Disparty%20in%20Cardiac%20Arrest%20Survival%20in%20the%20United%20States.pdf.

[24] Eisenberg and White.

[25] Eisenberg and White, 258.

communities. Eisenberg and White use the National Fire Protection Agency as a model organization that considers various organizations—specifically fire departments—for different levels of standards. The authors challenge the community of EMS medical directors to set new standards for care, oversight, and data collection. They also advocate local community training programs for cardiopulmonary resuscitation and automated external defibrillation to increase out-of-hospital cardiac-arrest survival.[26] Eisenberg and White speak to the core issues of the thesis—the geographic disparity in EMS care and the prehospital data desert.

Leeana Mims, too, shares concerns about the national EMS leadership vacuum in her 2011 Naval Postgraduate School master's thesis.[27] Mims argues that one solution to the leadership vacuum is to relocate EMS representation to the federal government. She claims that EMS belongs under the umbrella of the Department of Health and Human Services, not the Department of Transportation (DOT), where it currently resides. Mims maintains that under the current stewardship, the needs of the national EMS community are lost in the white noise of law enforcement and fire service interests. She feels the needs of EMS would have a more prominent voice within the Department of Health and Human Services along with an associated increase in funding for EMS initiatives. To this day, federal oversight of EMS remains hidden away under the umbrella of the DOT's National Highway Transportation and Safety Administration (NHTSA).

The reason EMS lives under the NHTSA umbrella is that the modern incarnation of professional EMS was born of that agency during the late 1960s. In 1966, the National Academy of Sciences for the NHTSA published *Accidental Death and Disability: The Neglected Disease*, also known in the EMS community as the "white paper."[28] This groundbreaking study ushered in the formation of modern EMS as a reaction to the

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[26] Eisenberg and White.

[27] Leeanna Mims, "Improving Emergency Medical Services (EMS) in the United States through Improved and Centralized Federal Coordination" (master's thesis, Naval Postgraduate School, 2011), 39–49, https://www.hsdl.org/?abstract&did=5413.

[28] National Academy of Sciences, *Accidental Death and Disability: The Neglected Disease* (Washington, DC: National Academy of Sciences, 1966), https://www.ems.gov/pdf/1997-Reproduction-AccidentalDeathDissability.pdf.

staggering number of traffic deaths nationwide. Because the study focused on traffic accidents, EMS on a national level fell under the purview of the NHTSA, where it has remained. According to Mims, federal oversight of EMS is antiquated under NHTSA, and EMS would be improved nationally under a more relevant federal entity.[29]

On the other hand, Eisenberg and White argue that the community of EMS medical directors has the responsibility to improve the inequities of standards, training, and data reporting, regardless of where EMS is housed.[30] That is understandable since Eisenberg and White are both doctors and feel the power to change EMS lies within their collective scope of authority. Although the Eisenberg and White article is eight years old at the time of this writing, it is still relevant in today's EMS landscape. The only difference between then and now is the advent of CARES, which uses the Utstein criteria to track cardiac-arrest survival nationwide.[31]

Eisenberg and White have not been the only ones to recognize the disparity of EMS standards and care from one geographic area to another. In 2015, Nikolay Dimitrov et al. published a study analyzing stroke patients in California who were and were not transported directly to designated stroke hospitals.[32] The work by Dimitrov et al. is important and particularly relevant because it deals specifically with the disparity in stroke care within California. The study concludes, "32% of California's population does not have access to acute stroke routing."[33] Dimitrov et al. demonstrate that a stroke patient is more likely to have a better outcome in some areas of California than others. This finding supports my hypothesis that the LEMSA system promotes inequality.

In a 2017 study, Silverman et al. examine the variances in the adult and pediatric seizure protocols of the 33 California LEMSAs. The goal of the study was to recommend

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[29] Mims, "Improving Emergency Medical Services."

[30] Eisenberg and White, "The Unacceptable Disparity."

[31] CARES, "About CARES."

[32] Nikolay Dimitrov et al., "Variability in Criteria for Emergency Medical Services Routing of Acute Stroke Patients to Designated Stroke Center Hospitals," *Western Journal of Emergency Medicine* 16, no. 5 (September 2015): 743–746, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4644044/.

[33] Dimitrov et al., 745.

an evidence-based set of protocols to replace the wide variance in seizure protocols across the 33 LEMSAs. They found that "protocols across EMS agencies in California varied widely. [They] identified multiple drugs, dosages, routes of administration, re-dosing instructions, and the requirement for blood glucose testing prior to medication delivery."[34] The work by Silverman et al. demonstrates that the wide variation in treatment protocols and medications administered for the same condition within the state exist across a multitude of other acute medical conditions.

The disparity of treatment is not limited to California. In 2016, the National Association of State EMS Officials (NASEMSO) sought to address this problem with a multistate study prepared for NHTSA. In the report, the team attempted to implement evidence-based changes to the pain management protocols for five states: Arizona, Idaho, Kansas, Tennessee, and Wyoming. The report acknowledges, "There is wide variation in prehospital patient care."[35] It proposes a model for introducing a new evidence-based protocol that would apply to all EMS providers across several states.[36] This study presents an excellent model for writing and implementing a set of statewide EMS treatment protocols that California could adopt.

Ken Jacobs et al. with the Berkeley Center for Labor Research and Education provide a general overview of EMS working conditions, wages, and training standards.[37] The authors break down the percentage of EMTs and paramedics who work for private ambulance entities versus public service agencies. Jacobs et al. also provide an understandable overview of California's arcane EMS regulatory system. Among many recommendations, the authors suggest imposing minimum labor standards for paramedics

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[34] Silverman et al., "Prehospital Care," 419–436.

[35] Matt Scholl et al., The Implementation and Evaluation of an Evidence-Based Statewide Prehospital Pain Management Protocol Developed Using the National Prehospital Evidence-Based Guideline Model Process for Emergency Medical Services (Falls Church, VA: National Association of State EMS Officials, September 2016), 5, https://www.nasemso.org/Projects/ImplementationOfEBG/documents/EBG_NHTSA_FinalReport.pdf.

[36] Scholl et al., 5.

[37] Ken Jacobs et al., "Emergency Medical Services in California: Wages, Working Conditions, and Industry Profile," UC Berkeley Labor Center, February 7, 2017, http://laborcenter.berkeley.edu/emergency-medical-services-in-california-wages-working-conditions-and-industry-profile/.

and EMTs. The authors advocate a statewide improvement in working conditions with the goal of improving the quality of prehospital provider: “To promote the creation of a long-term, well-trained EMS workforce, continuing education requirements should be revamped, and protections for incumbent workers should be established for when contracts change.”[38]

EMS insiders know that there is no universal standard to work as a field paramedic after obtaining a license. In California, paramedics must renew their license every two years with 48 hours of continuing education. Although there are some statewide requirements, such as American Heart Association basic life support, advanced cardiac life-support, and pediatric advanced life support certification, how the remainder of the 48 hours of training is delivered is up to the individual provider agency. Each LEMSA or individual provider agency does its own vetting and training to establish competency for its paramedics and EMTs, and it is an understatement to say training standards are uneven. EMS continuing education training standards are similar to the means by which Californians maintain a driver’s license—they have no bearing on the ability of the bearer to drive safely. Just as incompetent licensed drivers clog the rush-hour commute, incompetent licensed paramedics care for patients every day. Jacobs et al. have validated this view.[39]

Another California-specific study challenges, among other things, the entire business model for EMS. In his master’s thesis from the Naval Postgraduate School, Niko King analyzes the benefits of implementing a mobile integrated health (MIH) program, also known as community paramedicine, in Sacramento. King argues that the entire business model of EMS delivery, which focuses on volume and patient turnover based on a simple supply and demand metric, is fundamentally flawed. Additionally, he argues for an MIH program focusing resources to best serve the needs of patients. In this case, an MIH program can treat patients in the field, direct patients to chronic care, and free up finite emergency ambulances and emergency department beds for high-acuity calls. The

[38] Jacobs et al., 1.

[39] Jacobs et al.

focus on matching patient need with the appropriate service, according to King, "adds resilience to the emergency medical services and resources identified as critical infrastructure and key resources in the nations [*sic*] national response framework."[40] Although King does not directly address the research questions of this thesis, the flawed delivery system for EMS in California and the different models to tackle it contribute to the disparity conversation.

In 1999, a study by Narad and Driesbock addressed the disparities among and the lack of quantifiable EMS performance measures.[41] The authors examined how many California counties use EMS response times as a performance measure and concluded few use data collection methods that comply with state standards. Although this article is 18 years old at the time of this writing, it still applies in many parts of California.[42] Although the authors examine only one data point, it provides more evidence of a significant disparity in EMS standards and care within the California LEMSA system.

In 2008, Nichol, Thomas, and Callaway published a relevant regional study comparing cardiac-arrest survival outcomes among different cities and regions across the United States. The design of their study—rather than its vague conclusions—is most relevant to this thesis.[43] Researchers Nichol, Thomas, and Callaway retrospectively examined outcomes for all hospital cardiac-arrest patients between 2006 and 2007 in 11 regions or cities in North America. Tracking a subset of patients within the larger cardiac arrest population, they found "significant and important regional differences in out-of-hospital cardiac arrest incidence and outcome, which require additional investigation to improve public health."[44] Nichol, Thomas, and Callaway make no specific connections

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[40] Niko King, "The Evolving Role of Emergency Medical Services in Sacramento, CA" (master's thesis, Naval Postgraduate School, 2017), 35.

[41] Richard A. Narad and Kirsten R. Driesbock, "Regulation of Ambulance Response Times in California," *Prehospital Emergency Care* 3, no. 2 (January 1999): 131–135, http://dx.doi.org/10.1080/10903129908958921.

[42] California EMS Authority, *Core Measures 2015 Data*.

[43] Graham Nichol, Elizabeth Thomas, and Clifton W. Callaway, "Region Variation in Out-of-Hospital Cardiac Arrest Incidence and Outcome," *Journal of the American Medical Association* 300, no. 12 (September 24, 2008): 1423–1431, https://doi.org/10.1001/jama.300.12.1423.

[44] Nichol, Thomas, and Callaway, 1423.

regarding the type of EMS systems—they acknowledge only that there are regional differences. They also make little mention of the socioeconomic status of the regions they examined. Instead, the researchers focus on the patient age, population density of the areas, and geography of the regions they observed. From a methodological and analytical standpoint, the study provides an excellent model for analyzing outcomes between decentralized and centralized EMS regions.

An ambitious study by Wendy Shultis et al. addresses EMS disparity on a broader scale. The authors examine the differences between rural and urban EMS systems within several geographic regions in the Pacific Northwest—all decentralized local EMS authorities.[45] From an urban versus rural perspective, Shultis et al. found "striking rural-urban differences . . . with rural hospitals having a much lower capacity to adequately care for patients with stroke."[46] The suggestion that rural areas are not equipped for standard stroke care is an interesting conclusion; however, it is unclear whether this problem extends to cases nationwide. Even so, the scope of this paper is impressive. One aspect that Shultis et al. do not sufficiently explain is the socioeconomic dimension of their research. For instance, what is the median income of the population in the rural Pacific Northwest communities in their study? Is there is a correlation between low-income rural areas and poor stroke care or between high-income areas and better care—despite the rural environment? The socioeconomic relationship to quality EMS care is something that neither Shultis et al. nor any other authors have examined in detail thus far.

A 2015 study by Kupas et al. provides a comprehensive analysis of the various levels of statewide versus local EMS protocols throughout the country. Kupas et al. categorize states that decentralize protocols vis-à-vis states that use one unified set of EMS protocols.[47] Kupas et al. confirm that different states have widely varying EMS protocols for treating the same condition. The study is also an excellent research tool to determine

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[45] Wendy Shultis et al. "Striking Rural-Urban Disparities Observed in Acute Stroke Care Capacity and Services in the Pacific Northwest: Implications and Recommendations," *Stroke* 41, no. 10 (October 2010): 2278–2282, https://doi.org/10.1161/strokeaha.110.594374.

[46] Shultis et al., 2278.

[47] Kupas et al., "Characteristics of Statewide Protocols."

which states to include in data groups for "apples-to-apples" performance-measure comparisons. Kupas et al. offer a thoughtful pro and con analysis for statewide centralized EMS treatment protocols. The pros include "uniform care, the ability to update protocols on a regular basis, statewide, standardized care during disaster mutual aid response, more consistent collection and comparison of quality improvement data."[48] On the other hand, the authors point out "poorly designed statewide protocols" may negate any or all of the benefits.[49] In the end, Kupas et al. advocate for statewide protocols with a "regional" approach to oversight and authority.[50] According to the authors, the regional authority provides "the correct care to the correct patient at the correct time."[51] Although regionalization of authority with statewide protocols would be a better system intuitively, the authors do not present any performance-measure evidence to connect statewide protocols and regional authority with improved patient outcomes. It is an area open to further research.

B. THE DATA DESERT

One of the biggest challenges for this research is the lack of quantifiable EMS data. It is one of Eisenberg and White's primary criticisms from their aforementioned article.[52] There are very few standards for EMS data collection and dissemination nationwide. The exception is the Utstein out-of-hospital cardiac-arrest survival-to-discharge criteria, which are the universal performance measures in many EMS systems nationally. For other performance measures, there is now an initiative by the DOT's NHTSA to codify EMS data through the EMS Compass program, an off-shoot of NEMSIS. The recent effort by the NHTSA to coordinate EMS data through NEMSIS and the newly formed EMS Compass program is at the very least a move in the right direction.

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[48] Kupas et al.

[49] Kupas et al., 293–295.

[50] Kupas et al., 300.

[51] Kupas et al.

[52] Eisenberg and White, "The Unacceptable Disparity."

Taymour et al. have recently published a comprehensive analysis of EMS oversight. Their 2018 study is a retrospective analysis of dozens of peer-reviewed studies and grey literature on the subject of EMS oversight and protocol authority.[53] One notable finding of their study is that the "EMS quality measurement focused almost exclusively on response times."[54] However, the studies analyzed focus very little on patient outcomes. According to Taymour et al., response times are "relatively easy to measure and report," but the quality of care and patient outcomes are not.[55] The authors find that the grey literature, which includes position statements and policy memos from various EMS agencies and oversight boards, centers on patient outcomes and the quality of patient care. Taymour et al. argue that policy for EMS from the grey literature should "guide the policy and research agenda for EMS oversight quality measurement."[56] This article highlights what King identifies in his thesis—that the focus on response times, volume, and patient turnover as performance metrics is fundamentally flawed.

Renger et al. also validate the state of an EMS data desert.[57] The authors summarize the challenges for EMS agencies to provide accurate performance-measure data, particularly among small, rural volunteer-based agencies. The authors offer suggestions for promoting participation from smaller rural agencies such as through "bottom-up" approaches to data collection. Additionally, Renger et al. advocate for participation in national data-collection efforts, such as CARES and EMS Compass, and they strongly argue for state and federal funding. Furthermore, Render et al. validate the view that policymakers have no concept of how EMS is performing in systems throughout the country.

[53] Rekar K. Taymour et al., "Policy, Practice, and Research Agenda for Emergency Medical Services Oversight: A Systematic Review and Environmental Scan," *Prehospital and Disaster Medicine* 33, no. 1 (February 2018): 89–97, https://doi.org/10.1017/S1049023X17007129.

[54] Taymour et al., 94.

[55] Taymour et al, 94.

[56] Taymour et al., 89.

[57] Rengar et al., "National Data Collection Efforts."

An overview of the national data initiatives referenced by Renger et al. appears in Mark Rosekind's 2016 article for the *Journal of Emergency Medical Services*.[58] This article provides an overview of the EMS Compass program. According to Rosekind's article, EMS Compass has the potential to address the EMS data desert; however, the program is still in its infancy. This article seems to bolster the idea that the lack of quantifiable performance measures necessitates programs like EMS Compass.

Plenty of reference materials present nationwide heart disease and stroke statistics. One such source is a 2015 article by Dariush Mozaffarian et al., who present statistics in a clear and user-friendly manner, which is useful for describing the scope and commonality of these two diseases across the United States.[59] Their work is useful as background information because the continuum of care for both stroke and cardiac patients often begins with EMS.

Noticeably absent from much of the literature are authors carrying the NREMT-P credential, which identifies them as nationally registered paramedics. Most of the authors contributing to the literature are either physicians or epidemiologists. Although a physician's voice is obviously important in the national EMS conversation, when studying performance measures, a doctor's view of EMS is one from the "outside looking in" and does not always consider factors of working day-to-day on an ambulance or first response vehicle. For instance, very few studies control for the mental health effects on EMS personnel from dealing with low-acuity repeat 9-1-1 abusers every day or the dangers of the dynamic prehospital environment. The way a paramedic operates in the rural EMS environment is entirely different from that of urban EMS. Ground medic expectations are different from those of helicopter EMS. Incorporating the voices of working paramedics into research teams would add an important dimension to future EMS research.

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[58] Mark Rosekind, "EMS Compass: The Quality Imperative," *Journal of Emergency Medical Services* (May 2016), http://www.jems.com/articles/supplements/special-topics/ems-compass/harnessing-the-power-of-data.html.

[59] Dariush Mozaffarian et al., "Heart Disease and Stroke Statistics—2015 Update," *Circulation* 131, no. 4 (January 2015), http://circ.ahajournals.org/content/131/4/e29.

Collectively, the literature provides ample evidence of disparities in EMS performance, quality, and patient outcomes in California and nationwide. The literature also confirms that there is a national void of standardized EMS performance data. Reasons for the disparity are open for study. It is the goal of this thesis to use the snippets of information available to illuminate a few square feet of the vast EMS data desert.

C. EMS SYSTEMS AROUND THE COUNTRY

As previously cited, the Kupas et al. study details the variance in EMS authority and protocol systems around the country. According to Kupas et al., there are six EMS authority models operating in the U.S. today:

1. Mandatory A—a state has statewide protocols that all EMS providers within the state must use.
2. Mandatory B—a state has statewide protocols that all EMS providers within the state must use, but there is a process for services to petition the state to alter *some* of the protocols.
3. Mandatory C—a state has statewide protocols that all EMS providers within the state must use, but there is a process for services to petition the state to develop and use their own protocols.
4. Model—a state has model statewide protocols for providers, but each service or region may choose to use these protocols or may develop their own protocols.
5. Regional—a state has regional protocols that all services within the region must follow, and these cover a geographic area that includes multiple services.
6. Local—a state in which each EMS service or agency develops its own protocols[60]

The number of states that fall into each category varies, from just a few to many. For example,

- **Mandatory A** states include Hawaii, Maryland, West Virginia, Pennsylvania, New Hampshire, Maine, and New Jersey.

[60] Kupas et al., "Characteristics of Statewide Protocols," 293.

- **Mandatory B** states include North Carolina, Iowa, Montana, Michigan, Vermont, and Massachusetts.
- **Mandatory C** states include Oklahoma and Nevada.
- **Model** states include Arizona, New Mexico, Utah, Idaho, Missouri, North Dakota, Nebraska, Ohio, Arkansas, Tennessee, Kentucky, South Carolina, Wisconsin, Georgia, and Alabama.

The remaining states, which include California, employ a decentralized regional or local EMS authority structure.

III. RESEARCH DESIGN

A. EMS PERFORMANCE MEASURES

The first step to answer the research questions is to compare and contrast local known performance data from several California LEMSA agencies. To narrow the scope of the research, the research focused on the following quantifiable prehospital performance measures:

- Percentage of patients meeting trauma triage criteria routed directly to trauma specialty-care hospitals;
- Percentage of stroke patients routed directly to stroke specialty-care hospitals;
- Intubation success rates; and
- 12-lead ECG acquisition compliance for patients at risk for acute coronary syndromes.[61]

Although there are dozens of different pathologies that EMS is called to treat and transport, limited data exist on these performance measures in California.[62] The four measures are universal to all EMS systems—rural and urban—and are directly related to EMS actions in the field. Unlike other performance measures, they are not affected by forces outside the control and quality of field paramedic training or the mandates of the local protocol.

The state of California EMS Authority releases an annual core measures report identifying 17 performance measures from each participating LEMSA jurisdiction. Unfortunately, not all LEMSAs participate in statewide data-collection efforts, nor does California mandate they do so.[63] Despite the report's limitations, to its credit, California is

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[61] A 12-lead electrocardiogram is a machine that traces the heart's multidimensional electrical activity. When used by paramedics in the field, it can identify the early stages of what is commonly referred to as a heart attack, in medical parlance an ST-elevation myocardial infarction (STEMI), as well as other acute coronary syndromes.

[62] California EMS Authority, *Core Measures 2015 Data*, 31.

[63] California EMS Authority, *EMS Core Measures Project, Reporting Capability of EMSA and LEMSA Data Systems and Results From Performance Measures Data Year 2016* (Sacramento: California EMS Authority, 2016), 8–12, https://emsa.ca.gov/ems-core-quality-measures-project/.

one of the few U.S. states that openly publishes an annual analysis of statewide EMS performance. In this research, regression analysis was used to control for factors such as population density, geographical size, availability of specialty hospitals in a region, and median income to determine whether the data support the hypothesis that the system of 33 LEMSA "fiefdoms" causes disparate care and outcomes in California.

1. Limitations of the California EMS Authority's Core Measures Report

Of the 33 California LEMSAs, not all collect and/or share performance-measure data with the state; there is neither a mandate to do so nor consequences for failing to provide data. In 2015, of the LEMSAs that did share data, only four collected and reported on all 17 trackable performance measures. The following four LEMSAs reported no data: El Dorado County EMS, Imperial County EMS, Sacramento County EMS, and Solano County EMS. In 2016, the number of LEMSAs that failed to report data rose to five. In 2016, Tuolumne County EMS joined the list from 2015. On a positive note, the number of LEMSAs that reported all 17 measures rose from four to seven in 2016 (see Figures 1 and 2).

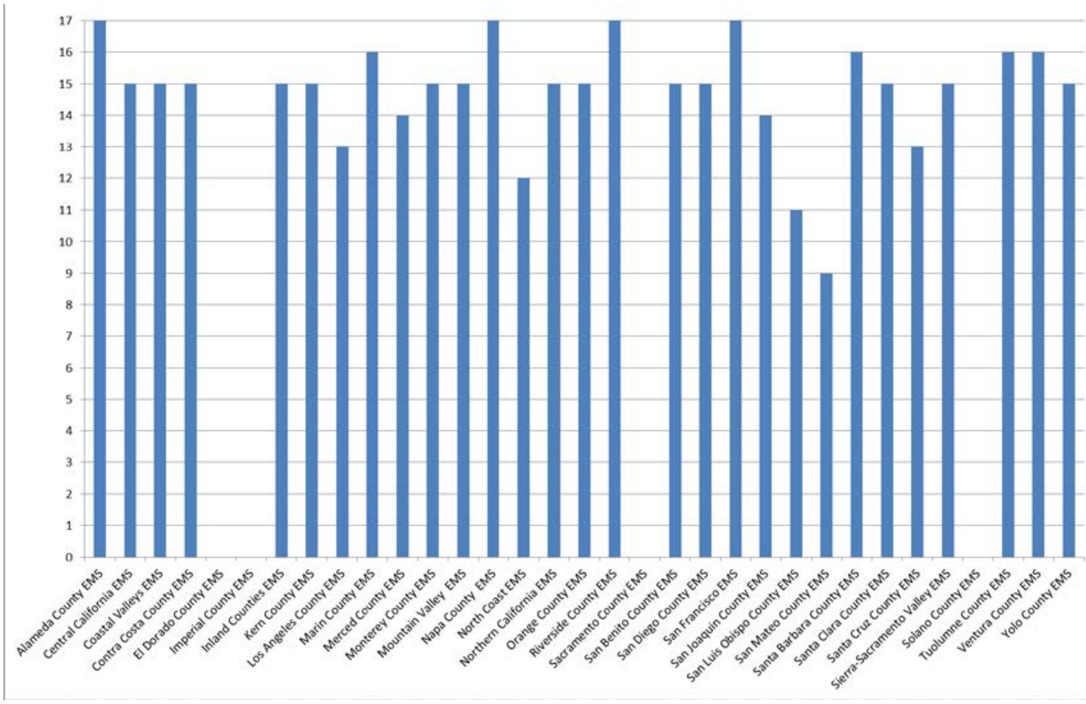

Figure 1. LEMSAs Reporting 17 Clinical Measures in 2015[64]

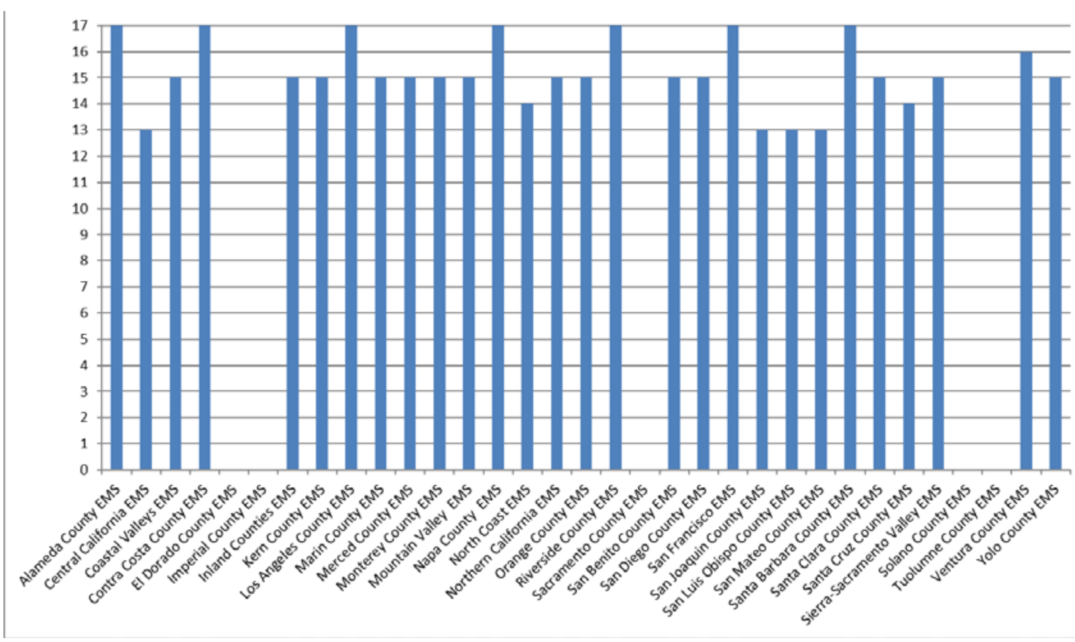

Figure 2. LEMSAs Reporting 17 Clinical Measures in 2016[65]

The *Core Measures 2016 Data* report offers the following disclaimer regarding reporting compliance,

> For 2016, all 28 LEMSAs that reported data provided results for at least 13 measures. The others (represented in the 0-2 category) reported no core measure results. The ability to report these measures is an indicator of the capability of the LEMSA data system to report the retrospective clinical data, and may not represent a LEMSA's commitment to data collection or quality improvement.[66]

In addition to the lack of full reporting compliance, there is no vetting process for the data the LEMSAs provide. The coordinator for the core measures report simply publishes whatever each LEMSA submits. An additional disclaimer appearing in the 2016 report states,

> Multiple factors impact the validity and analysis of these retrospective data, including but not limited to incomplete documentation, documentation not reflective of services provided prior to ambulance arrival, inconsistent data dictionary definitions between local jurisdictions, geographic resource disparities, and inability to collect hospital outcome data. These retrospective data have not been validated. These limitations caution against comparison between jurisdictions and limit the reliance of the aggregate values."[67]

Regardless of disclaimers, these are official published reports from the California State EMS Authority, the only source for available data, despite its "caution against comparison between jurisdictions."[68] It is fair to analyze these reports as general measures of statewide EMS performance.

2. Regression Analysis Data

Additional datasets were obtained for the purpose of regression analysis:

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[64] Source: California EMS Authority, *Core Measures 2016 Data*, 12.

[65] Source: California EMS Authority, *Core Measures 2016 Data*, 12.

[66] California EMS Authority, *Core Measures 2016 Data*, 11.

[67] California EMS Authority, 24.

[68] California EMS Authority, 24.

- The population for each LEMSA jurisdiction from 2012 U.S. census data organized by US-Places[69]
- The 2015 median income from the California Franchise Tax Board[70]
- The square mileage of each LEMSA jurisdiction from the California State Association of Counties[71]
- The number of stroke and trauma specialty hospitals in each LEMSA jurisdiction from the California Office of Statewide Health Planning and Development[72]
- Additional hospital designation data from individual LEMSA protocols

3. National EMS Information System

NEMSIS is an effort sponsored by the NHTSA to standardize and collect EMS data at the national level. As stated in the literature review, EMS on a federal level is administered by the NTHSA, which outsources the primary repository and administration of the data to researchers at the University of Utah.[73]

NEMSIS data are not open source. Researchers must request a specific dataset, and if NEMSIS approves the request, it releases relevant data batches. NEMSIS does not prepare reports, such as the California core measure reports; researchers must sift through the raw data and create reports themselves. Additionally, NEMSIS provides the data in STATA statistical software format. Each dataset has 30 to 50 million data points to analyze, and each variable is coded. NEMSIS provides separate keys for interpreting the codes of various conditions, source patients, performance measures, and outcomes.

[69] "California Population by County," US-Places, accessed August 25, 2018, http://www.us-places.com/California/population-by-County.htm.

[70] "B-6 Comparison by County," California Franchise Tax Board, accessed May 17, 2018, https://data.ftb.ca.gov/California-Personal-Income-Tax/B-6-Comparison-By-County/usjx-d8a6/data.

[71] "Square Mileage by County," California State Association of Counties, accessed January 31, 2018, http://www.counties.org/pod/square-mileage-county.

[72] "List of Hospitals in California by County," Office of Statewide Health Planning and Development, accessed February 4, 2018, http://gis.oshpd.ca.gov/atlas/places/list-of-hospitals/county.

[73] "History of NEMSIS," National EMS Information System (NEMSIS), accessed April 29, 2018, https://nemsis.org/what-is-nemsis/history-of-nemsis/.

In an attempt to analyze the NEMSIS datasets for national EMS performance-measure data outside California, we asked for information from different U.S. states. NEMSIS denied the request to identify datasets by individual U.S. state due to agreements with participating agencies and patient privacy concerns based on the Health Insurance Portability and Accountability Act. The administrators agreed, however, to provide datasets broken into two groups: an aggregate group of U.S. states employing a centralized system of EMS protocols and a second aggregate group of states, like California, using a decentralized set of treatment protocols.

The goal of this thesis is to make an apples-to-apples comparison between the "A" centralized EMS authority group and the "B" decentralized EMS authority group to learn whether there are significant differences in performance measures. One of the limitations of this research is that NEMSIS reporting compliance from many of the participating states is low. Because the data do not identify either group of states individually, and they are all aggregated into either an A or B group, we included all states within each group despite their levels of compliance.

It is preferable to examine more performance measures, particularly direct routing of stroke patients to specialty centers, which California's EMS Authority tracks. However, the complicated structure of NEMSIS data represents the limits of the data available and the ability to organize it.

Because U.S. EMS data are fragmented and incomplete, it is difficult to compare performance measures of U.S. states that centralize EMS authority with measures of states, like California, that decentralize authority. For such a comparison, the scope of the research was broadened to examine centralized EMS systems outside the United States that rigorously collect and openly share performance data.

4. London Ambulance Service, U.K. National Health System Trust

The London Ambulance Service (LAS) is a subdistrict of the nationally centralized National Health System (NHS) in the United Kingdom. The U.K. Department of Health oversees EMS, which has a nationalized vertically integrated authority structure. The Department of Health dictates treatment protocols, transportation guidelines, and dispatch algorithms. There are 11 NHS Trust districts for EMS in the U.K., all operating under the same protocols and dispatch algorithms. LAS serves the capital region and employs over 5,000 members, including paramedics, advanced paramedics, dispatchers, and support and command staff. In stark contrast to most U.S. EMS systems, the LAS collects and openly publishes comprehensive performance-measure data on a quarterly basis. For example, in 2016–2017 LAS medics tended to 550,106 patients with life-threatening conditions, up from 504,685 patients in 2015–2016 and 490,196 patients in 2014–2015.[74] Since EMS policies and protocols in the U.K. are centralized on a national level, it is an ideal system to compare with California's decentralized LEMSA structure.[75] The same four measures examined in the California core measures reports also appear in the LAS data, which facilitates an apples-to-apples comparison between a decentralized system and a centralized one.

5. Limitations in Comparing California LEMSAs and London Ambulance Service

As previously detailed, unlike the standardized comprehensive NHS/LAS data, California LEMSA information is not standardized, nor is it vetted. Additionally, unlike the mandatory EMS data-reporting requirements in England, many of California's LEMSAs submit incomplete performance-measure data, and several report nothing at all.

B. DATA ANALYSIS

As described in Section A of this chapter, there are three datasets used for analysis:

- California core performance-measure report for 2015 and 2016, published by the California Emergency Medical Service (EMS) Authority
- Selected performance measures from NEMSIS
- London ambulance service performance measures from 2016 to 2017

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[74] "Meeting Our Targets," London Ambulance Service, accessed May 4, 2018, https://www.londonambulance.nhs.uk/about-us/how-we-are-doing/meeting-our-targets/.

[75] John J. M. Black and Gareth D. Davies, "International EMS Systems: United Kingdom," *Resuscitation 64*, no. 1 (2005): 21–29, https://www.resuscitationjournal.com/article/S0300-9572(04)00406-X/fulltext.

1. California Core Measures Report, 2015 and 2016

The California EMS Authority's annual core measures reports itemize 17 separate performance measures broken down by LEMSA jurisdiction. As described in the research design, four of the 17 performance measures were examined.[76]

2. Direct Routing of Stroke Patients to Stroke Specialty Hospitals

Patient outcomes in the United States for acute stroke are directly related to how quickly EMS responders identify the stroke and how quickly a stroke specialty-care facility can provide definitive care.[77] The national standard of care—established by the American Heart Association and which subsequent research has expanded—dictates that patients who present with symptoms of an acute stroke should be routed directly to a stroke-specialty receiving hospital.[78] The Joint Commission, a body that accredits and certifies health care organizations and programs in the United States, establishes the standards whereby hospitals become stroke specialty facilities.[79] One quantifiable universal measure of performance is the percentage of stroke patients paramedics identify in the field and route directly to a stroke specialty-care hospital (see Table 1).

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[76] California EMS Authority, *Core Measures 2015 Data*.

[77] Powers et al., "2015 American Heart Association."

[78] Nancy K. Glober et al., "Acute Stroke: Current Evidence-Based Recommendations for Prehospital Care," *Western Journal of Emergency Medicine* 17, no. 2 (March 2016): 104–128, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4786229/.

[79] "Discover the Most Comprehensive Stroke Certifications," Joint Commission, accessed August 25, 2018, http://www.jointcommission.org/certification/dsc_neuro2.aspx.

Table 1. 2015 and 2016 Stroke Direct-Routing by California LEMSA

LEMSA	2015 Stroke Direct-Routing (22/33 LEMSAs Reporting)[80]	2016 Stroke Direct-Routing (23/33 LEMSAs Reporting)[81]
Alameda	85%	85%
Coastal Valleys (Sonoma/Mendocino)	0%	0%
Contra Costa	91.80%	91.80%
El Dorado	X	X
Fresno/Central Cali	X	X
ICEMA	79%	82%
Imperial	X	X
Kern	85%	X
Los Angeles	89%	95%
Marin	100%	100%
Merced	X	71%
Mnt Valley	0%	0%
Monterey	99.38%	96%
N. Calif.	45.36%	45.74%
Napa	0%	0%
North Coast	X	X
Orange	93%	92.40%
Riverside	89%	80%
Sacramento	X	X
San Benito	0%	0%
San Diego	99.68%	99.75%
San Francisco	90%	93%
San Joaquin	X	X
San Luis Obispo	X	X
San Mateo	97%	96%
Santa Barbara	X	98%
Santa Clara	99.81%	100%
Santa Cruz	X	X
Sierra-Sac	88.39%	90.34%

80 Adapted from California EMS Authority, *Core Measures 2015 Data*, 37.

81 Adapted from California EMS Authority, *Core Measures 2016 Data*, 37.

LEMSA	2015 Stroke Direct-Routing (22/33 LEMSAs Reporting)[80]	2016 Stroke Direct-Routing (23/33 LEMSAs Reporting)[81]
Solano	X	X
Tuolumne	0%	X
Ventura	99%	99%
Yolo	96.10%	85.07%

X = failed to report

The California *Core Measures* reports from 2015 and 2016 validate the previously cited work of Dimitrov et al., who conclude that “32% of California’s population does not have access to acute stroke routing.”[82] However, to test the hypothesis that the decentralized LEMSA system is the root cause of the disparity, regression analysis must control for median income, geography, population size, and the number of stroke centers within a given LEMSA jurisdiction. The p-values and regression statistics for each controlled variable appear in Tables 2–5.[83]

82 Dimitrov et al., “Variability in Criteria,” 745.

83 California EMS Authority, *Core Measures 2015 Data*.

Table 2. 2015 California Stroke Data Regression Analysis[84]

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.158083873	0.493576548	0.320282383	0.752899009	-1.204419413	0.888251667	-1.204419413	0.888251667
Median Income (2015)	1.59898E-05	1.12482E-05	1.421542419	0.174358102	-7.85531E-06	3.98348E-05	-7.85531E-06	3.98348E-05
Population (2012)	-2.02715E-08	1.75197E-07	-0.11570645	0.909324953	-3.91674E-07	3.51131E-07	-3.91674E-07	3.51131E-07
Population Density	7.36242E-06	2.60129E-05	0.28302964	0.780783201	-4.77824E-05	6.25073E-05	-4.77824E-05	6.25073E-05
# of Centers w/in LEMSA area	0.024404026	0.045366841	0.537926497	0.598031469	-0.07176938	0.120577431	-0.07176938	0.120577431
% Stroke Ctrs by Population Density	1.861507134	2.361317152	0.788334228	0.442025464	-3.14426161	6.867275877	-3.14426161	6.867275877

Table 3. 2015 Stroke Direct-Routing Regression Statistics

Multiple R	0.562424616
R Square	0.316321448
Adjusted R Square	0.102671901
Standard Error	0.380475218
Observations	22

84 Adapted from California EMS Authority, *Core Measures 2015 Data*; California EMS Authority, *Core Measures 2016 Data*; US-Places.com, “California Population by County”; California Franchise Tax Board, “B-6 Comparison by County”; California State Association of Counties, “Square Mileage by County”; and Office of Statewide Health Planning and Development, “List of Hospitals in California by County.” See also Appendix B.

Table 4. 2016 California Stroke Data Regression Analysis[85]

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.547817631	0.146877217	3.729765871	0.002522815	0.230508695	0.865126567	0.230508695	0.865126567
Median Income (2015)	6.9346E-06	3.24239E-06	2.138729885	**0.052015189**	-7.01614E-08	1.39394E-05	-7.01614E-08	1.39394E-05
Population Density	-2.26071E-06	8.51922E-06	-0.265366372	0.794888713	-2.06654E-05	1.61439E-05	-2.06654E-05	1.61439E-05
# of Stroke centers within LEMSA area	0.005879764	0.003580259	1.64227334	0.124489693	-0.001854915	0.013614443	-0.001854915	0.013614443
Percent Stroke Centers by Population Density	0.263138967	0.652783838	0.403102761	0.693423745	-1.147114776	1.673392711	-1.147114776	1.673392711

Table 5. 2015 Stroke Direct-Routing Regression Statistics

Multiple R	0.562424616
R Square	0.316321448
Adjusted R Square	0.102671901
Standard Error	0.380475218
Observations	22

85 See Appendix C for further details.

3. Stroke Data Regression Analysis Results

There are no statistically significant relationships among any of the independent variables. Median income is borderline ($p = 0.052$) in 2016 but is not even borderline in 2015. There is no statistically significant relationship between patients routed directly to stroke centers and the number of stroke hospitals in the LEMSA area, geographic square mileage, or population density.

Looking at the raw data, one can conclude that the number of stroke centers within the LEMSA area do not determine the outcome of stroke direct-routing. Even counties that have no stroke centers within a LEMSA area, such as northern California and Merced, have successful stroke direct-routing. LEMSAs, such as Mountain Valley, with three stroke centers in the jurisdiction have 0 percent stroke direct-routing.

4. Trauma Center Direct-Routing for Patients Meeting Trauma Center Criteria

Definitive critical trauma care is specialized because it often involves surgery. One of the many mantras taught to paramedic students is “trauma is a surgical disease.” Protocols direct paramedics to direct-transport a patient exhibiting “trauma center triage criteria” to a designated trauma center. Table 6 indicates the percentages of trauma triage patients who were transported directly to a trauma center, by reporting LEMSA. Tables 7–10 summarize the regression analysis controlling for median income, population density, and the number of trauma centers in a LEMSA jurisdiction. Figure 3 illustrates the relationship between percentages of trauma patients direct routed to trauma centers by LEMSA and number of trauma centers in the LEMSA area.

Table 6. 2015 and 2016 Direct Transport to Trauma Center When Meeting Trauma Center Criteria by California LEMSA

LEMSA	2015 Direct Transport to Trauma Center When Meeting Trauma Center Criteria (26/33 LEMSAs Reporting)[86]	2016 Direct Transport to Trauma Center When Meeting Trauma Center Criteria (27/33 LEMSAs Reporting)[87]
Alameda	90.00%	95%
Coastal Valleys (Sonoma/Mendocino)	38.00%	75.88%
Contra Costa	47.80%	49.90%
Fresno/Central Cali	95.63%	93.34%
ICEMA	48.00%	49%
Kern	91.80%	92.00%
Los Angeles	X	95.97%
Marin	100.00%	99%
Merced	11.76%	35.21%
Mnt Valley	83.73%	86.38%
Monterey	54.69%	73%
N. Calif.	56.41%	72.22%
Napa	86.16%	76.15%
North Coast	X	X
Orange	83.00%	77.20%
Riverside	33.12%	63%
San Benito	17.00%	10.20%
San Diego	94.69%	95.05%
San Francisco	75.00%	66%
San Joaquin	53.31%	58.40%
San Luis Obispo	97.00%	95%
San Mateo	X	59.32%
Santa Barbara	89.20%	96%
Santa Clara	85.49%	86.11%

86 Adapted from California EMS Authority, *Core Measures 2015 Data*, 17.

87 Adapted from California EMS Authority, *Core Measures 2016 Data*, 17.

LEMSA	2015 Direct Transport to Trauma Center When Meeting Trauma Center Criteria (26/33 LEMSAs Reporting)[86]	2016 Direct Transport to Trauma Center When Meeting Trauma Center Criteria (27/33 LEMSAs Reporting)[87]
Santa Cruz	11.00%	29%
Sierra-Sac	98.03%	96.05%
Tuolumne	91.00%	X
Ventura	96.00%	95.50%
Yolo	60.20%	60%

X indicates failed to report

Table 7. 2015 Direct Transport to Trauma Center for Patients Meeting Trauma Center Criteria by California LEMSA Regression Analysis[88]

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.159241917	0.2922366	0.5449074	0.591557725	-0.4484974	0.7669813	-0.44849743	0.7669813
Median Income (2015)	1.04163E-05	7.315E-06	1.4239142	0.169161248	-4.797E-06	2.563E-05	-4.7966E-06	2.563E-05
Population Density	-4.20764E-06	1.871E-05	-0.2249233	0.824213161	-4.311E-05	3.47E-05	-4.3111E-05	3.47E-05
# of Trauma centers within LEMSA area	0.059152316	0.0417785	1.4158538	0.171479714	-0.0277309	0.1460356	-0.02773093	0.1460356
Percent Trauma Centers by Population Density	1.277547096	3.4514485	0.3701481	0.714979098	-5.9001331	8.4552272	-5.90013305	8.4552272

Table 8. 2015 Trauma Direct Transport Regression Statistics

Multiple R	0.489425
R Square	0.239537
Adjusted R Square	0.094687
Standard Error	0.273939
Observations	26

88 See Appendix D for further details.

Table 9. 2016 Direct Transport to Trauma Center for Patients Meeting Trauma Center Criteria California LEMSA Regression Analysis[89]

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.40217802	0.224210824	1.793749351	0.086611187	-0.062806769	0.867162809	-0.062806769	0.867162809
Median Income (2015)	5.97998E-06	5.27964E-06	1.132648759	0.269555758	-4.96933E-06	1.69293E-05	-4.96933E-06	1.69293E-05
Population Density	-7.86571E-06	1.49237E-05	-0.527063509	0.603424295	-3.88155E-05	2.30841E-05	-3.88155E-05	2.30841E-05
# of Trauma centers within LEMSA area	0.033282557	0.015314673	2.173246361	**0.040805623**	0.001521869	0.065043244	0.001521869	0.065043244
Percent Trauma Centers by Population Density	2.188608793	2.299890782	0.951614229	0.351631331	-2.581072759	6.958290344	-2.581072759	6.958290344

Table 10. 2016 Trauma Direct Transport Regression Statistics

Multiple R	0.50283
R Square	0.252838
Adjusted R Square	0.11699
Standard Error	0.22206
Observations	27

89 See Appendix E for further details.

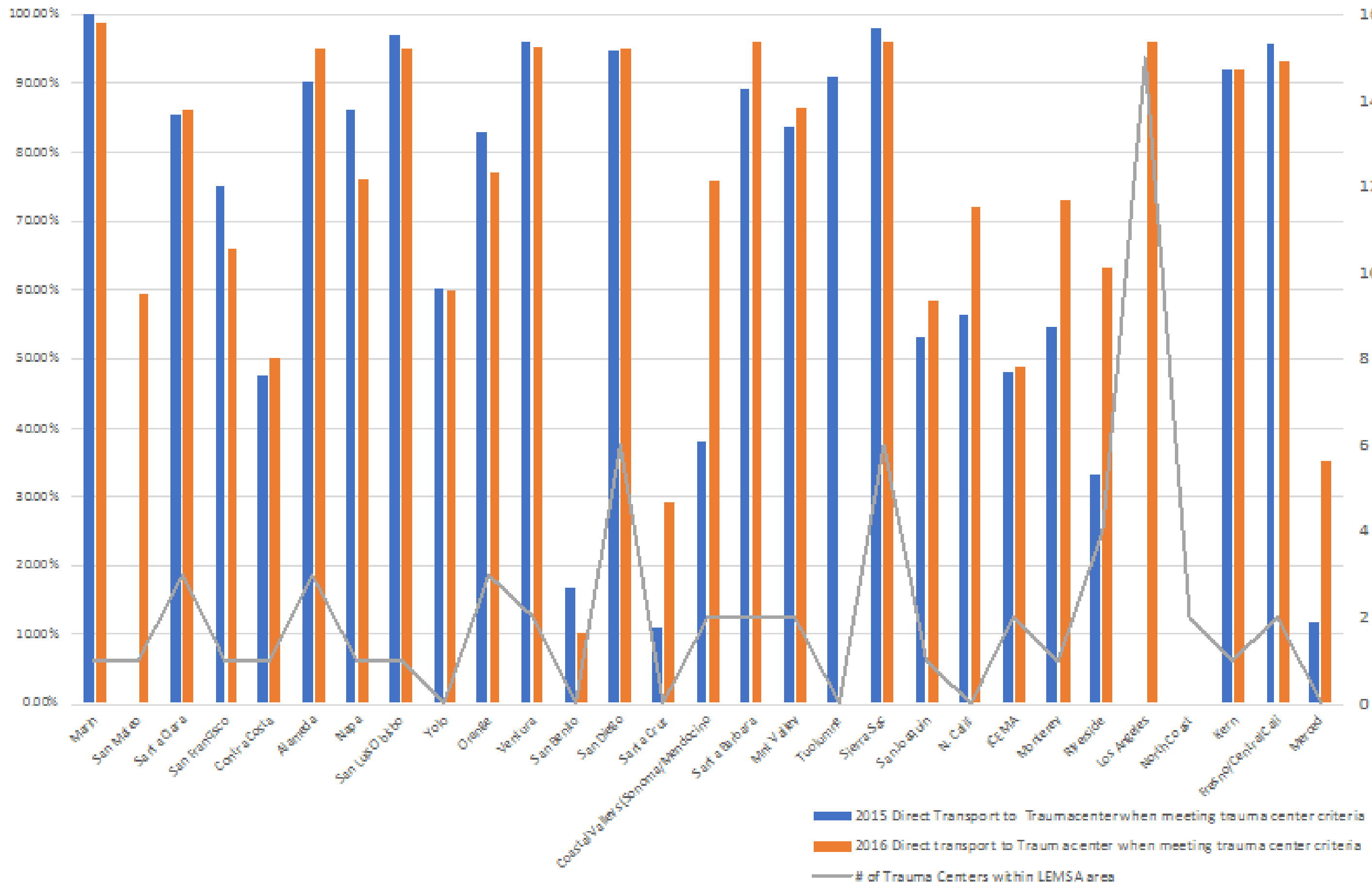

Figure 3. Direct Transport to Trauma Center When Meeting Trauma Center Criteria and Number of Trauma Centers within the LEMSA Area

5. Trauma Data Regression Results

In 2016, there is a statistically significant relationship between trauma triage patients who are routed directly to trauma specialty centers and the number of trauma centers in a geographical LEMSA area ($p = 0.0408$). Surprisingly, in 2015, no statistical relationship exists between direct routing and number of trauma centers in a geographical LEMSA area ($p = 0.171$). There is no statistical relationship between the direct routing of trauma patients to trauma centers and median income, population density, or percent of trauma centers by population density.

6. Oral-Tracheal Intubation Success Rates

Oral tracheal intubation (OTI) is a critical skill for ALS prehospital providers. An OTI involves the process of inserting an endotracheal tube, commonly known as a breathing tube, into a patient's trachea. It is performed on critical patients to prevent vomitus, blood, and other obstructions from blocking the airway and allowing fluid to seep into the bronchiole tree and lungs, which can lead to aspirational pneumonia. Paramedics commonly perform OTIs as part of the prehospital treatment algorithm for resuscitation of cardiac arrest. However, any patient in an altered mental state who cannot control his or her airway is a candidate for OTI.

Because the procedure itself interrupts the patient's breathing, causes trauma, and exacerbates existing irritants, the goal of every ALS provider is to perform OTI successfully on the first attempt. "First pass success" is a benchmark performance measure for all EMS agencies as well as for in-hospital providers. Repeated intubation attempts are associated with an increase in morbidity and mortality for high-acuity patient populations.[90] Moreover, performing an OTI is a critical skill that can be improved if the provider agency invests in comprehensive training and equipment for its paramedics. Finally, it is a universal performance measure. Table 11 shows the 2015 and 2016

[90] Kohei Hasegaw et al., "Association between Repeated Intubation Attempts and Adverse Events in Emergency Departments: An Analysis of a Multicenter Prospective Observational Study," *Annals of Emergency Medicine* 60, no. 6 (December 2012): 749–754, https://doi.org/10.1016/j.annemergmed.2012.04.005.

intubation success percentages for California LEMSAs. Tables 12–15 highlight the regression analysis, controlling for median income and population density.

Table 11. 2015 and 2016 Intubation Success Rate by LEMSA

LEMSA	2015 Intubation Success[91]	2016 Intubation Success[92]
Alameda	70.47%	71.96%
Coastal Valleys (Sonoma/Mendocino)	88%	70.20%
Contra Costa	78.41%	78.60%
El Dorado	X	X
Fresno/Central Cali	63.72%	63.70%
ICEMA	64%	64%
Imperial	X	X
Kern	72.74%	78.89%
Los Angeles	82%	71.47%
Marin	59%	64%
Merced	62.41%	59.39%
Mnt Valley	82.71%	80%
Monterey	72.60%	83%
N. Calif.	74%	60.61%
Napa	49.23%	64.62
North Coast	44%	61.25%
Orange	78%	72.10%
Riverside	82.03%	85%
Sacramento	X	X
San Benito	92%	87.50%
San Diego	X	X
San Francisco	62%	63%
San Joaquin	87.16%	88.46%
San Luis Obispo	84%	85%
San Mateo	81%	81%
Santa Barbara	92.90%	87%
Santa Clara	57.70%	59.62%
Santa Cruz	60%	49%
Sierra-Sac	83.76%	81.91%

91 Adapted from California EMS Authority, *Core Measures 2015 Data*, 45.

92 Adapted from California EMS Authority, *Core Measures 2016 Data*, 45.

LEMSA	2015 Intubation Success[91]	2016 Intubation Success[92]
Solano	X	X
Tuolumne	88%	X
Ventura	69%	73%
Yolo	56%	66.66%

Table 12. 2015 Intubation Success by California LEMSA Regression Analysis[93]

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.818042	0.120731	6.775725	4.22E-07	0.569390995	1.066692	0.569391	1.066692
Median Income (2015)	-2.2E-06	3.04E-06	-0.71454	0.481514	-8.4247E-06	4.08E-06	-8.4E-06	4.08E-06
Population Density	-2.7E-06	8.96E-06	-0.30001	0.766649	-2.1148E-05	1.58E-05	-2.1E-05	1.58E-05

Table 13. 2015 Intubation Regression Statistics

Multiple R	0.1924
R Square	0.037018
Adjusted R Square	-0.04002
Standard Error	0.135059
Observations	28

93 See Appendix F for further details.

Table 14. 2016 Intubation Success by California LEMSA Regression Analysis[94]

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.750561	0.09874035	7.601361	7.70497	0.546771	0.9543511	0.54677099	0.95435113
Median Income (2015)	-5.4E-07	2.4726E-06	-0.21682	0.830181	-5.6E-06	4.567E-06	-5.639E-06	4.5671E-06
Population Density	-5E-06	7.2779E-06	-0.69213	0.495499	-2E-05	9.984E-06	-2.006E-05	9.9837E-06

Table 15. 2016 Intubation Regression Statistics

Multiple R	0.17931
R Square	0.032152
Adjusted R Square	-0.0485
Standard Error	0.109617
Observations	27

94 See Appendix G for further details.

7. Intubation Data Regression Analysis Results

There is no statistically significant relationship between 2015 intubation success and median income or population density. Additionally, there is no statistically significant relationship between 2016 intubation success and median income or population density.

8. Twelve-Lead ECG Compliance for Complaints Consistent with Acute Coronary Syndrome

A 12-lead ECG is a procedure performed in the prehospital environment to examine the electrical activity of the heart from various angles. It is the primary way to determine whether a patient is suffering from the early stages of an acute coronary event, the most urgent of which is an ST-elevation myocardial infarction (STEMI). Early recognition of a STEMI is critical for the overall care continuum of an acute cardiac patient. All paramedics and emergency physicians learn the mantra "time equals muscle." If a field crew can transmit the 12-lead tracing to the emergency department before it arrives, the hospital will be better prepared and can fast-track the STEMI patient from the emergency department to definitive care in a specialty in-hospital unit called a "cath-lab." There, a cardiologist inserts a cardiac catheter directly into the clogged coronary artery and clears the blockage. A patient suffering from a STEMI benefits most from direct routing to a hospital with 24/7 interventional cath-lab capabilities. Hospitals with this specialty designation are labeled STEMI-receiving centers.

The goal is to reduce the time between a STEMI patient's arrival at the hospital and the inflation of the microballoon in the coronary artery by the cath-lab team. That period is known as the "door-to-balloon time."[95] The ultimate strategy is to do everything possible to reduce that time. A 12-lead ECG acquisition in the field is the first step in the process, so compliance is a universal performance measure. See Tables 16–20 for 2015 and 2016 12-Lead ECG compliance percentages by California LEMSA and regression analysis, controlling for median income and population density.

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[95] Shoji Kawakami et al., "Time to Reperfusion in ST-Segment Elevation Myocardial Infarction Patients with vs. without Pre-hospital Mobile Telemedicine 12-Lead Electrocardiogram Transmission," *Circulation Journal* 80, no. 7 (June 2016): 1624–1633, https://doi.org/10.1253/circj.CJ-15-1322.

Table 16. 2015 and 2016 12-Lead ECG Compliance by California LEMSA

LEMSA	2015 12-Lead ECG Compliance[96]	2016 12-Lead ECG Compliance[97]
Marin	93%	93%
San Mateo	92%	91%
Santa Clara	78.71%	76%
San Francisco	96%	94%
Contra Costa	84.08%	96.60%
Alameda	99%	99%
El Dorado	X	X
Napa	78.42%	91.04%
Solano	X	X
San Luis Obispo	96%	99%
Yolo	95.60%	95.74%
Orange	87%	81.20%
Ventura	80%	71.00%
San Benito	45%	90.11%
San Diego	84.39%	83.06%
Santa Cruz	84%	84%
Sacramento	X	X
Coastal Valleys (Sonoma/Mendocino)	80%	97.99%
Santa Barbara	98%	100%
Mnt Valley	90.47%	94%
Tuolumne	94%	X
Sierra-Sac	97.17%	98.31%
San Joaquin	87.23%	92%
N. Calif.	53.32%	50.20%
ICEMA	44%	37%
Monterey	89%	95%
Riverside	94%	95%

96 Adapted from California EMS Authority, *Core Measures 2015 Data*, 21.

97 Adapted from California EMS Authority, *Core Measures 2016 Data*, 21.

LEMSA	2015 12-Lead ECG Compliance[96]	2016 12-Lead ECG Compliance[97]
Los Angeles	79%	66%
North Coast	17%	16%
Kern	69%	11%
Fresno/Central Cali	85.81%	98.31%
Merced	77%	88%
Imperial	X	X

X indicates failed to report.

Table 17. 2015 12-Lead Compliance by California LEMSA Regression Analysis Overview[98]

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%
Intercept	0.568343487	0.166267014	3.418258	0.002086	0.226577	0.91011	0.22657675
Median Income (2015)	5.84804E-06	4.18658E-06	1.396853	0.174268	-2.8E-06	1.45E-05	-2.7576E-06
Population Density	5.14002E-06	1.23524E-05	0.416116	0.68074	-2E-05	3.05E-05	-2.0251E-05

Table 18. 2015 12-Lead Regression Statistics

Multiple R	0.331700299
R Square	0.110025088
Adjusted R Square	0.04156548
Standard Error	0.186186851
Observations	29

Table 19. 2016 12-Lead Compliance by California LEMSA Regression Analysis Overview[99]

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.466866893	0.215366099	2.167782652	0.039899225	0.023312109	0.910421676
Median Income (2015)	8.68439E-06	5.39953E-06	1.608361217	0.120313363	-2.43614E-06	1.98049E-05
Population Density	-1.62022E-06	1.58889E-05	-0.101971921	0.91959246	-3.43441E-05	3.11036E-05

98 See Appendix H for further details.

99 See Appendix I for further details.

Table 20. 2016 12-Lead Regression Statistics

Multiple R	0.327301
R Square	0.107126
Adjusted R Square	0.035696
Standard Error	0.23938
Observations	28

9. Twelve-Lead ECG Data Regression Analysis Results

The California 12-lead data show a wide variance in compliance. Based on available data, there is no statistically significant relationship between 12-lead compliance and median income or population density in California for 2015 or 2016.

10. National EMS Information System Data

The following groups of U.S. states were analyzed using NEMSIS data. According to the administrators of NEMSIS, the compliance percentage is based on the percent of all EMS activations that are submitted (e.g., 2015) divided by the number of credentialed EMS agencies in a state. The denominator for this percentage is all credentialed EMS agencies within the state (see Table 21).[100]

[100] N. Clay Mann, University of Utah, NEMSIS, email message to author, October 18, 2017.

Table 21. 2015 Decentralized Protocol Group/Percentage of Agency Reporting Compliance

2015—Group A *Centralized Protocol Group/Percentage of Agency Reporting Compliance*	**2015—Group B** *Decentralized Protocol Group/Percentage of Agency Reporting Compliance*
Iowa 33%	California 17%
Maine 77%	Colorado 71%
Massachusetts 2%	Florida 57%
Montana 42%	Kansas 54%
Nevada 60%	Louisiana 34%
North Carolina 25%	Mississippi 50%
Pennsylvania 71%	Oregon 65%
Vermont 57%	Texas 2%
Maryland 100%	Minnesota 94%
Oklahoma 95%	Connecticut 90%
West Virginia 100%	Missouri 95%
New Hampshire 91%	Virginia 94%
Michigan 87%	Wyoming 80%
Hawaii 100%	Indiana 76%
Alabama 91%	
*Average Compliance Group A: **68.7%***	Average Compliance Group B: **62.78%**

Since national EMS reporting compliance is low, using NEMSIS data for conclusive research proves problematic. An examination of NEMSIS data for OTI success rates between the A and B group reveals problems comparing two types of EMS systems (see Table 22).

Table 22. Airway-Orotracheal Intubation

Group	Outcomes	Airway Orotracheal
A	0	1994
A	1	8651
A	Not Applicable	184
A	Not Available	242
A	Not Known	232
A	Not Recorded	188
A	Not Reporting	105
B	0	2552
B	1	9855
B	Not Applicable	749
B	Not Available	21
B	Not Known	3
B	Not Recorded	825
B	Not Reporting	97

Of the patients in Group A for whom EMS responders attempted prehospital intubation, 1,194 of the intubations were unsuccessful, and 8,651 were successful (88 percent success rate). Information was “not available” for 242 patients, “not known” for 232, “not reported” for 188, and “not recorded” for 105. There is no outcome information for 767 patients (0.077 percent), for whom EMS responders attempted intubation.

Of the patients in Group B for whom EMS responders attempted prehospital intubation, 2,552 of the intubations attempts were unsuccessful, and 9,855 were successful (81 percent success rate). Information was “not available” for 21 patients, “not known” for three, “not recorded” for 825, and “not reported” for 97. There is no outcome information for 940 patients (0.075 percent), for whom EMS responders attempted intubation.

At first glance, these findings seem to indicate that centralized Group A states (88 percent) have a slightly higher success rate of prehospital intubation than decentralized Group B states (81 percent). However, considering the reporting compliance of Group A (68.7 percent) versus Group B (62.78 percent) states, Group A has a slightly higher level of average agency reporting. It is impossible to determine whether the raw observed difference by group is statistically significant given the different rates in reporting, which are generally low.

However, there is an exacerbating issue. Even if a state is officially listed as compliant, organizations do not enter much patient information into the dataset, making the amount of data available for analysis even smaller. Even so, we attempted a comparison of cardiac-arrest survival data mined from the 2015 NEMSIS datasets with survival rates between Group A (centralized EMS authority states) versus Group B (decentralized states). Table 23 shows the results of the NEMSIS cardiac-arrest disposition comparisons.

Table 23. Cardiac Arrests prior to EMS Arrival Disposition from Hospital[101]

Group	Number_Cardiac_Arrests	Outcomes	Total
A	26242	Not Known	9985
A	26242	Not Reporting	1974
A	26242	Not Recorded	5766
A	26242	Not Applicable	3038
A	26242	Not Available	5025
A	26242	Death	335
A	26242	Discharged	2
A	26242	Transfer to Hospital	107
A	26242	Transfer to Other	9
A	26242	Transfer to Rehabilitation Facility	1
B	25268	Not Known	4686
B	25268	Not Reporting	8201
B	25268	Not Recorded	5202
B	25268	Not Applicable	2081
B	25268	Not Available	3694
B	25268	Death	211
B	25268	Discharged	495
B	25268	Transfer to Hospital	69
B	25268	Transfer to Other	629

An analysis of NEMSIS cardiac-arrest outcomes between the A and B groups reveals large information gaps in the datasets.

The NEMSIS cardiac-arrest data showed a total patient population in Group A of 26,242 cardiac-arrest patients. Outcomes for 9,985 are not known, 1,974 did not report, 5,766 are not recorded, and 5,025 patient outcomes are listed as not available. There is no outcome information for 22,750 cardiac-arrest patients (86.6 percent).

[101] Adapted from NEMSIS, unpublished EMS datasets provided to author, November 7, 2017.

Of the 25,268 cardiac-arrest patients identified in Group B, the outcome of 4,686 is not known, 8,201 did not report, 5,202 are not recorded, and 3,694 are not available. There is no outcome information for 21,783 cardiac-arrest patients (86 percent).

Therefore, even if a researcher performed a more detailed analysis with this measure, the analysis would account for only 14 percent of cases. This sample is too small for any meaningful statistical analysis; it highlights the expanse of the data desert. Due to the inherent gaps in the NEMSIS data, it is difficult to determine a statistical significance between one group and the other.

C. LONDON AMBULANCE SERVICE PERFORMANCE-MEASURE DATA

As described in the research design, LAS data are standardized and centralized, and services are 100 percent compliant in data reporting. In Table 24, the four performance measures are examined from the California core measure data (averaged for the entire state) and LAS for the same period. It also contains cardiac-arrest survival and STEMI specialty-center direct-routing.

Table 24. California versus LAS Performance-Measure Comparison and T-Test Overview

Performance Measure	California 2016[102]	LAS 2016	T-Test
Cardiac arrest survival to hospital discharge[103]	10.8%[104]	29.5%[105]	t = +3.97 P (two-tailed) 0.000300 Mean a-Mean b: 6.5185
Intubation success rates[106]	72.26%	90%[107]	t = -7.24 P (two-tailed) .0001 Mean a - Mean b: -19.3926
12-Lead ECG Compliance for patient c/o acute cardiac[108]	81.57%	96%	t = -2.9 P (two-tailed) 0.005493 Mean a-Mean b: 14.3643
Direct routing of STEMI patients to STEMI specialty hospitals (U.K. equivalent)[109]	79.41%	97%[110]	t = -2.7 P (two-tailed) 0.009875 Mean a - Mean b: -19.1684
Direct routing of stroke patients to stroke specialty care facility	73.27%	99.6%[111]	Unable to perform t-test; LAS stroke destination data not broken down by EMS districts
Direct routing of trauma triage criteria patients to designated trauma centers (U.K. equivalent)	73.33%	98.7%[112]	Unable to perform t-test; LAS trauma triage destination data not broken down by EMS districts

The t-test comparisons of four of the six measures show high statistical significance. T-tests for stroke direct-routing and trauma direct-routing could not be

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102 California EMS Authority, *Core Measures 2016 Data*.

103 See Appendix J for further details.

104 Cardiac Arrest Registry to Enhance Survival, *Utstein Survival Report* (Atlanta, GA: Cardiac Arrest Registry To Enhance Survival, 2017).

105 London Ambulance Service, *Cardiac Arrest Annual Report: 2016/2017* (London: Clinical Audit and Research Unit, 2017).

106 See Appendix K for further details.

107 London Ambulance Service, *Cardiac Arrest Annual Report: 2016/2017*.

108 See Appendix L for further details.

109 See Appendix M for further details.

110 London Ambulance Service, Cardiac Care Pack: Monthly Cardiac Arrest and ST-Elevation Myocardial Infarction Annual Reports (London: Clinical Audit and Research Unit, 2018).

111 London Ambulance Service, *Stroke Annual Report 2016–2017* (London: Clinical Audit and Research Unit, 2017).

112 London Ambulance Service, *Major Trauma Annual Report 2016–2017* (London: Clinical Audit and Research Unit, 2017).

performed due to the way LAS aggregates data for those two measures. However, since four of the measures are clearly significant, it is fair to speculate the remaining two would be as well if the data could be broken down in a way that allowed statistical comparison.

D. SUMMARY OF DATA RESULTS

Despite the aforementioned gaps in the data, there are some conclusions to draw. The regression analysis of the California *Core Measures* report lends support to the hypothesis of this thesis.

1. California LEMSA Performance-Measure Data

There is a borderline statistical relationship between median income and patients who are routed directly to stroke specialty hospitals in California only in 2016 (p-value of 0.052). This was not the case in 2015, as presumably, higher data compliance would have shown a more significant relationship between median income and stroke routing. It is interesting that despite the borderline relationship between stroke care and median income in 2016, there is no statistical relationship between the number of stroke specialty centers and direct routing. Although the datasets are incomplete, this lack of connection may suggest that areas with higher incomes receive better stroke care in California, regardless of geographic location. This does not reject the hypothesis of the thesis; rather, it supports the disparate LEMSA system, implying that higher-income areas mandate a higher level of stroke care.

There is also a statistical relationship between trauma triage patients who are routed directly to trauma specialty centers and the number of available trauma centers in a LEMSA jurisdiction in 2016; however, this is not the case for 2015. The 2016 results are not terribly surprising; the more trauma centers available in a geographic area, the more likely EMS is to transport a patient there. The lack of a relationship in 2015 is surprising; however, neither of the results conflicts with the underlying hypothesis.

For all other performance measures examined, there is no statistical relationship between median income, population density, number of specialty hospitals in the LEMSA jurisdiction, or size of a geographic area. The lack of relationships between the controlled factors and the four performance measures supports the hypothesis that the decentralized LEMSA system is the underlying cause of performance disparities. However, more research is necessary to examine all 17 performance measures in the *Core Measures* report. Future research may control for additional variables, such as availability of aeromedical resources in rural areas, the number of in-service EMS resources in a given area, and the level of sophistication in critical infrastructure such as roads and telecommunication systems.

2. NEMSIS Datasets

While intubation success rates have fewer instances of missing data, the observed raw difference of 7 percent between Group A and Group B cannot be judged as meaningful given the disparity in reporting compliance between the two groups. In many states, EMS agency data-reporting is largely dark. Only three states in Group A—Maryland, Hawaii, and West Virginia—are 100 percent compliant with data reporting to NEMSIS. None of the states in Group B is 100 percent compliant, and California is only 17 percent compliant. With an average of 68.7 percent average compliance in Group A and 62.78 percent in Group B, we are unable to form a conclusion regarding centralized versus decentralized EMS authority from NEMSIS datasets.

Additionally, in some cases, NEMSIS suffers from a large amount of missing data in some of its variables—even for the states that are officially reporting data. An information gap in Group A of 86.6 percent and in Group B of 86 percent is the best we can glean from the 2015 cardiac-arrest NEMSIS datasets. It is also important to note that these gaps are from the EMS agencies within the states that are reporting information to NEMSIS. The non-reporting agencies are not represented in these results.

If the administrators of NEMSIS would allow the individual identification of states with high compliance rates for comparison, perhaps someone could undertake meaningful research on this topic using NEMSIS statistics. Unfortunately, the current environment does not allow administrators to share information from individual states. The best that we can conclude from the NEMSIS data is just how vast the EMS data desert is in the United States.

3. National Health Service Trust / London Ambulance Service Comparison

Given the limitations of the California data in almost every comparable measure, the nationally centralized LAS is superior to the decentralized systems in California. The t-tests show statistical significance for two of the original four measures compared as well as the two additional measures—cardiac-arrest survival and STEMI-center direct-routing. Due to the way LAS organizes certain datasets, t-tests for stroke direct-routing and trauma direct-routing could not be performed; however, LAS's raw percentages of stroke and trauma direct-routing are superior to those of California. Additionally, LAS is superior when compared to individual LEMSAs that report data.

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IV. DISCUSSION

A. WHAT THE DATA TELL US

Since California's EMS disparity is not in question, this discussion focuses on how best to improve inconsistency and overall patient outcomes. The research detailed in Chapter III does not definitively prove that the fragmented California LEMSA system is the primary culprit for disparate performance and outcomes. We are only examining a handful of performance measures, and available data are not standardized, nor are they vetted. Future research should examine all 17 measures in the annual California *Core Measures* report and compare them to centralized EMS systems, such as the NHS in the U.K. However, what the regression analysis reveals thus far lends preliminary support for the hypothesis that the California EMS authority system is the underlying cause of disparate EMS performance. The primary obstacle to determining the cause definitively is the EMS data desert. One could speculate that the borderline statistical relationships might change if the absent LEMSAs participated in data reporting. Although it is hypothetical, future research may assume that non-reporting jurisdictions have below-average performance measures.

To California EMS Authority's credit, the Core Measures Project established a framework to address the data desert. California is one of few states that care to produce and openly publish such data. Hopefully, in the future, LEMSA reporting compliance will be a mandatory requirement with standardized collection methods. NEMSIS could also propel future research by creating a national core measures report, state by state, modeled on the 17 measures tracked in the California EMS Authority's reports.

The United Kingdom's remarkably high performance compared to California is compelling. The comprehensive data from the centralized U.K. system provides the most persuasive evidence to support a centralized EMS authority. Moreover, it certainly validates the requirement for and benefits of mandatory standardized data reporting.

California is vast and diverse in both population and geography. Arguably, it would be unreasonable to expect that a one-size-fits-all set of EMS policies would work in every rural, urban, desert, and mountainous corner of the state. In areas of rural California, the only way to route a stroke, trauma, or STEMI patient directly to a specialty-care hospital within a therapeutic time window is via helicopter. As described in the introduction of this thesis, aeromedical transport can be prohibitively expensive. Many patients in rural areas may not want the medical benefits of direct routing if it means they and their families will be hobbled under the weight of tens of thousands of dollars in debt. California should consider different delivery models for aeromedical resources. Private for-profit entities should not provide an emergency public service if it impoverishes those they serve.

As previously discussed in the literature review, Kupas et al. advocate for a regional approach to EMS authority that falls under the umbrella of a baseline set of statewide treatment protocols.[113] Even in the nationally centralized U.K. system, EMS is broken down into 11 administrative districts, each with a selection of policies that are unique for the demands of the geographic region.

To reorganize California's 33 LEMSAs into centralized regions from scratch would be a daunting task. With an area that large, how would one draw the boundary lines between one regional EMS authority (REMSA) and another? Fortunately, geographic EMS regions are already established in California.

B. CALIFORNIA'S REGIONAL TRAUMA COMMITTEES

The California EMS Authority impanels the State Trauma Advisory Committee (STAC), which is composed of physicians, nurses, and EMS providers, "for the purpose of advising the EMSA director on matters pertaining to the planning, development, and implementation of the State Trauma System."[114] One of the STAC recommendations, enacted in 2008, is to divide the state into five trauma regions, which are advised by the regional trauma coordinating committees (RTCCs). The report identifies four goals of the current RTCCs:

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[113] Kupas et al., "Characteristics of Statewide Protocols."

[114] California EMS Authority, *California-Statewide-Trauma System Planning STAC Recommendations* (Sacramento: California EMS Authority, 2017), 61, https://emsa.ca.gov/wp-content/uploads/sites/47/2017/07/California-Statewide-Trauma-System-Planning_STAC-Recommendations.pdf.

1. To encourage the collaborative efforts of the counties to support and share resources for a regionally-based trauma system.
2. To work with the LEMSAs, STAC, and the RTCCs to develop a consensus compendium of trauma-related policies, procedures, and clinical guidelines that may be shared throughout the state.
3. To develop local trauma plans in the context of regional trauma care with input from trauma centers and RTCCs.
4. Establish basic quality and activity reporting standards and report templates for the LEMSAs to ensure that EMSA, STAC, subcommittee receive sufficient data to assess state trauma system performance.[115]

The most recent trauma committee recommendations state,

> RTCCs may facilitate discussions related to trauma care challenges within the region working towards resolutions to minimize variations in practice. Additional regional issues may include addressing geographic isolation, coordination of trauma care resources, and funding for out-of-county patients.[116]

The borders of the five RTCC regions are based on a combination of factors, including population distribution, geography, and the number of trauma centers within a given area. Figure 4 is a map of the five RTCC regions and the LEMSAs that reside within each.

[115] California EMS Authority, 29.

[116] California EMS Authority, 20.

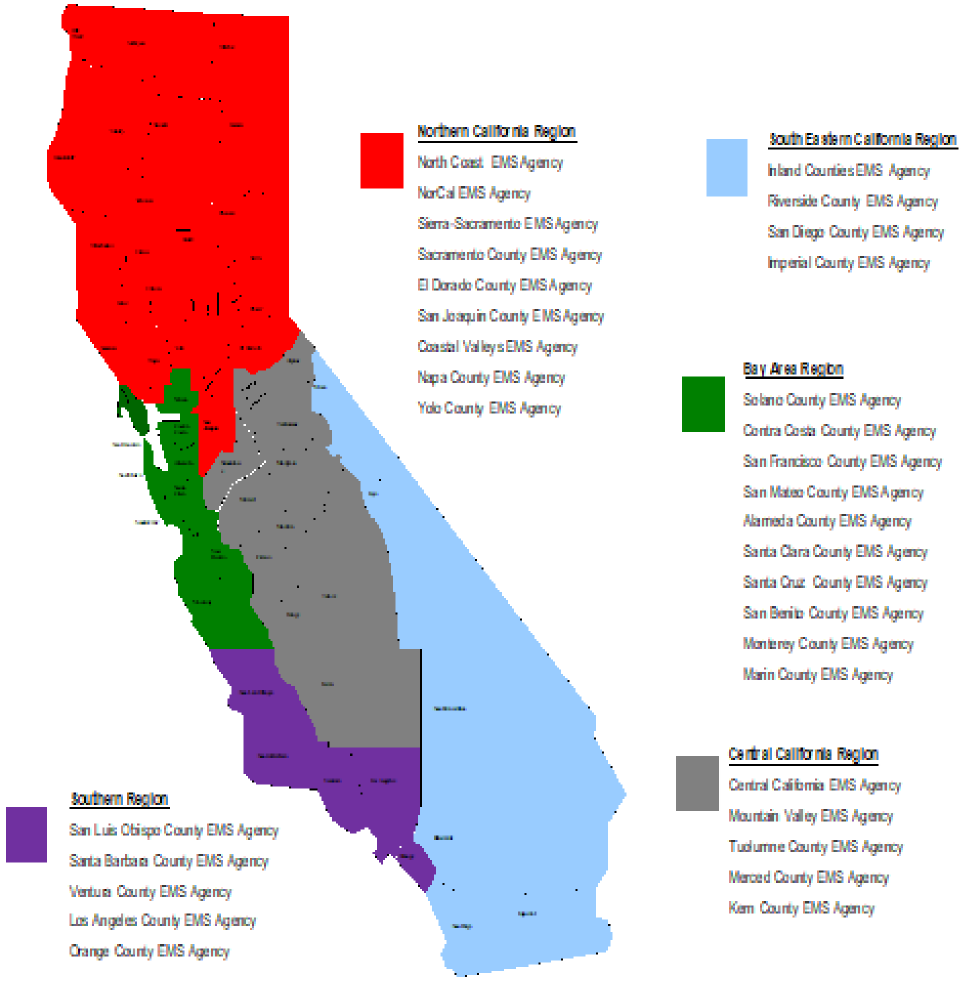

Figure 4. Map of California Regional Trauma Coordinating Committees[117]

The trauma regions provide a preexisting framework to reorganize EMS authority in California. The state currently mandates that RTCCs Develop a consensus compendium of trauma-related policies, procedures, and clinical guidelines that may be shared throughout the state."[118] It would not be a stretch to expand their mandate and evolve

117 Source: California EMS Authority, *California-Statewide-Trauma*, 19.

118 California EMS Authority, 3.

RTCCs into regional EMS authorities, vertically integrated within the State EMS Authority.

C. STATEWIDE PROTOCOLS

Establishing a set of statewide EMS protocols based on the latest evidence-supported standard of care is not as herculean a challenge as it may sound. There are evidence-based models for EMS protocols from high-performing jurisdictions throughout the country. Additionally, NASEMSO publishes an evidence-based set of model EMS protocols that are regularly updated, which the organization describes as follows: "A resource to be used or adapted for use on a state, regional or local level to enhance patient care."[119]

The model protocols are based on subject-matter experts from a wide range of disciplines, including the

> American College of Emergency Physicians (ACEP), National Association of EMS Physicians (NAEMSP), American Academy of Emergency Medicine (AAEM), American Academy of Pediatrics, Committee on Pediatric Emergency Medicine (AAP-COPEM), American College of Surgeons, Committee on Trauma (ACS-COT) and Air Medical Physician Association (AMPA).[120]

The NASEMSO clinical guidelines provide an excellent framework of scientifically vetted prehospital protocols, and at a minimum, they could serve as a starting point for the California EMS Authority to establish consistent statewide EMS treatment policies.

As mentioned in the literature review, the NASEMSO also produces a study that details the framework for EMS protocol development, *Using the National Prehospital Evidence-Based Guideline Model Process for Emergency Medical Services*.[121] Changing the EMS authority structure and establishing statewide protocols in California is not as

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[119] National Association of State EMS Officials, *National Model EMS Clinical-Guidelines*, version 2 (Falls Church, VA: National Association of State EMS Officials, 2017), http://www.nasemso.org/documents/National-Model-EMS-Clinical-Guidelines-Version2-Sept2017.pdf.

[120] National Association of State EMS Officials.

[121] Scholl et al., Implementation and Evaluation.

complicated as it might seem. There is a wide selection of available resources to facilitate this change.

D. CONTINUOUS QUALITY IMPROVEMENT WITH STATEWIDE PROTOCOLS

One argument against consolidating LEMSAs is that the span of control for continuous quality improvement (CQI) would become too large for a regional authority to maintain. Under a consolidation plan, each REMSA would have several dozen EMS agencies within its domain. To maintain paramedic clinical proficiency requires an intimate relationship between the CQI officer, the training officer, and the field provider. Proper CQI requires a significant investment in personnel time and training. Currently, according to Policy 166 of the California EMS Authority, the state mandates only that each LEMSA and provider agency has an established CQI program under a model described in the policy. According to the California EMS Authority, "The following staffing positions are identified (organizations with limited resources may combine positions): Provider Medical Director or Designee, EMS QI Program Coordinator, Data Specialist."[122]

The California state CQI requirements for LEMSAs and individual providers do not establish a CQI span-of-control requirement, nor do they establish minimum training standards or competencies for accreditation as a paramedic in the LEMSA jurisdiction beyond the minimums to maintain state licensure. Each jurisdiction currently decides how robust its continuing education and remediation training will be.

If all paramedics in the state were required to meet a baseline set of competencies, and the EMS agency's medical director and CQI staff were mandated to evaluate and maintain those competencies, the span of control would actually improve under centralized control. A mandated CQI coordinator-to-provider ratio of 30:1 would create the intimacy required for effective quality improvement.

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[122] California EMS Authority, *Emergency Medical Service System Quality Improvement Program Model Guidelines* (Sacramento: California EMS Authority, 2016), 11, https://emsa.ca.gov/wp-content/uploads/sites/47/2017/07/emsa166.pdf.

With mandated CQI ratios in place and all EMS agencies compelled to report performance data, the span of control would improve. The onus to maintain proficiency would rest on the individual provider's medical director and CQI team. The regional authority would have a regular flow of data to track each agency's performance and intervene as needed.

A quote, attributed to management guru Peter Drucker, proclaims, "If you can't measure it, you can't improve it."[123] Without firmly mandated data-reporting and a schedule of consequences for non-compliance, a vertically integrated REMSA will be ineffectual.

123 "The Two Most Important Quotes in Business," Grow Think, accessed July 12, 2018, https://www.growthink.com/content/two-most-important-quotes-business.

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V. A THEORETICAL MODEL FOR A VERTICALLY INTEGRATED EMS AUTHORITY

A. STRUCTURE

Establishing statewide protocols for California, administered by five regional EMS authorities, would require a streamlined model. The goal would be to centralize protocols while maintaining a strict span of control for CQI and data reporting. Under the theoretical plan, there would be a medical director at each of the three-tiered levels: EMS provider agency, regional authority, and state authority. The mandated CQI staff at a 1:30 ratio would report to the medical director at each level. A mandated set of performance-measure data would flow upward, and problems would be managed at the appropriate level. Figure 5 is an overview of some of the roles and responsibilities that could be delegated in a vertically integrated state EMS system.

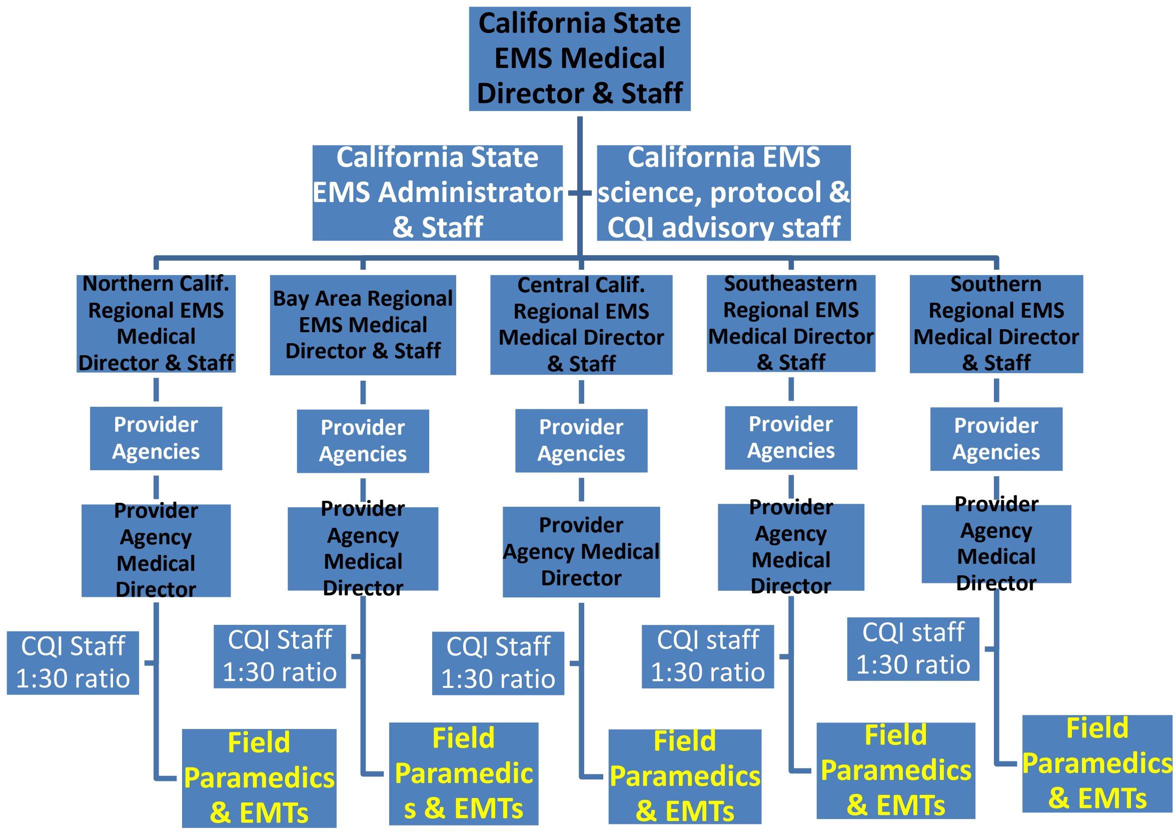


Figure 5. Theoretical Organization Chart for a Vertically Integrated REMSA System in California

1. California State EMS Medical Director

The state EMS medical director would establish statewide treatment protocols, which would be reviewed and updated annually in consultation with the science protocol and CQI advisory staff. This person would also establish minimum clinical-training standards and CQI requirements for all state EMS providers and agencies. The state authority would establish mandatory data-reporting standards for all providers, regional authorities, and specialty hospitals.

The state EMS medical director would establish license maintenance requirements and minimum equipment standards for BLS and ALS providers. In addition, the medical director would oversee disaster planning and mutual aid committees and, along with the state EMS administrator, be in charge of the day-to-day operations of California's EMS system. Finally, the state EMS director would supervise all license revocation actions and other state-level disciplinary actions for individual providers as referred by the REMSA.

2. California State EMS Administrator

The state EMS administrator would report to the state EMS medical director and be the chief compliance officer for the state EMS system. The state EMS administrator would be in charge of enforcing data-reporting compliance from all regional authorities, hospitals, and individual providers. He or she would supervise all license revocation-level investigations and disciplinary issues. Moreover, the state administrator would maintain a staff to administrate licensing and renewal requirements. Additionally, the state EMS administrator would sit on all significant committees related to EMS policy including mutual aid, disaster planning, and science and protocol updates.

3. Regional EMS Medical Directors

In a model for a vertically integrated EMS authority, the oversight of EMS agencies would be delegated to the regional medical director and his/her staff. Regional medical directors would report to the California state EMS medical director. The regional EMS medical director would have the authority to adjust state protocols to fit unique requirements or operational needs of his/her region. Additionally, the regional medical director would have the authority to suspend a paramedic's or EMT's license to practice pending an investigation for gross negligence and/or professional standard violations.

Moreover, the REMSA would collect the mandated data from each provider agency and analyze them for trends. It could impose an agency-wide performance improvement plan if it observes a negative performance trend. The regional director should have the authority to suspend a provider agency's credentials to provide ALS or take over the direct jurisdiction of a poorly performing agency. The regional authority should enforce data-reporting compliance and could institute a schedule of consequences for non-compliance.

The regional authority should establish requirements for initial accreditation for paramedics and EMTs to work in the region, as well as continuing education requirements in coordination with the state authority. Also in coordination with the state, the regional

EMS medical director and staff should maintain and update the regional disaster plans, mutual aid plans, and all relevant policies related to mass-casualty events.

All receiving hospitals in the region should report to the REMSA and integrate into data-reporting requirements, local and regional disaster management plans, and surge-capacity requirements as prescribed by the state. A REMSA should validate a hospital's trauma/stroke/STEMI/pediatric or other specialty-center status based on established parameters from the state EMS authority.

4. Provider Agency Medical Directors

Each provider agency, whether it be a private ambulance, fire department, or aeromedical program, should have a medical director and CQI staff. The medical director, with his/her CQI staff, would ensure all paramedics and EMTs are competent to regional and state standards as well as enforce statewide and regional protocols. The agency's medical director could petition the regional medical director for pilot study programs and alternative protocols to suit the unique operational needs of the agency. Additionally, the agency's medical director should have the authority to temporarily remove a paramedic or EMT from the field and enforce a clinical performance improvement plan in coordination with the CQI staff. The provider's medical director should also be the lead educator for the field crews, responsible for vetting all continuing education programs to maintain certification within the REMSA. Furthermore, the CQI staff under the medical director would be responsible for submitting all performance-measure data to the regional authority.

B. ECONOMIC IMPACTS OF A REGIONAL EMS AUTHORITY

This thesis does not address the economic ramifications of a California EMS Authority consolidation. How does the state determine the budget for each REMSA, and how is that cost shared among the counties served within each region? Budgetary questions are beyond the scope of this research; however, they do warrant future examination. Whatever the cost at the local level, a proportional county contribution to maintain a REMSA would likely be significantly less than the cost of sustaining the local EMS bureaucracy as it is now.

Mandated data reporting, CQI ratios, and advanced continuing education would likely increase the financial burdens on individual EMS provider agencies. The contracted for-profit private ambulance companies—providing 9–1-1 EMS transport services in large portions of the state—would be particularly affected. However, disincentivizing the for-profit model for EMS delivery may have benefits for our citizens. California communities do not outsource police or fire departments to private companies, nor do they expect to generate a profit for their services; however, many counties do expect this from their EMS providers. Greater requirements for EMS agencies to operate may move policymakers to reevaluate the inherent conflict of interest when a for-profit company provides a critical public service. Perhaps it will force them to consider EMS as a public good to be funded using the same model as police and fire counterparts.

C. RECOMMENDATIONS

Although further research is required to support the general hypothesis of this thesis, the broad disparity of EMS in California is not in doubt, and the current model of EMS authority does not address the problem. Based on the research presented, disparate prehospital care and outcomes may be improved in California with the following proposals.

1. Establish Statewide EMS Policies and Treatment Protocols for All Basic Life Support and Advanced Life Support Providers

The guidelines shall be rooted in the latest evidence, as detailed in the NASEMSO model protocols. Regional medical directors may then amend state protocols to suit the unique operational requirements of their regions. The state medical director shall impanel a committee to review the state protocols on an annual basis to make updates. The model for creating new protocols shall also be rooted in the framework established by the NASEMSO.

2. Eliminate the Local EMS Authority System, and Consolidate All LEMSAs into Five Regional Authorities

The regions shall be based on the preexisting boundaries of the California regional trauma committees. The regions shall establish a vertically integrated approach to EMS authority to standardize training, data reporting, and performance expectations of all providers. Treatment protocols shall be standardized based on the latest evidence-based research and shall bring all providers up to the same level of care no matter what geographic area they serve.

3. Mandate Data Gathering and Reporting from All EMS Agencies

Agencies shall collect and report all 17 performance measures tracked by the annual California *Core Measures* report. Additionally, all agencies and cardiac-receiving hospitals shall participate in CARES. The state EMS administrator shall standardize collection and reporting methods. The results of each agency's performance-measure data shall be public and transparent. Additionally, the regional authority and the state shall administer a schedule of consequences for data-reporting compliance failures. Punitive measures for non-compliance shall begin with a notice to improve and/or fines and progress to loss of accreditation to provide EMS. Statewide data reporting to the National EMS Information System and new national data-collection efforts, such as EMS Compass, shall also be mandatory and transparent.

4. Establish a Standard for Continuous Quality Improvement for Every Provider Agency

The criteria shall include mandated ratios of CQI oversight personnel to field providers. It should also establish performance-based accreditation requirements for all paramedics and EMTs in the state. Additionally, all paramedics and EMTs in the state shall participate in a robust continuing-education schedule prescribed by the regional authority.

C. CONCLUSION

If it were your family member who suffered a stroke, would you not expect the same level of prehospital care in San Bernardino as in Marin County? If my father suffers a stroke in Imperial County, I would expect that he be taken to a specialty facility—as he would if his call originated in San Francisco. When someone dials 9–1-1, the level of care should not depend on the area code from which they call. Citizens and visitors of California deserve the highest level of prehospital care, no matter where in our state there is a need for emergency medical services.

APPENDIX A. RAW CALIFORNIA DATA

LEMSA	2015 CARES Cardiac Arrest Survival	2016 CARES Cardiac Arrest Survival to Discharge	2015 Stroke Direct-Routing	2016 Stroke Direct-Routing	2015 Direct Transport to Trauma Center When Meeting Trauma Center Criteria	2016 Direct Transport to Trauma Center When Meeting Trauma Center Criteria	2015 Intubation Success	2016 Intubation Success	2015 12-Lead ECG Compliance	2016 12-Lead ECG Compliance
Marin	X	X	100%	100%	100.00%	99%	59%	64%	93%	93%
San Mateo	X	X	97%	96%	X	59.32%	81%	81%	92%	91%
Santa Clara	7.90%	X	99.81%	100%	85.49%	86.11%	57.70%	59.62%	78.71%	76%
San Francisco	6.34%	12%	90%	93%	75.00%	66%	62%	63%	96%	94%
Contra Costa	28%	28.90%	91.80%	91.80%	47.80%	49.90%	78.41%	78.60%	84.08%	96.60%
Alameda	8.63%	9.16%	85%	85%	90.00%	95%	70.47%	71.96%	99%	99%
El Dorado	X	X	X	X	X	X	X	X	X	X
Napa	X	6.45%	0%	0%	86.16%	76.15%	49.23%	64.62	78.42%	91.04%
Solano	X	X	X	X	X	X	X	X	X	X
San Luis Obisbo	X	26%	X	X	97.00%	95%	84%	85%	96%	99%
Yolo	34%	X	96.10%	85.07%	60.20%	60%	56%	66.66%	95.60%	95.74%
Orange	X	X	93%	92.40%	83.00%	77.20%	78%	72.10%	87%	81.20%
Ventura	10.50%	15.40%	99%	99%	96.00%	95.50%	69%	73%	80%	71.00%
San Benito	X	X	0%	0%	17.00%	10.20%	92%	87.50%	45%	90.11%
San Diego	X	X	99.68%	99.75%	94.69%	95.05%	X	X	84.39%	83.06%
Santa Cruz	X	X	X	X	11.00%	29%	60%	49%	84%	84%
Sacramento	X	X	X	X	X	X	X	X	X	X

LEMSA	2015 CARES Cardiac Arrest Survival	2016 CARES Cardiac Arrest Survival to Discharge	2015 Stroke Direct-Routing	2016 Stroke Direct-Routing	2015 Direct Transport to Trauma Center When Meeting Trauma Center Criteria	2016 Direct Transport to Trauma Center When Meeting Trauma Center Criteria	2015 Intubation Success	2016 Intubation Success	2015 12-Lead ECG Compliance	2016 12-Lead ECG Compliance
Coastal Valleys (Sonoma/Mendocino	X	X	0%	0%	38.00%	75.88%	88%	70.20%	80%	97.99%
Santa Barbara	X	14%	X	98%	89.20%	96%	92.90%	87%	98%	100%
Mnt Valley	X	X	0%	0%	83.73%	86.38%	82.71%	80%	90.47%	94%
Tuolumne	11%	X	0%	X	91.00%	X	88%	X	94%	X
Sierra-Sac	X	X	88.39%	90.34%	98.03%	96.05%	83.76%	81.91%	97.17%	98.31%
San Joaquin	X	X	X	X	53.31%	58.40%	87.16%	88.46%	87.23%	92%
N. Calif.	X	X	45.36%	45.74%	56.41%	72.22%	74%	60.61%	53.32%	50.20%
ICEMA	X	X	79%	82%	48.00%	49%	64%	64%	44%	37%
Monterey	X	X	99.38%	96%	54.69%	73%	72.60%	83%	89%	95%
Riverside	11.50%	19%	89%	80%	33.12%	63%	82.03%	85%	94%	95%
Los Angeles	17.30%	15.90%	89%	95%	X	95.97%	82%	71.47%	79%	66%
North Coast	X	X	X	X	X	X	44%	61.25%	17%	16%
Kern	X	X	85%	X	91.80%	92.00%	72.74%	78.89%	69%	11%
Fresno/Central Cali	8.10%	X	X	X	95.63%	93.34%	63.72%	63.70%	85.81%	98.31%
Merced	X	X	X	71%	11.76%	35.21%	62.41%	59.39%	77%	88%
Imperial	X	X	X	X	X	X	X	X	X	X
Average	14%	16%	69%	73%	69%	73%	73%	309%	81%	82%
Median	11%	15%	89%	91%	83%	76%	73%	72%	86%	92%
Variance	1%	1%	16%	14%	8%	6%	2%	15122%	4%	6%

LEMSA[124]	Median Income (2015)	Population (2012)	LEMSA Sq Miles	Population Density	# of Stroke Centers within LEMSA Area	# of Trauma Centers within LEMSA Area	# of Stroke Centers within LEMSA Area	# of Trauma Centers within LEMSA Area	Percent Stroke Centers by Population Density	% Trauma Centers by Population Density
Marin	63,110	255,841	520	492.0019231	3	1	3	1	0.61%	0.20%
San Mateo	59,192	738,681	448	1648.841518	6	1	6	1	0.36%	0.06%
Santa Clara	57,281	1,836,025	1290	1423.275194	10	3	10	3	0.70%	0.21%
San Francisco	56,722	827,420	49	16886.12245	5	1	5	1	0.03%	0.01%
Contra Costa	50,667	1,078,257	716	1505.945531	6	1	6	1	0.40%	0.07%
Alameda	50,031	1,553,960	739	2102.787551	3	3	3	3	0.14%	0.14%
El Dorado	48,826	180,616	1,708	105.7470726	0	1	0	1	0.00%	0.95%
Napa	44,878	138,916	748	185.7165775	0	1	0	1	0.00%	0.54%
Solano	42,983	420,335	822	511.3564477	5	2	5	2	0.98%	0.39%
San Luis Obisbo	41,851	274,622	3,299	83.24401334	5	1	5	1	6.01%	1.20%
Yolo	40,571	203,838	1,015	200.8256158	2	0	2	0	1.00%	0.00%
Orange	40,243	3,085,355	791	3900.575221	9	3	9	3	0.23%	0.08%
Ventura	39,799	834,398	1,843	452.7390125	2	2	2	2	0.44%	0.44%
San Benito	39,663	56,869	1,389	40.94240461	0	0	0	0	0.00%	0.00%
San Diego	39,515	3,176,138	4,207	754.9650582	18	6	18	6	2.38%	0.79%
Santa Cruz	38,989	266,508	445	598.894382	1	0	1	0	0.17%	0.00%
Sacramento	38,606	1,448,053	965	1500.573057	10	3	10	3	0.67%	0.20%
Coastal Valleys (Sonoma/ Mendocino	37,273	577,969	5,082	113.7286501	2	2	2	2	1.76%	1.76%
Santa Barbara	36,985	430,426	2,735	157.3769653	3	2	3	2	1.91%	1.27%

124 Adapted from California EMS Authority, *Core Measures 2015 Data*; California EMS Authority, *Core Measures 2016 Data*; US-Places, "California Population"; California Franchise Tax Board, "B-6 Comparison by County"; California State Association of Counties, "Square Mileage by County"; and Office of Statewide Health Planning and Development, "List of Hospitals in California by County."

LEMSA[125]	Median Income (2015)	Population (2012)	LEMSA Sq Miles	Population Density	# of Stroke Centers within LEMSA Area	# of Trauma Centers within LEMSA Area	# of Stroke Centers within LEMSA Area	# of Trauma Centers within LEMSA Area	Percent Stroke Centers by Population Density	% Trauma Centers by Population Density
Mnt Valley	35,514	622,210	4,997	124.51671	3	2	3	2	2.41%	1.61%
Tuolumne	35,305	54,050	2,221	24.33588474	0	0	0	0	0.00%	0.00%
Sierra-Sac	35,012	1,183,498	20,703	57.16553157	10	6	10	6	17.49%	10.50%
San Joaquin	34,684	701,151	1,391	504.0625449	1	1	1	1	0.20%	0.20%
N. Calif.	34,280	78,922	15,144	5.211436873	0	0?	0	0	0.00%	0.00%
ICEMA	34,207	2,110,243	33,287	63.39540962	9	2	9	2	14.20%	3.15%
Monterey	33,557	426,072	3,381	126.0195209	2	1	2	1	1.59%	0.79%
Riverside	33,375	2,264,879	7,206	314.3046073	7	4	7	4	2.23%	1.27%
Los Angeles	33,369	9,951,690	4,058	2452.363233	37	15	37	15	1.51%	0.61%
North Coast	31,106	226,797	5830	38.90171527	0?	2	0	2	0.00%	5.14%
Kern	30,942	855,498	8,132	105.2014265	5	1	5	1	4.75%	0.95%
Fresno/Central Cali	29,328	1,702,241	14,308	118.9712748	1	2	1	2	0.84%	1.68%
Merced	29,113	261,632	1,935	135.2103359	0	0	0	0	0.00%	0.00%
Imperial	24,921	176,768	4,177	42.31936797	0	2	0	2	0.00%	4.73%

125 Adapted from California EMS Authority, *Core Measures 2015 Data*; California EMS Authority, *Core Measures 2016 Data*; US-Places, "California Population"; California Franchise Tax Board, "B-6 Comparison by County"; California State Association of Counties, "Square Mileage by County"; and Office of Statewide Health Planning and Development, "List of Hospitals in California by County."

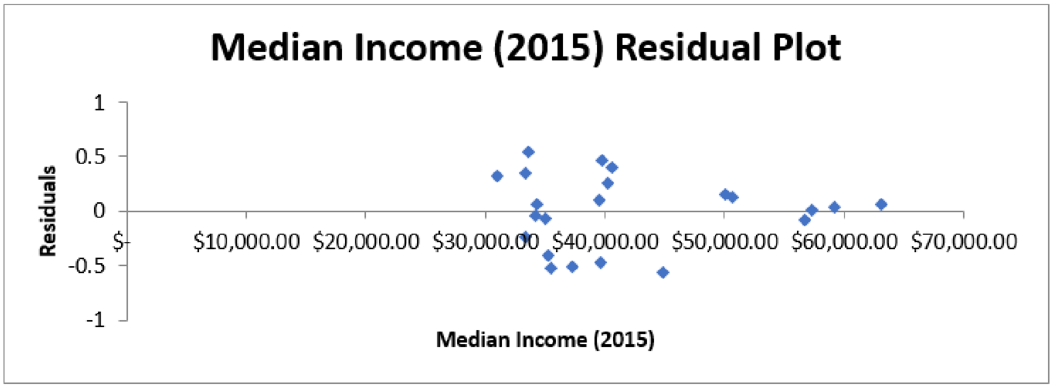
APPENDIX B. 2015 DIRECT STROKE ROUTING TO STROKE CENTER

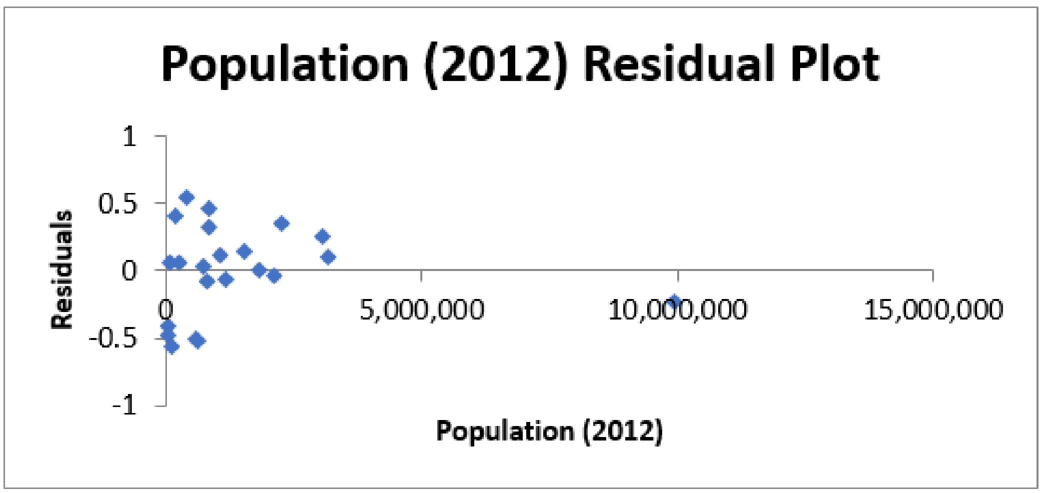
Regression Statistics		
Multiple R	0.562424616	HO: There is no relationship between the dependent and independent (X and Y) variables HA: There is a relationship between the dependent and independent variable α: Reject region = .05 Fail to reject the null hypothesis. There is no relationship between 2015 stroke direct-routing and income or population density, number of stroke centers within the LEMSA area, or percent of stroke centers by population density.
R Square	0.316321448	
Adjusted R Square	0.102671901	
Standard Error	0.380475218	
Observations	22	

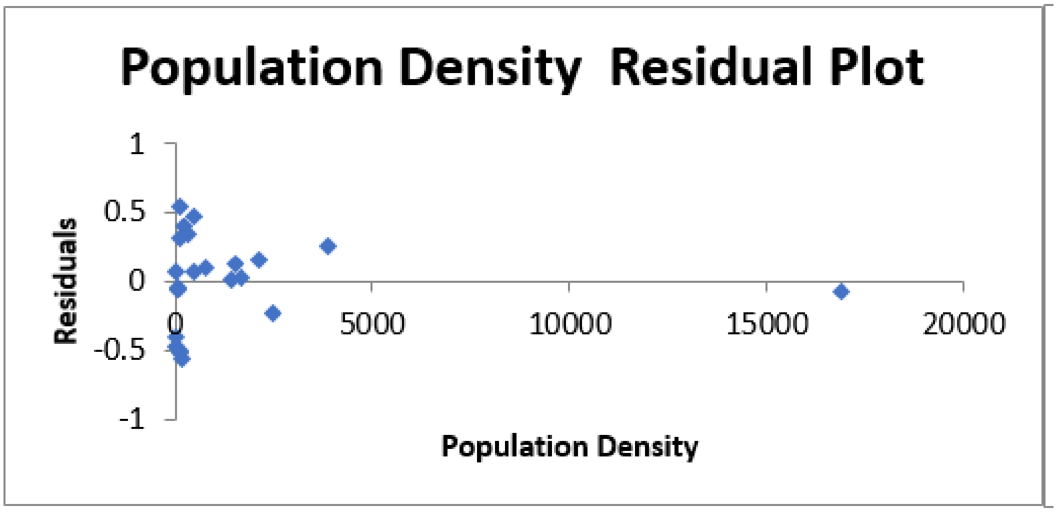
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	1.071641237	0.214328247	1.48056222	0.250667064
Residual	16	2.316182267	0.144761392		
Total	21	3.387823504			

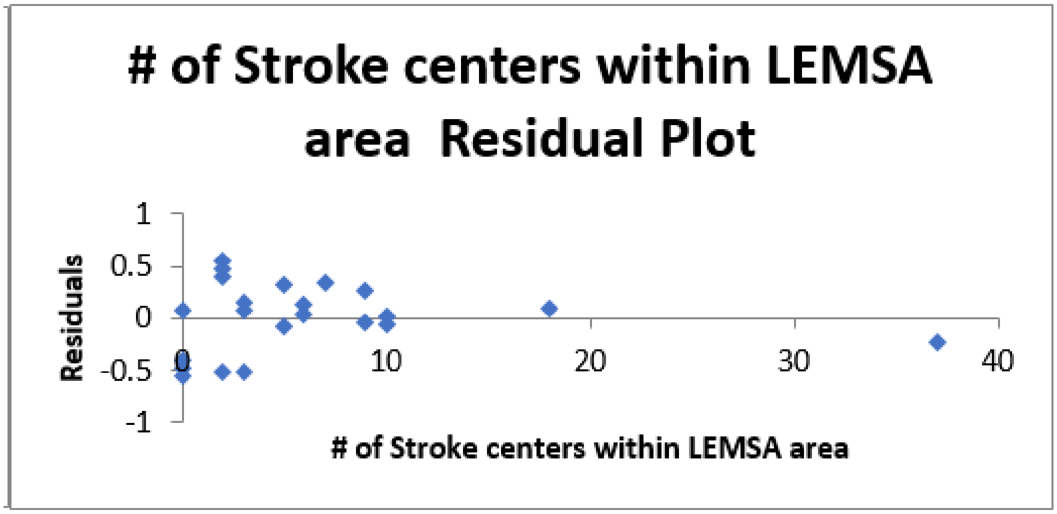
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.158083873	0.493576548	0.320282383	0.752899009	-1.204419413	0.888251667	-1.204419413	0.888251667
Median Income (2015)	1.59898E-05	1.12482E-05	1.421542419	0.174358102	-7.85531E-06	3.98348E-05	-7.85531E-06	3.98348E-05
Population (2012)	-2.02715E-08	1.75197E-07	-0.11570645	0.909324953	-3.91674E-07	3.51131E-07	-3.91674E-07	3.51131E-07
Population Density	7.36242E-06	2.60129E-05	0.28302964	0.780783201	-4.77824E-05	6.25073E-05	-4.77824E-05	6.25073E-05
# of Stroke centers within LEMSA area	0.024404026	0.045366841	0.537926497	0.598031469	-0.07176938	0.120577431	-0.07176938	0.120577431
Percent Stroke Centers by Population Density	1.861507134	2.361317152	0.788334228	0.442025464	-3.14426161	6.867275877	-3.14426161	6.867275877


Median Income (2015) Residual Plot
1
0.5
0
-0.5
-1
Residuals
$-
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Median Income (2015)

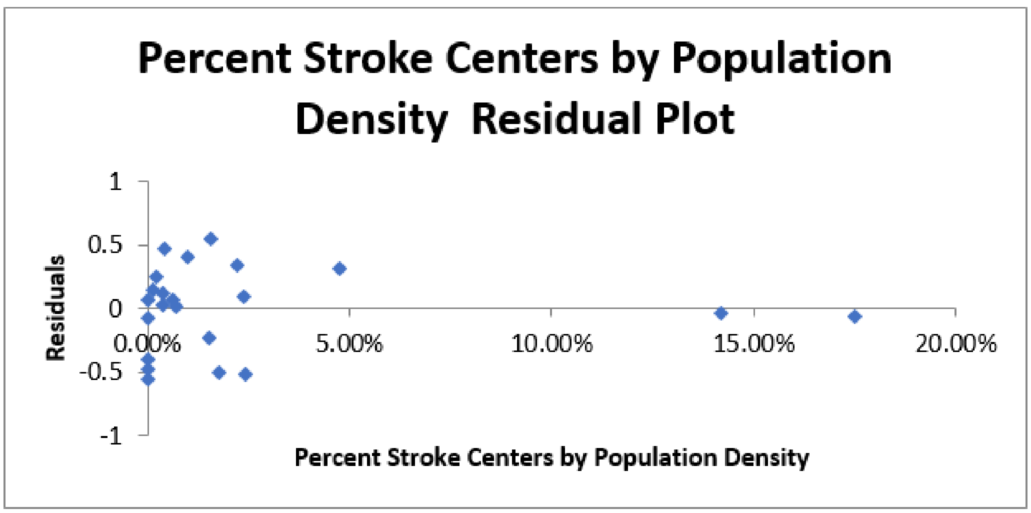

Population (2012) Residual Plot
1
0.5
0
-0.5
-1
Residuals
0
5,000,000
10,000,000
15,000,000
Population (2012)



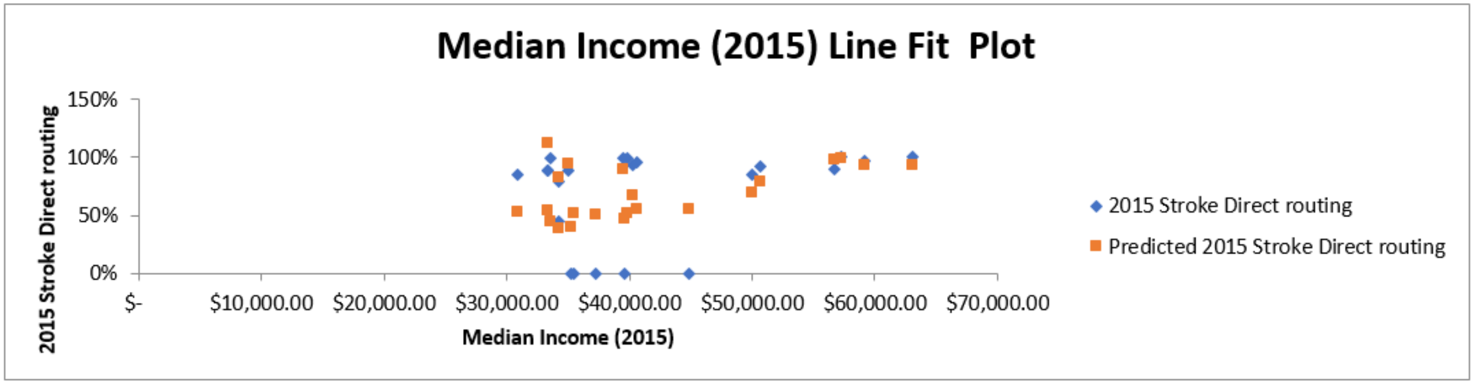
Population Density Residual Plot
1
0.5
0
-0.5
-1
Residuals
0
5000
10000
15000
20000
Population Density

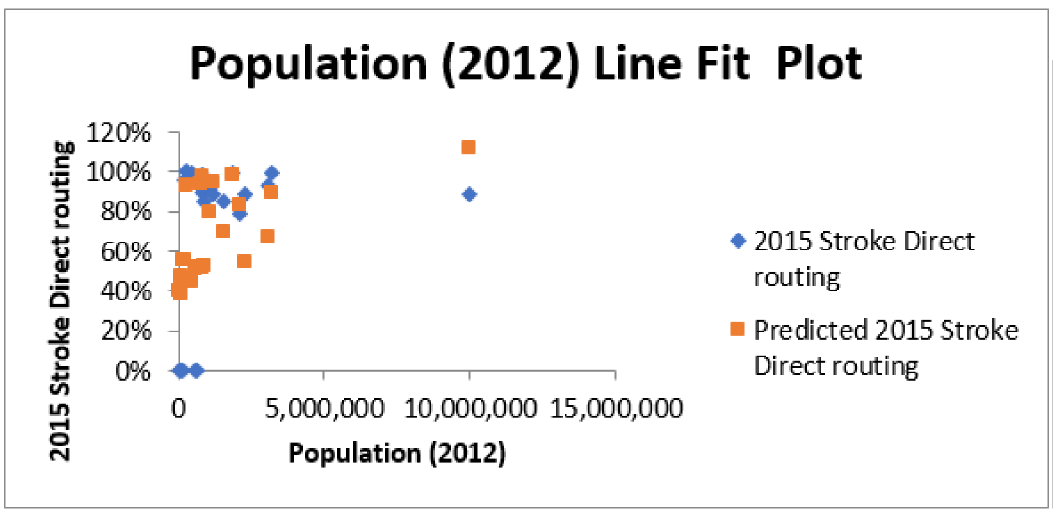


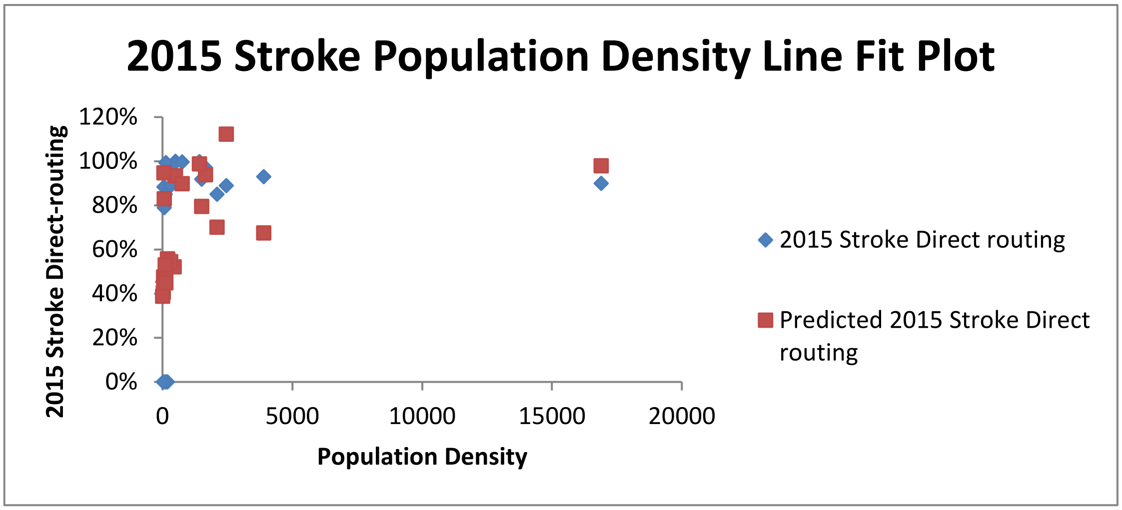
# of Stroke centers within LEMSA area Residual Plot
Residuals
1
0.5
0
-0.5
-1
0
10
20
30
40
# of Stroke centers within LEMSA area

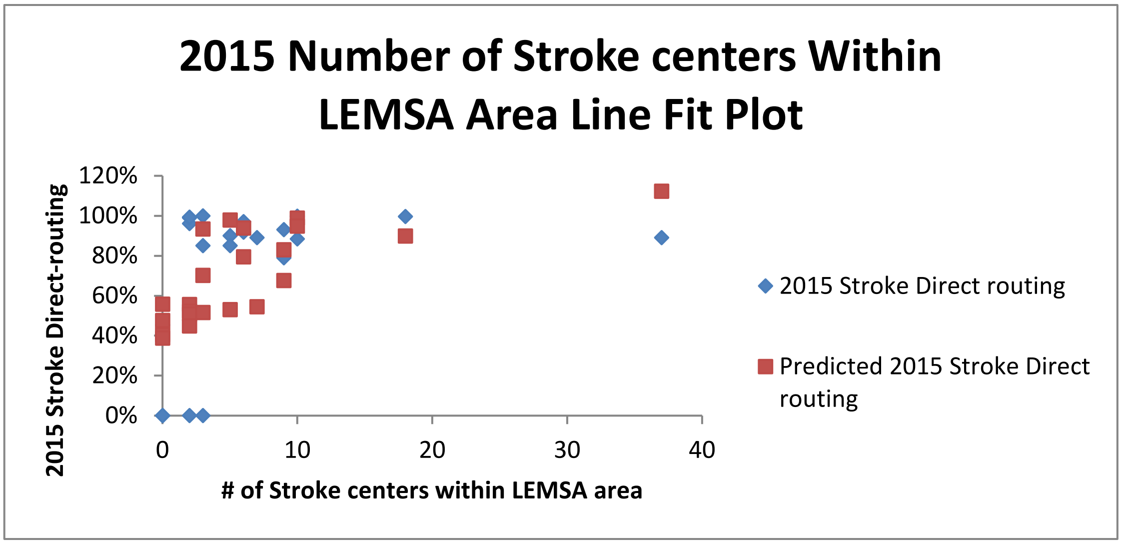


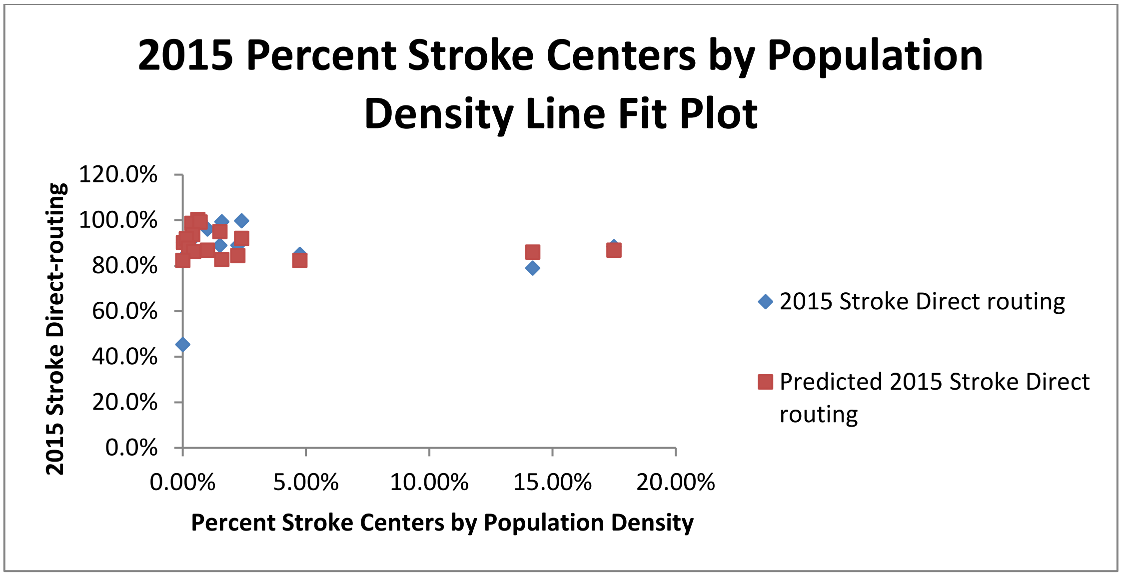
Percent Stroke Centers by Population Density Residual Plot
Residuals
1
0.5
0
-0.5
-1
0.00%
5.00%
10.00%
15.00%
20.00%
Percent Stroke Centers by Population Density

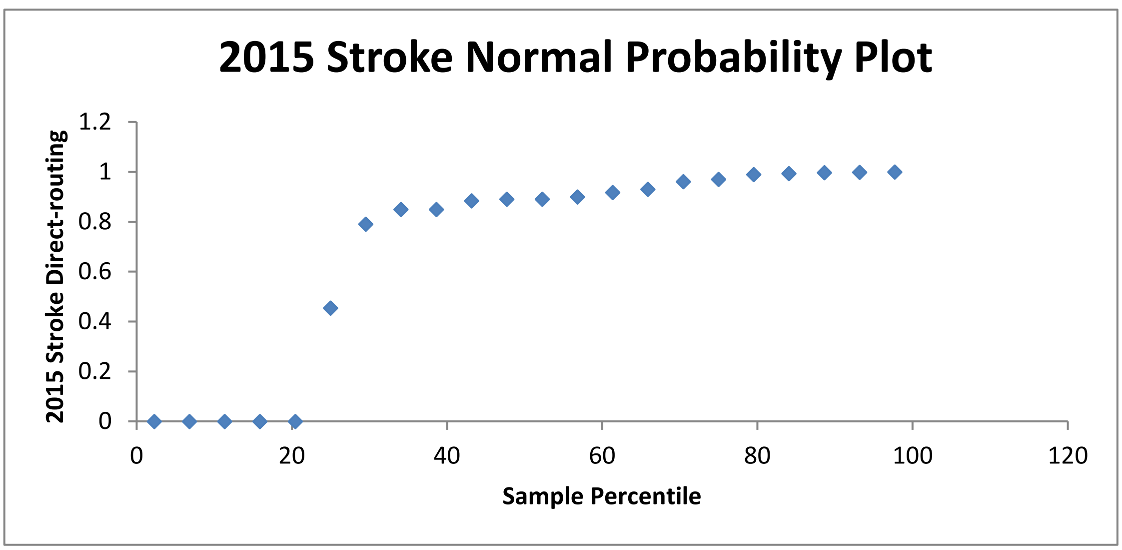

Median Income (2015) Line Fit Plot
150%
100%
50%
0%
2015 Stroke Direct routing
$-
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Median Income (2015)
2015 Stroke Direct routing
Predicted 2015 Stroke Direct routing


Population (2012) Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
2015 Stroke Direct routing
0
5,000,000
10,000,000
15,000,000
Population (2012)
2015 Stroke Direct routing
Predicted 2015 Stroke Direct routing


2015 Stroke Population Density Line Fit Plot
2015 Stroke Direct-routing
120%
100%
80%
60%
40%
20%
0%
0
5000
10000
15000
20000
Population Density
2015 Stroke Direct routing
Predicted 2015 Stroke Direct routing


2015 Number of Stroke centers Within LEMSA Area Line Fit Plot
2015 Stroke Direct-routing
120%
100%
80%
60%
40%
20%
0%
0
10
20
30
40
# of Stroke centers within LEMSA area
2015 Stroke Direct routing
Predicted 2015 Stroke Direct routing


2015 Percent Stroke Centers by Population Density Line Fit Plot
2015 Stroke Direct-routing
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
0.00%
5.00%
10.00%
15.00%
20.00%
Percent Stroke Centers by Population Density
2015 Stroke Direct routing
Predicted 2015 Stroke Direct routing


2015 Stroke Normal Probability Plot
2015 Stroke Direct-routing
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Sample Percentile

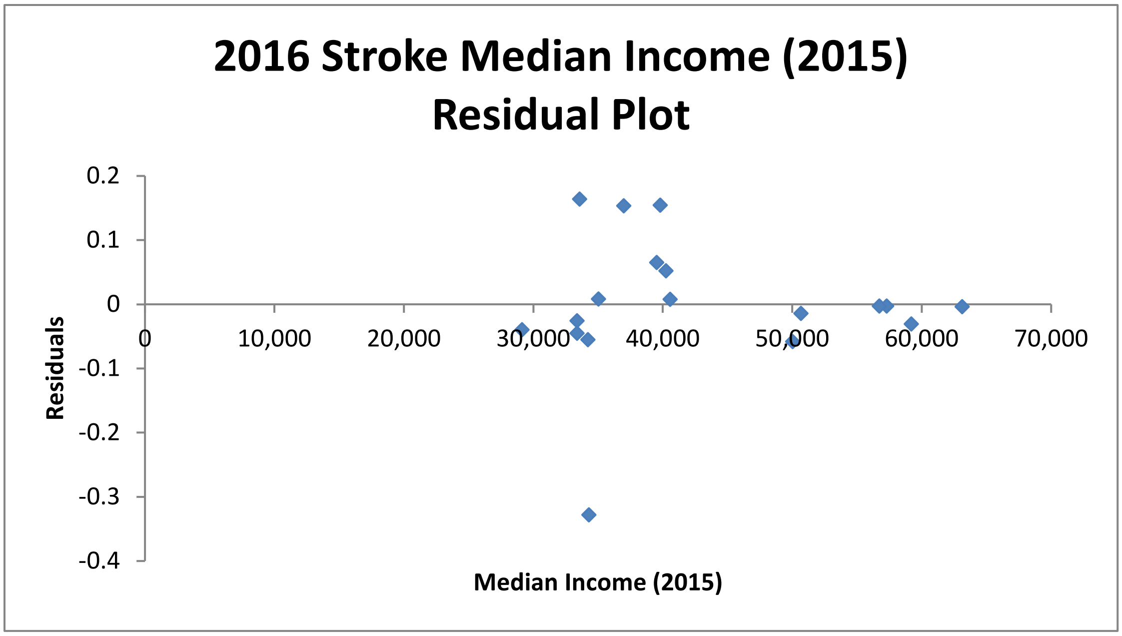
APPENDIX C. 2016 DIRECT STROKE ROUTING TO STROKE CENTER

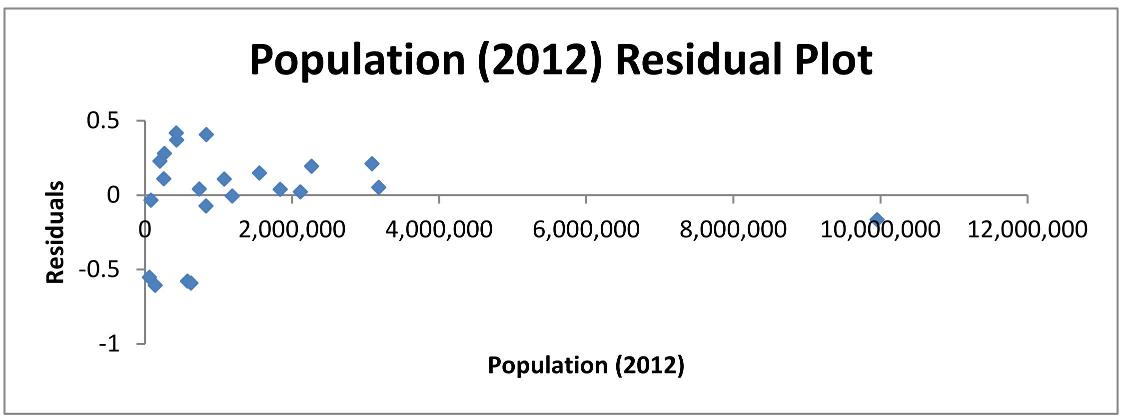
Regression Statistics		
Multiple R	0.587493597	HO: There is no relationship between the dependent and independent (X and Y) variables HA: There is a relationship between the dependent and independent variable α: Reject region = .05 The residuals show that there are outliers in the data: Y = .547818 + .00000693*median income - .0000023*population density + .00588* # of stroke centers within LEMSA area + .263139* %stroke centers by population density There is a borderline relationship (p = .052) between median income and 2016 direct routing of stroke patients to a designated stroke receiving hospital. There is no statistically significant relationship between 2016 stroke direct-routing and population density, or # of stroke centers within LEMSA area and % stroke centers by population density Looking at the raw data, we can conclude that the number of stroke centers within the LEMSA area does not determine the outcome of stroke direct-routing. Even with counties that have 0 stroke centers within the LEMSA area, Northern California and Merced have higher stroke direct-routing than counties, such as Mountain Valley, which have 3 stroke centers within the LEMSA area have a 0% outcome in stroke direct-routing.
R Square	0.345148726	
Adjusted R Square	0.143656027	
Standard Error	0.124284278	
Observations	18	

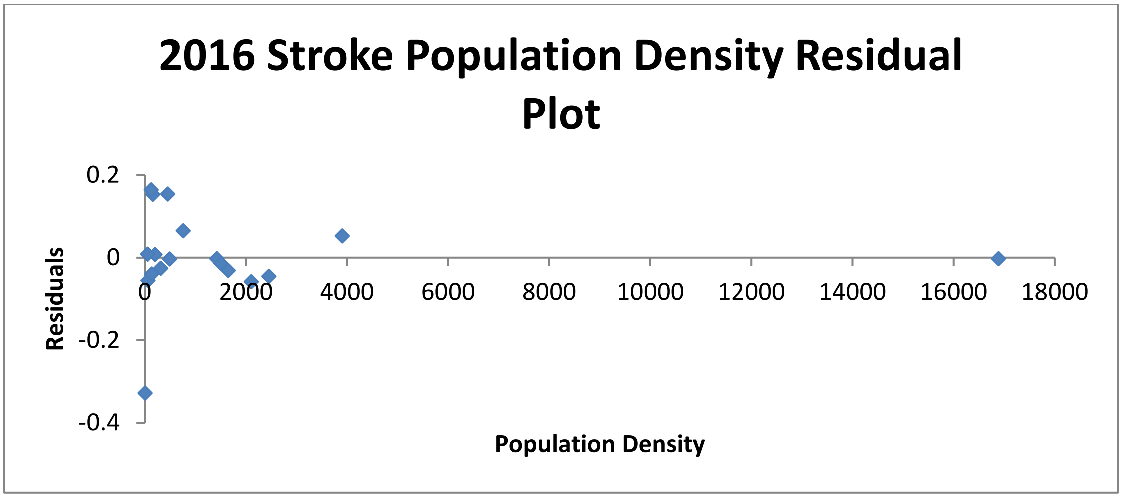
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.105837442	0.026459361	1.712958965	0.206984033
Residual	13	0.200805562	0.015446582		
Total	17	0.306643004			

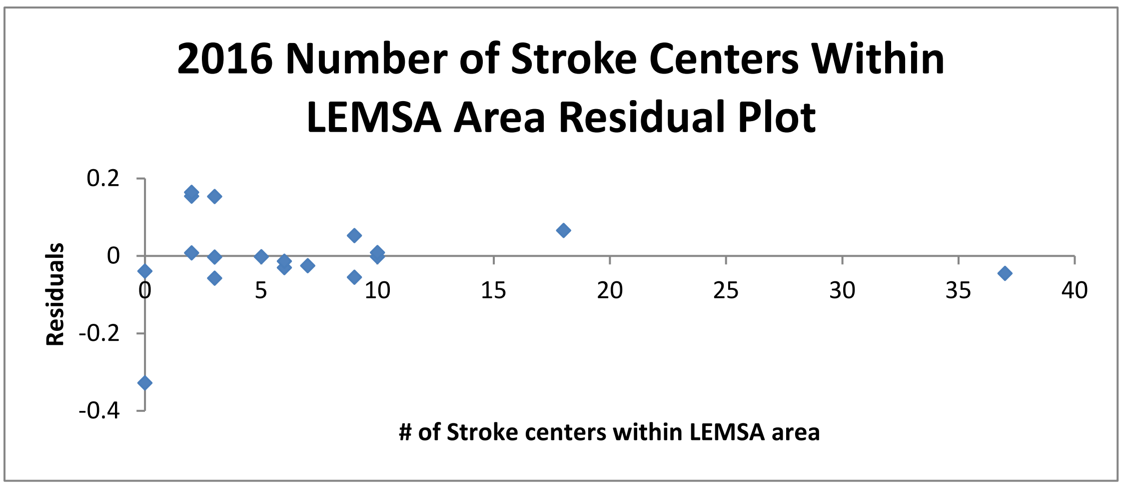
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.547817631	0.146877217	3.729765871	0.002522815	0.230508695	0.865126567	0.230508695	0.865126567
Median Income (2015)	6.9346E-06	3.24239E-06	2.138729885	**0.052015189**	-7.01614E-08	1.39394E-05	-7.01614E-08	1.39394E-05
Population Density	-2.26071E-06	8.51922E-06	-0.265366372	0.794888713	-2.06654E-05	1.61439E-05	-2.06654E-05	1.61439E-05
# of Stroke centers within LEMSA area	0.005879764	0.003580259	1.64227334	0.124489693	-0.001854915	0.013614443	-0.001854915	0.013614443
Percent Stroke Centers by Population Density	0.263138967	0.652783838	0.403102761	0.693423745	-1.147114776	1.673392711	-1.147114776	1.673392711


2016 Stroke Median Income (2015)
Residual Plot
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Residuals
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
Median Income (2015)

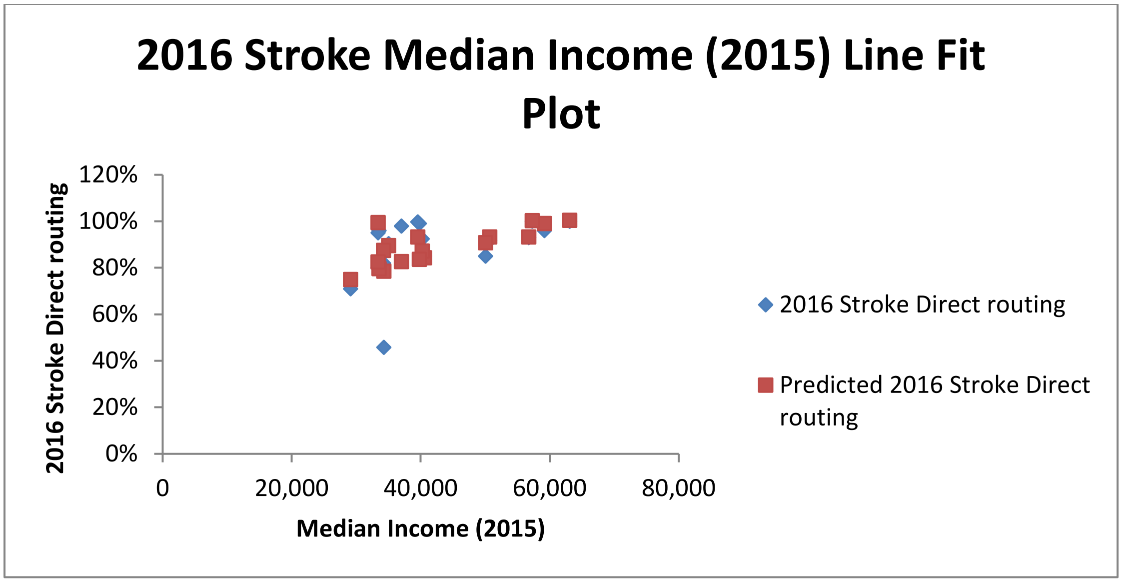

Population (2012) Residual Plot
0.5
0
-0.5
-1
Residuals
0
2,000,000
4,000,000
6,000,000
8,000,000
10,000,000
12,000,000
Population (2012)

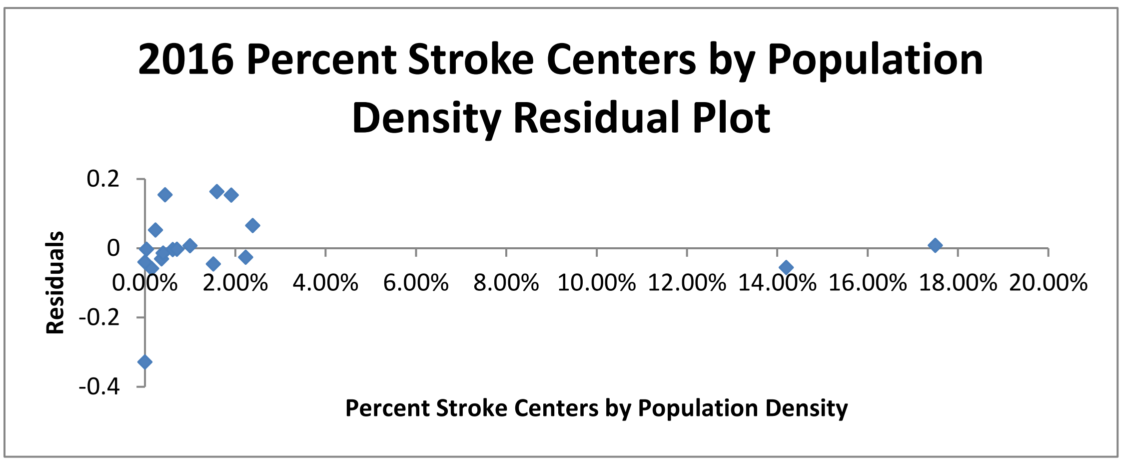


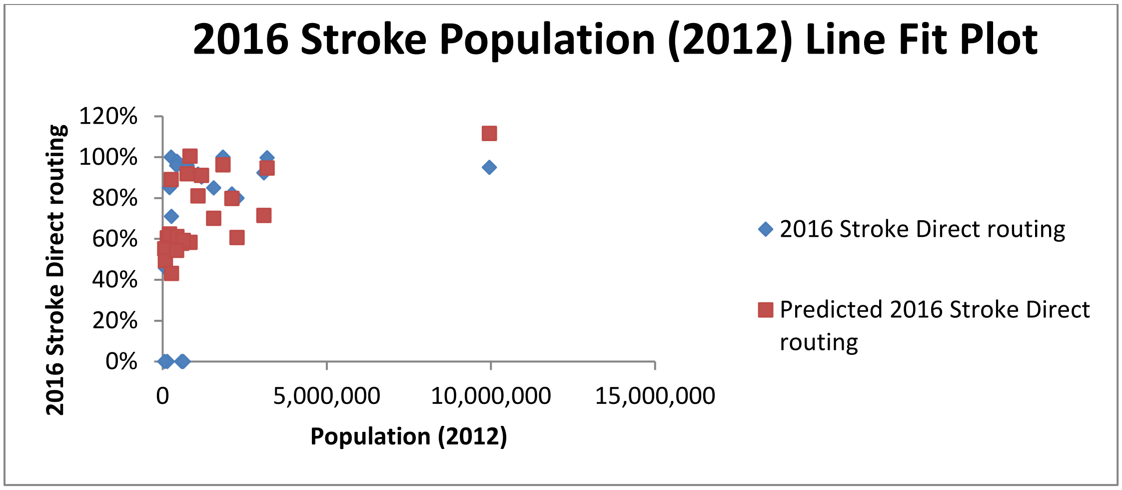
2016 Stroke Population Density Residual Plot
0.2
0
-0.2
-0.4
Residuals
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Population Density

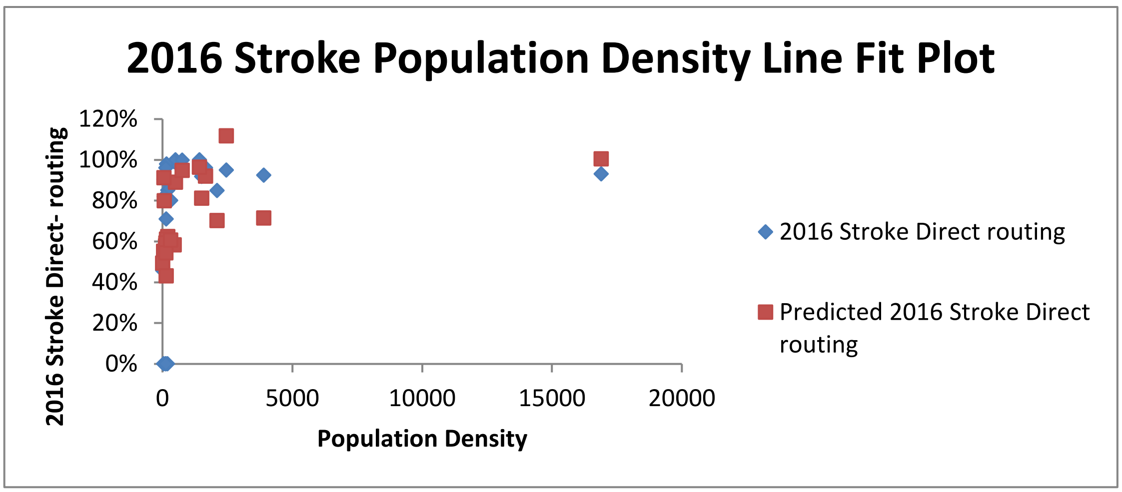


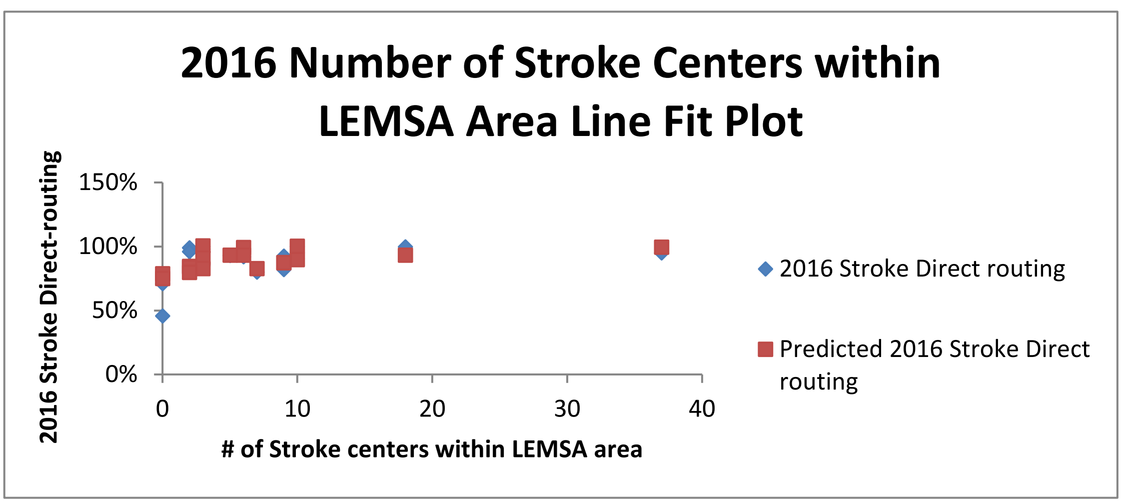
2016 Number of Stroke Centers Within LEMSA Area Residual Plot
0.2
0
-0.2
-0.4
Residuals
0
5
10
15
20
25
30
35
40
# of Stroke centers within LEMSA area

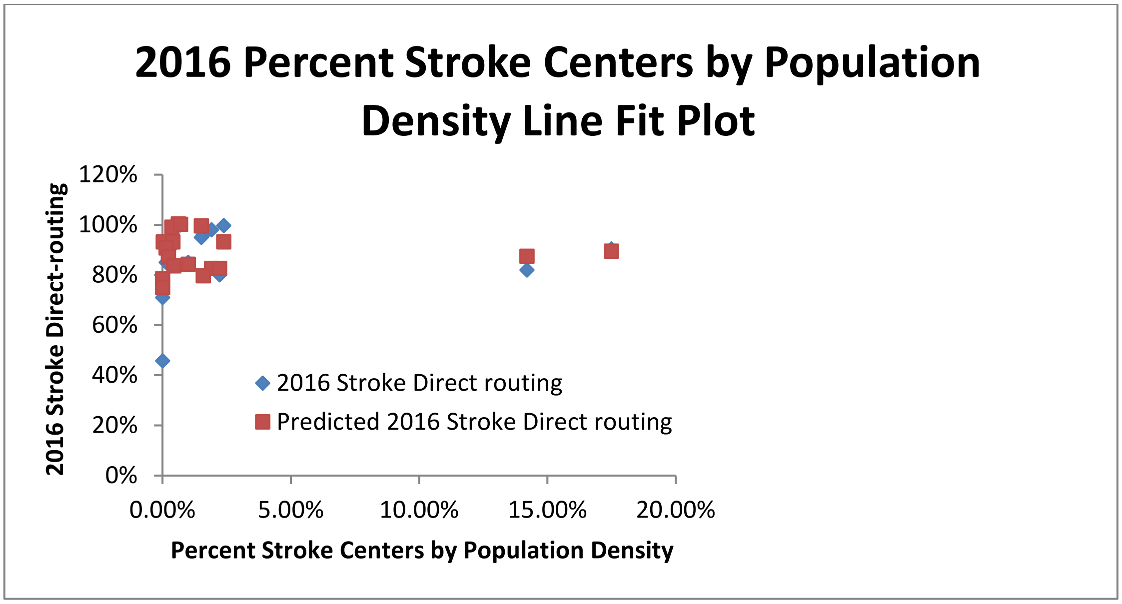

2016 Stroke Median Income (2015) Line Fit Plot
2016 Stroke Direct routing
120%
100%
80%
60%
40%
20%
0%
0
20,000
40,000
60,000
80,000
Median Income (2015)
2016 Stroke Direct routing
Predicted 2016 Stroke Direct routing

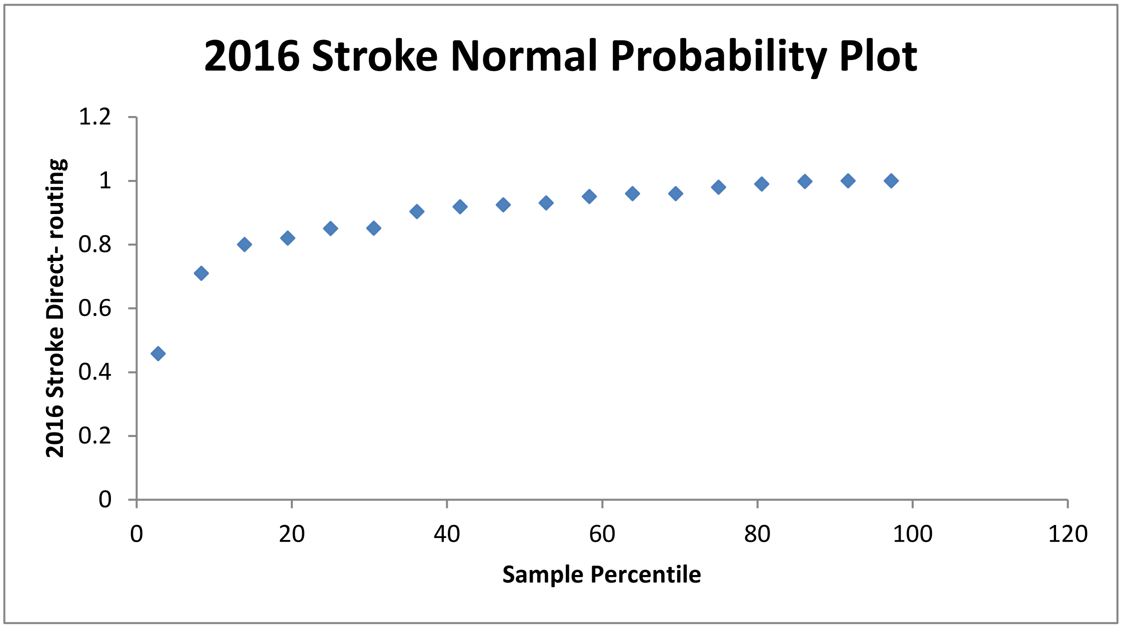

2016 Percent Stroke Centers by Population Density Residual Plot
Residuals
0.2
0
-0.2
-0.4
0.00%
2.00%
4.00%
6.00%
8.00%
10.00%
12.00%
14.00%
16.00%
18.00%
20.00%
Percent Stroke Centers by Population Density


2016 Stroke Population (2012) Line Fit Plot
2016 Stroke Direct routing
120%
100%
80%
60%
40%
20%
0%
0
5,000,000
10,000,000
15,000,000
Population (2012)
2016 Stroke Direct routing
Predicted 2016 Stroke Direct routing


2016 Stroke Population Density Line Fit Plot
2016 Stroke Direct- routing
120%
100%
80%
60%
40%
20%
0%
0
5000
10000
15000
20000
Population Density
2016 Stroke Direct routing
Predicted 2016 Stroke Direct routing


2016 Number of Stroke Centers within LEMSA Area Line Fit Plot
2016 Stroke Direct-routing
150%
100%
50%
0%
0
10
20
30
40
# of Stroke centers within LEMSA area
2016 Stroke Direct routing
Predicted 2016 Stroke Direct routing


2016 Percent Stroke Centers by Population Density Line Fit Plot
2016 Stroke Direct-routing
120%
100%
80%
60%
40%
20%
0%
0.00%
5.00%
10.00%
15.00%
20.00%
Percent Stroke Centers by Population Density
2016 Stroke Direct routing
Predicted 2016 Stroke Direct routing


2016 Stroke Normal Probability Plot
2016 Stroke Direct- routing
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Sample Percentile

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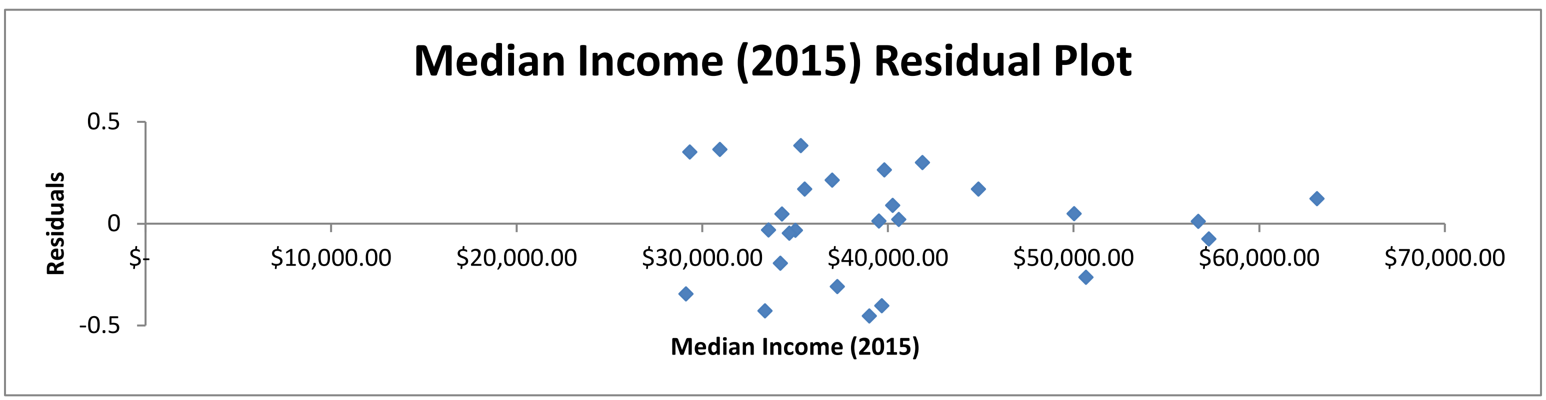
APPENDIX D. 2015 DIRECT ROUTING OF TRAUMA TRIAGE CRITERIA PATIENTS TO TRAUMA CENTERS

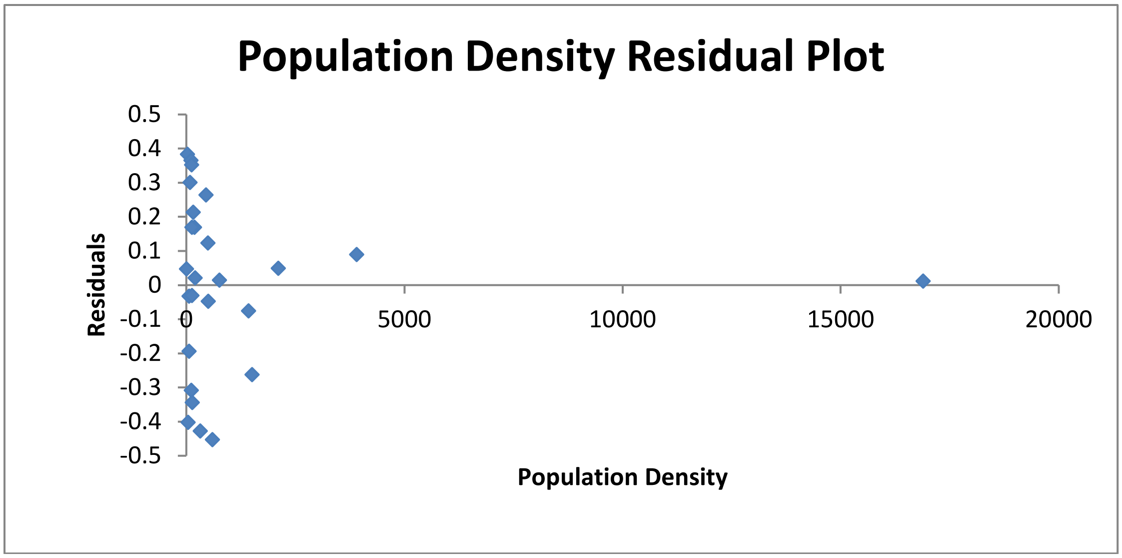
Regression Statistics		
Multiple R	0.489425151	HO: There is no relationship between the dependent and independent (X and Y) variables HA: There is a relationship between the dependent and independent variable α: Reject region = .05 Fail to reject HO for population density, #trauma centers within LEMSA area, % trauma centers by population density, median income Conclusion: There is no statistically significant relationship between 2015 trauma direct-routing and median income, population density, # of trauma centers within LEMSA area and % stroke centers by population density.
R Square	0.239536979	
Adjusted R Square	0.094686879	
Standard Error	0.273939304	
Observations	26	

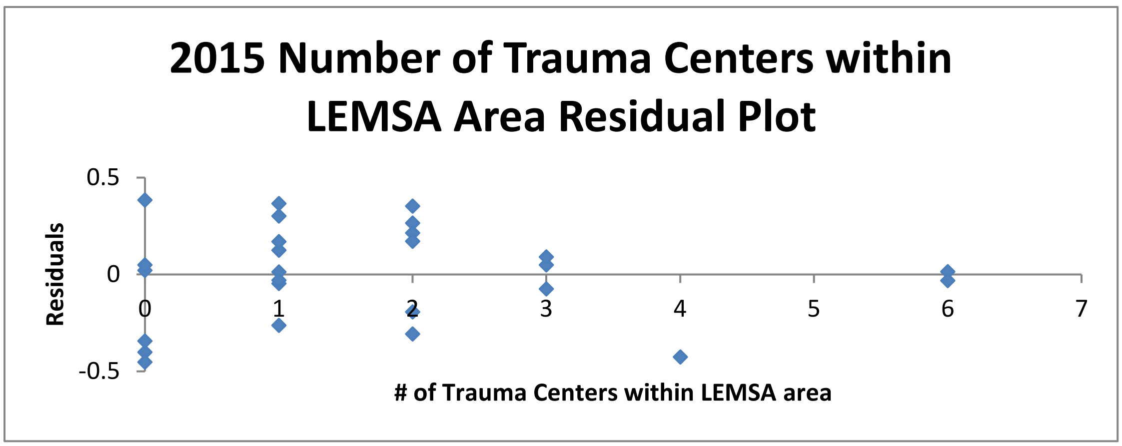
ANOVA

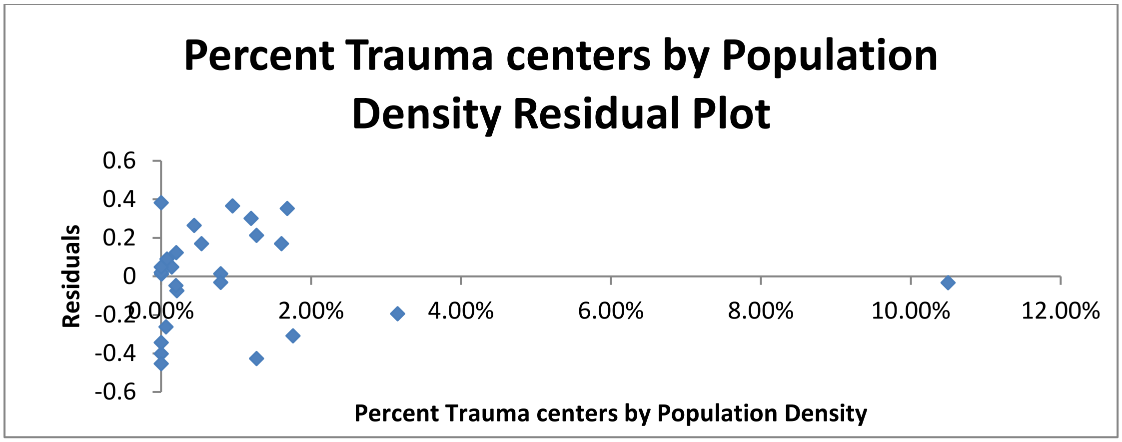
	df	*SS*	*MS*	*Significance F*
Regression	4	0.4963894	0.1240973	0.198272495
Residual	21	1.5758976	0.0750427	
Total	25	2.0722869		

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.159241917	0.2922366	0.5449074	0.591557725	-0.4484974	0.7669813	-0.44849743	0.7669813
Median Income (2015)	1.04163E-05	7.315E-06	1.4239142	0.169161248	-4.797E-06	2.563E-05	-4.7966E-06	2.563E-05
Population Density	-4.20764E-06	1.871E-05	-0.2249233	0.824213161	-4.311E-05	3.47E-05	-4.3111E-05	3.47E-05
# of Trauma centers within LEMSA area	0.059152316	0.0417785	1.4158538	0.171479714	-0.0277309	0.1460356	-0.02773093	0.1460356
Percent Trauma Centers by Population Density	1.277547096	3.4514485	0.3701481	0.714979098	-5.9001331	8.4552272	-5.90013305	8.4552272

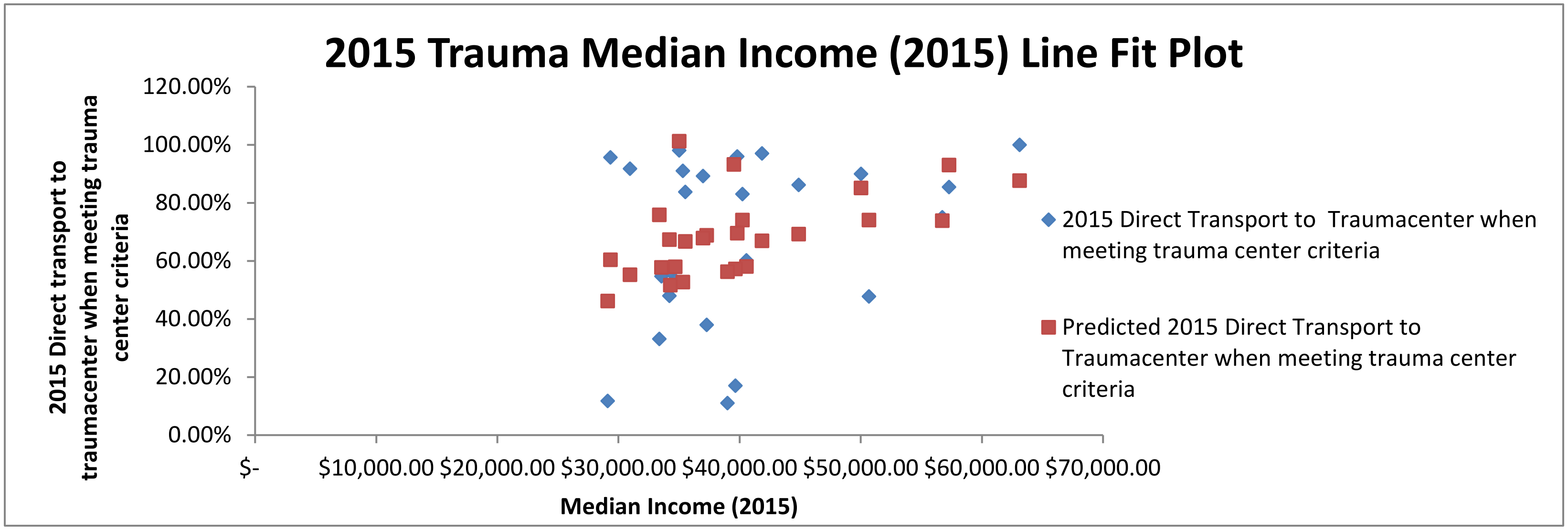



Population Density Residual Plot
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Residuals
0
5000
10000
15000
20000
Population Density

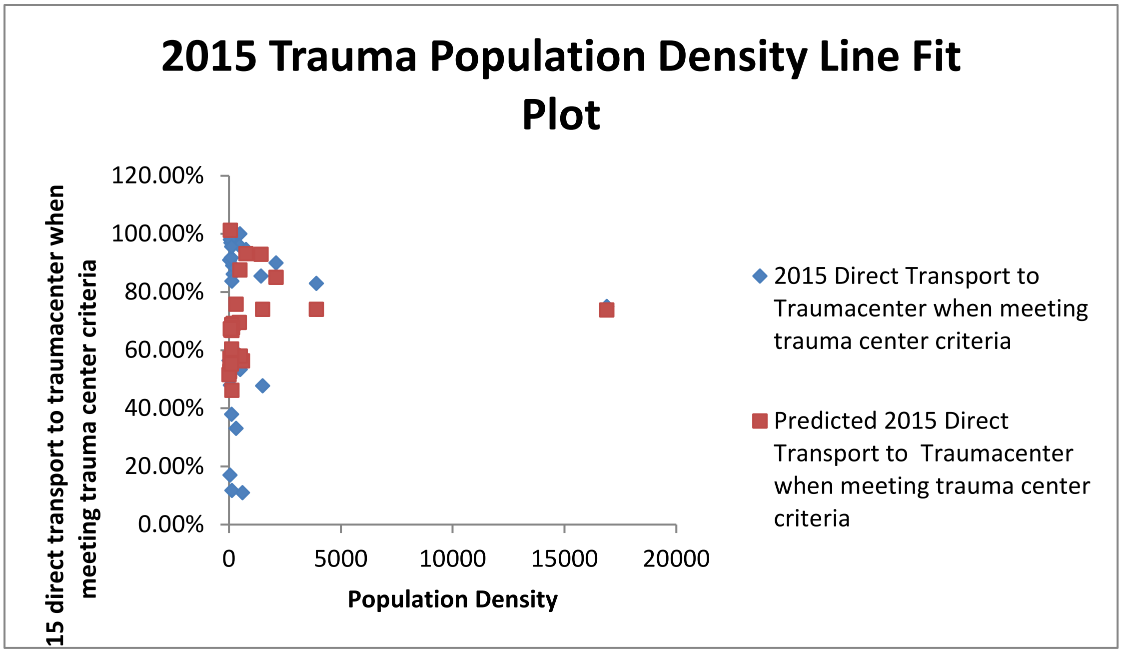

2015 Number of Trauma Centers within LEMSA Area Residual Plot
0.5
0
-0.5
Residuals
0
1
2
3
4
5
6
7
# of Trauma Centers within LEMSA area

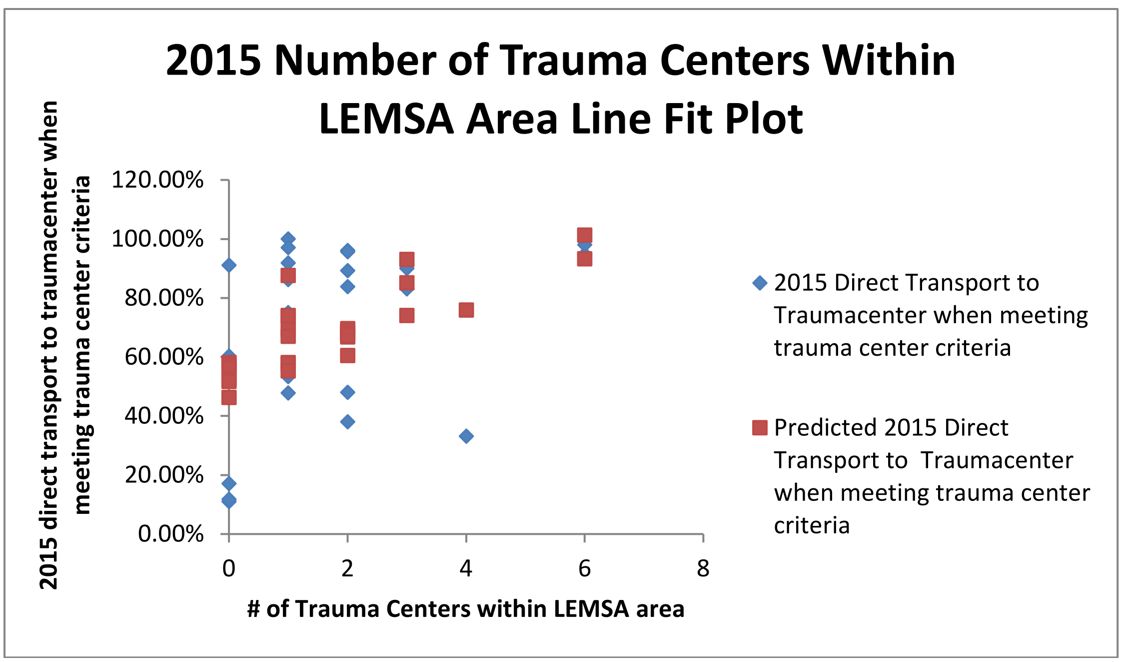


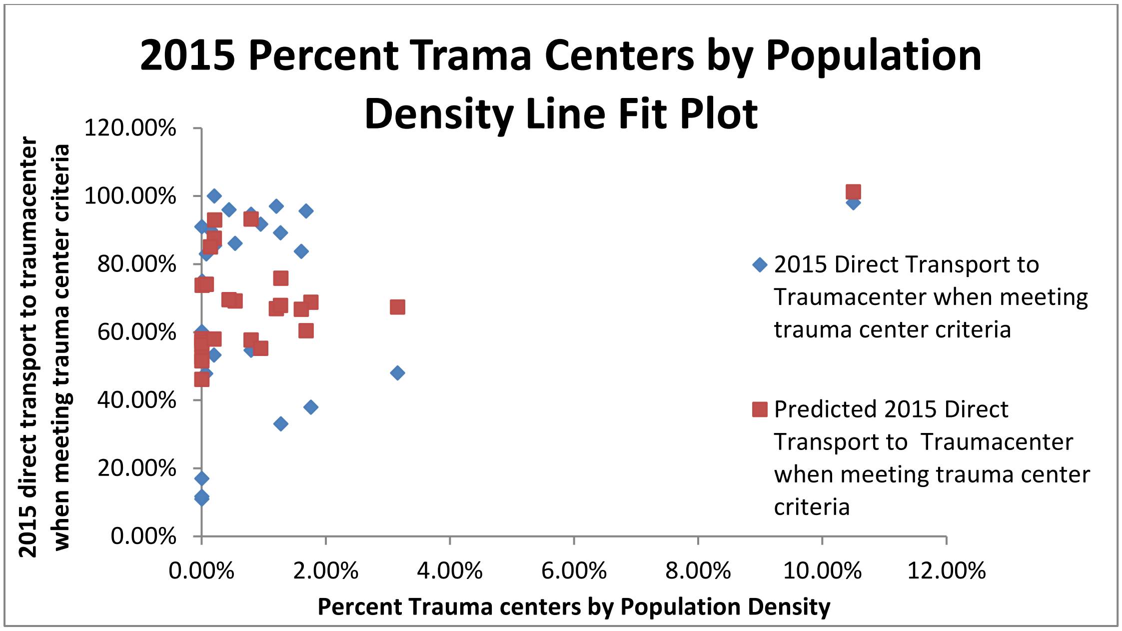
Percent Trauma centers by Population Density Residual Plot
Residuals
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0.00%
2.00%
4.00%
6.00%
8.00%
10.00%
12.00%
Percent Trauma centers by Population Density



2015 Trauma Median Income (2015) Line Fit Plot
2015 Direct transport to traumacenter when meeting trauma center criteria
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
$-
$10,000.00 $20,000.00 $30,000.00 $40,000.00 $50,000.00 $60,000.00 $70,000.00
Median Income (2015)
2015 Direct Transport to Traumacenter when meeting trauma center criteria
Predicted 2015 Direct Transport to Traumacenter when meeting trauma center criteria


2015 Trauma Population Density Line Fit Plot
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
0
5000
10000
15000
20000
Population Density
15 direct transport to traumacenter when meeting trauma center criteria
2015 Direct Transport to Traumacenter when meeting trauma center criteria
Predicted 2015 Direct Transport to Traumacenter when meeting trauma center criteria


2015 Number of Trauma Centers Within LEMSA Area Line Fit Plot
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
0
2
4
6
8
# of Trauma Centers within LEMSA area
2015 direct transport to traumacenter when meeting trauma center criteria
2015 Direct Transport to Traumacenter when meeting trauma center criteria
Predicted 2015 Direct Transport to Traumacenter when meeting trauma center criteria


2015 Percent Trama Centers by Population Density Line Fit Plot
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
2015 direct transport to traumacenter when meeting trauma center criteria
0.00%
2.00%
4.00%
6.00%
8.00%
10.00%
12.00%
Percent Trauma centers by Population Density
2015 Direct Transport to Traumacenter when meeting trauma center criteria
Predicted 2015 Direct Transport to Traumacenter when meeting trauma center criteria

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APPENDIX E. 2016 DIRECT ROUTING OF TRAUMA TRIAGE CRITERIA PATIENTS TO TRAUMA CENTERS

<table>
<tr><th colspan="3">Regression Statistics</th></tr>
<tr><td>Multiple R</td><td>0.502829941</td><td rowspan="5">HO: There is no relationship between the dependent and independent (X and Y) variables
HA: There is a relationship between the dependent and independent variable
α: Reject region = .05
Residual plots show outliers in data

Y = .402178 + .0000598*median income - .0000079*population
density + .033283* # of trauma centers within LEMSA area + 2.188609*
% trauma centers by population density

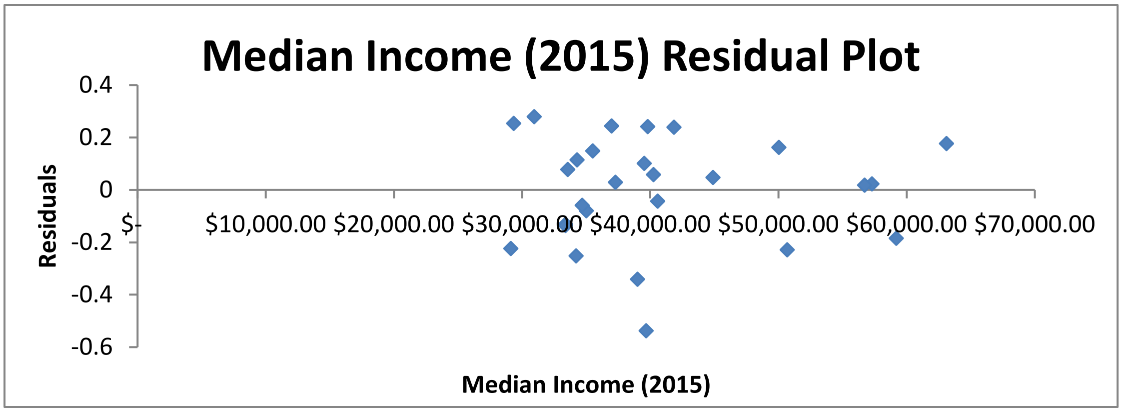
Conclusion: There is a statistically significant relationship between
2016 direct transport to trauma center when meeting trauma center criteria
and # of trauma centers within the LEMSA area

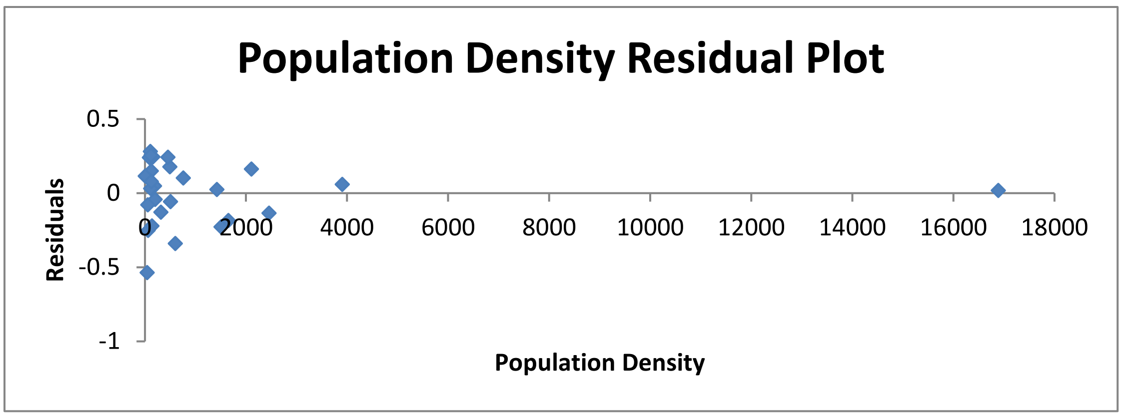
The more centers, the more likely patient will receive direct transport to trauma center, meeting trauma center criteria.</td></tr>
<tr><td>R Square</td><td>0.25283795</td></tr>
<tr><td>Adjusted R Square</td><td>0.116990305</td></tr>
<tr><td>Standard Error</td><td>0.222059796</td></tr>
<tr><td>Observations</td><td>27</td></tr>
</table>

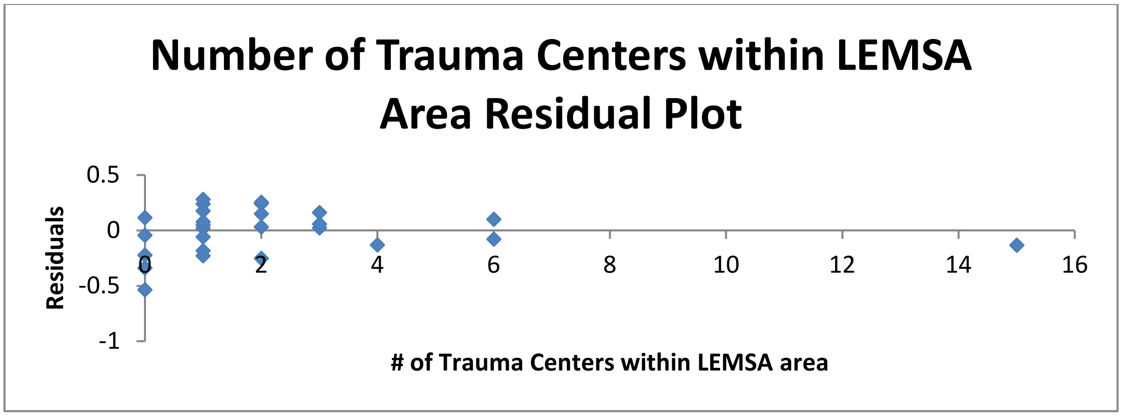
ANOVA

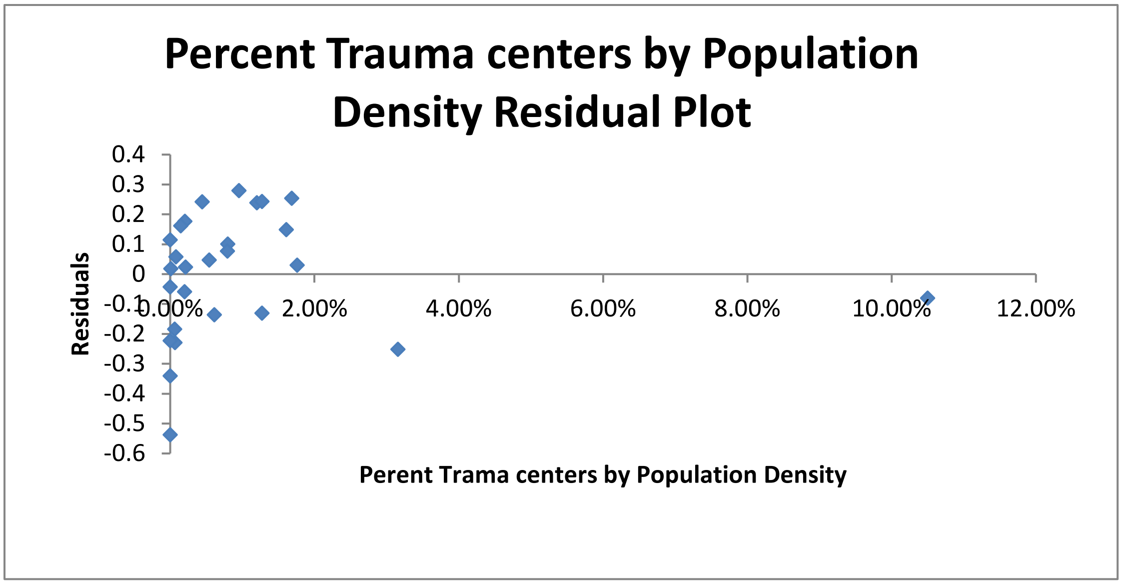
	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.367104756	0.091776189	1.861187577	0.153177335
Residual	22	1.084832171	0.049310553		
Total	26	1.451936927			

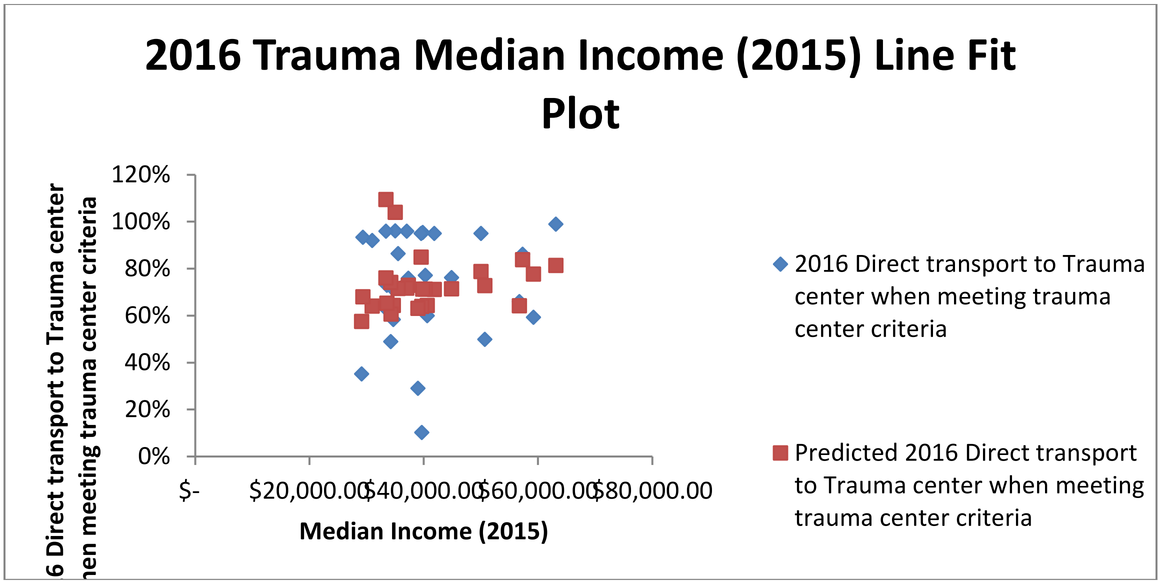
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.40217802	0.224210824	1.793749351	0.086611187	-0.062806769	0.867162809	-0.062806769	0.867162809
Median Income (2015)	5.97998E-06	5.27964E-06	1.132648759	0.269555758	-4.96933E-06	1.69293E-05	-4.96933E-06	1.69293E-05
Population Density	-7.86571E-06	1.49237E-05	-0.527063509	0.603424295	-3.88155E-05	2.30841E-05	-3.88155E-05	2.30841E-05
# of Trauma centers within LEMSA area	0.033282557	0.015314673	2.173246361	**0.040805623**	0.001521869	0.065043244	0.001521869	0.065043244
Percent Trauma Centers by Population Density	2.188608793	2.299890782	0.951614229	0.351631331	-2.581072759	6.958290344	-2.581072759	6.958290344


Median Income (2015) Residual Plot
0.4
0.2
0
-0.2
-0.4
-0.6
Residuals
$-
$10,000.00 $20,000.00 $30,000.00 $40,000.00 $50,000.00 $60,000.00 $70,000.00
Median Income (2015)

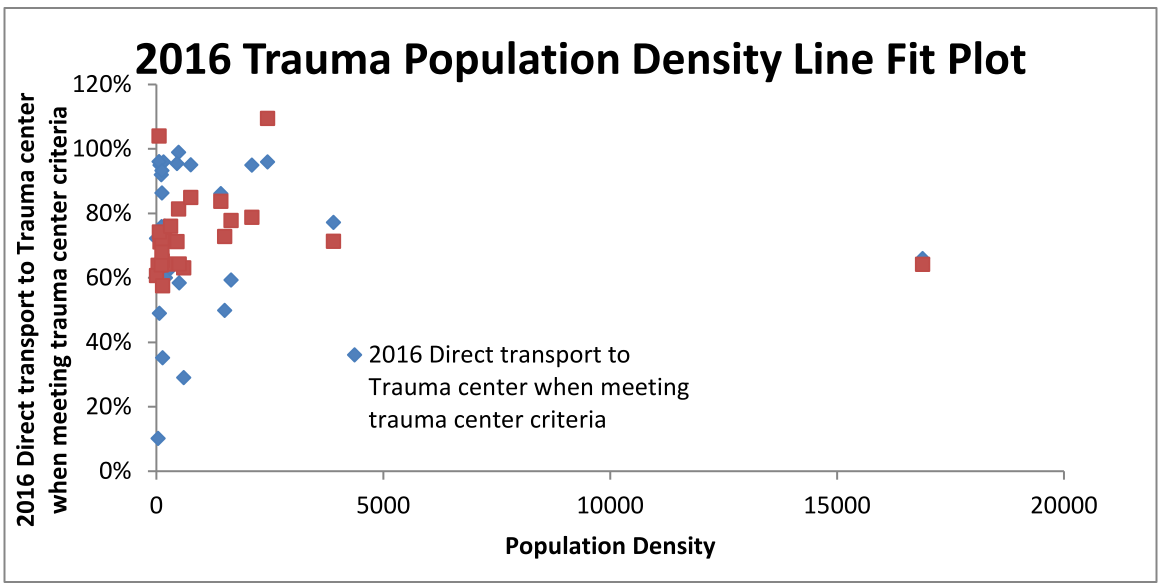

Population Density Residual Plot
0.5
0
-0.5
-1
Residuals
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Population Density


Number of Trauma Centers within LEMSA Area Residual Plot
Residuals
0.5
0
-0.5
-1
0
2
4
6
8
10
12
14
16
# of Trauma Centers within LEMSA area

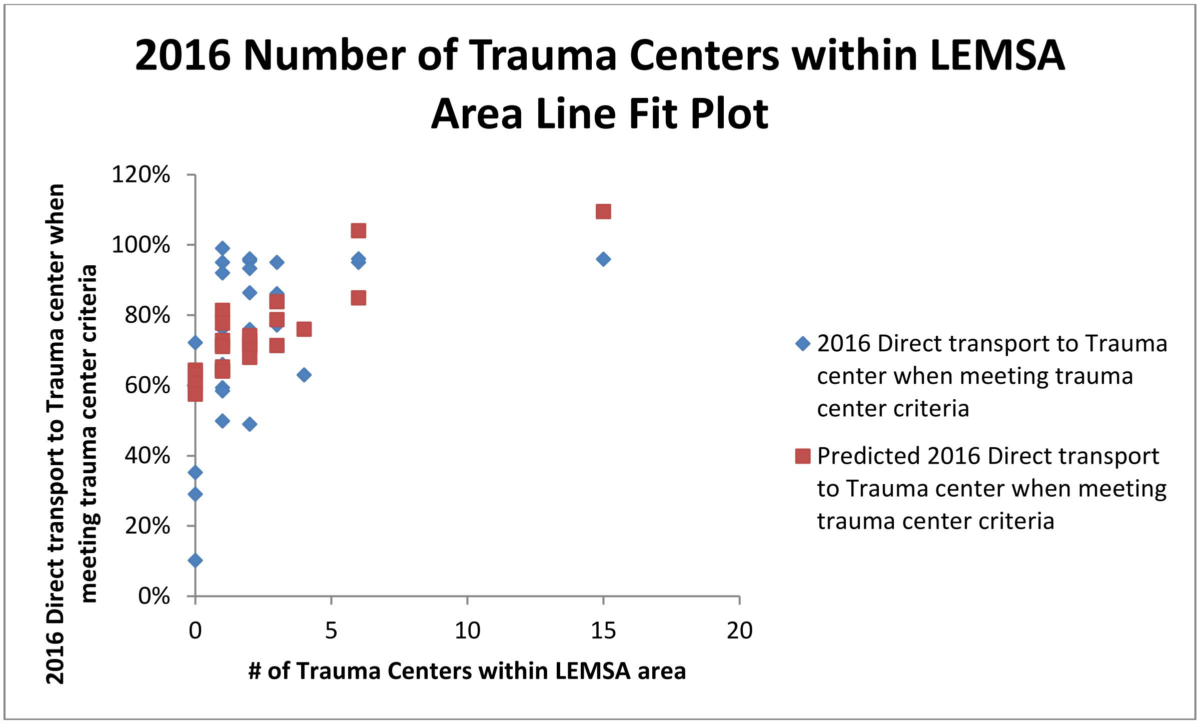

Percent Trauma centers by Population Density Residual Plot
Residuals
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0.00%
2.00%
4.00%
6.00%
8.00%
10.00%
12.00%
Perent Trama centers by Population Density

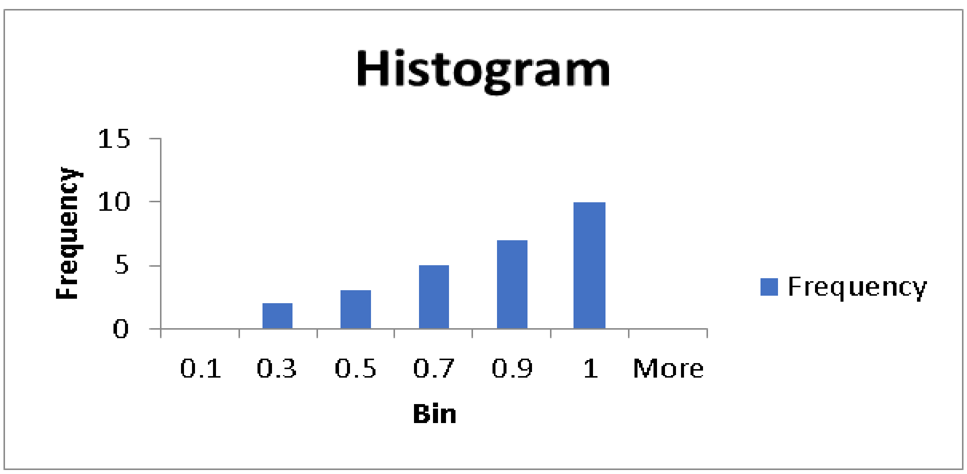


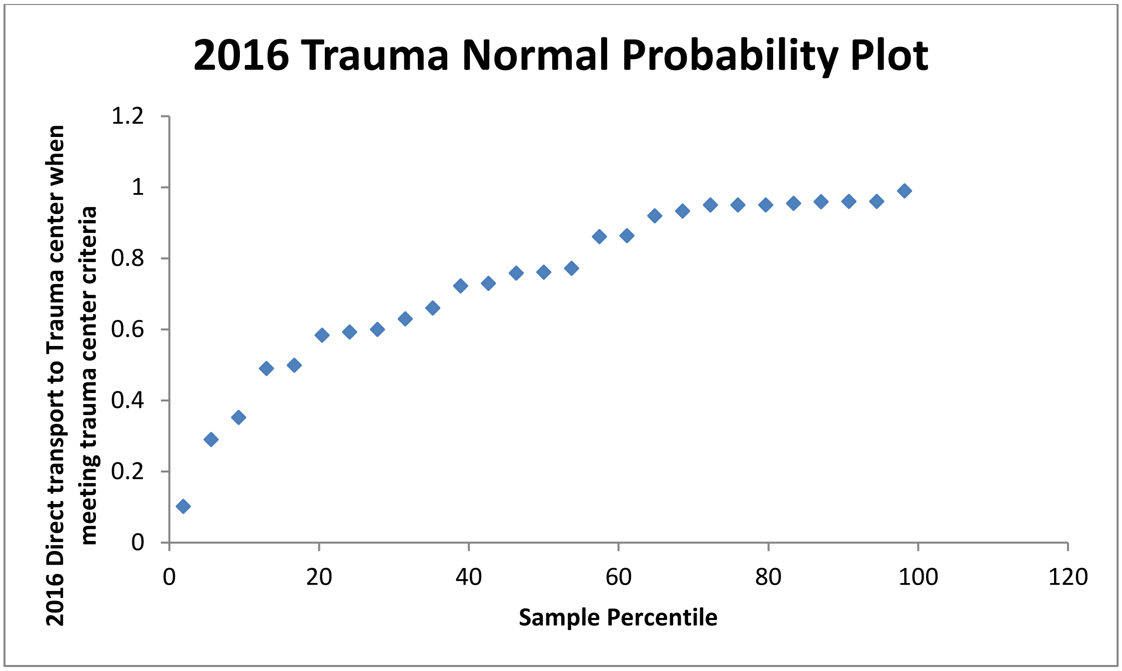
2016 Trauma Median Income (2015) Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
$-
$20,000.00
$40,000.00
$60,000.00
$80,000.00
Median Income (2015)
6 Direct transport to Trauma center
hen meeting trauma center criteria
2016 Direct transport to Trauma center when meeting trauma center criteria
Predicted 2016 Direct transport to Trauma center when meeting trauma center criteria



2016 Trauma Population Density Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
0
5000
10000
15000
20000
Population Density
2016 Direct transport to Trauma center when meeting trauma center criteria
2016 Direct transport to Trauma center when meeting trauma center criteria


2016 Number of Trauma Centers within LEMSA Area Line Fit Plot
2016 Direct transport to Trauma center when meeting trauma center criteria
120%
100%
80%
60%
40%
20%
0%
0
5
10
15
20
# of Trauma Centers within LEMSA area
2016 Direct transport to Trauma center when meeting trauma center criteria
Predicted 2016 Direct transport to Trauma center when meeting trauma center criteria


Histogram
Frequency
15
10
5
0
0.1
0.3
0.5
0.7
0.9
1
More
Bin
Frequency


2016 Trauma Normal Probability Plot
2016 Direct transport to Trauma center when meeting trauma center criteria
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Sample Percentile

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APPENDIX F. 2015 ORAL TRACHEAL INTUBATION SUCCESS RATES BY LEMSA

Regression Statistics		
Multiple R	0.192400308	The histogram appears to be normally distributed.
R Square	0.037017878	Residuals show an outlier
Adjusted R Square	-0.040020691	Y = .818042 - .0000022*median income - .0000027*population density
Standard Error	0.135059293	HO: There is no relationship between the dependent and independent (X and Y) variables
Observations	28	HA: There is a relationship between the dependent and independent variable Fail to reject the null hypothesis α: Reject Region = .05 Conclude: There is no statistically significant relationship between 2015 intubation success and median income or population density.

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.017530014	0.008765007	0.480510977	0.624062092
Residual	25	0.456025315	0.018241013		
Total	27	0.473555329			

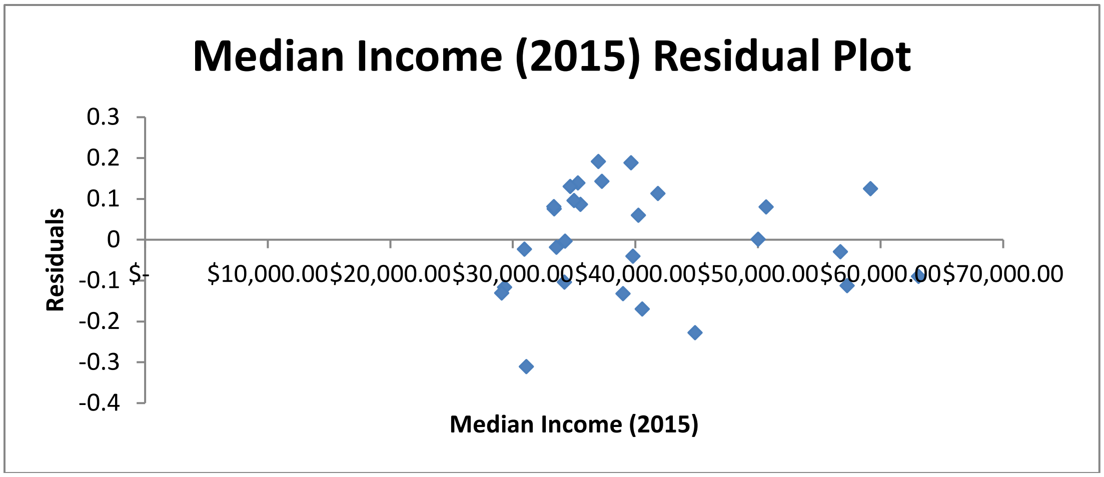
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.818041628	0.120731235	6.775724845	4.21711E-07	0.569390995	1.06669226
Median Income (2015)	-2.17002E-06	3.03695E-06	-0.714538012	0.481513899	-8.42474E-06	4.0847E-06
Population Density	-2.6889E-06	8.96266E-06	-0.30001167	0.766648696	-2.11479E-05	1.577E-05

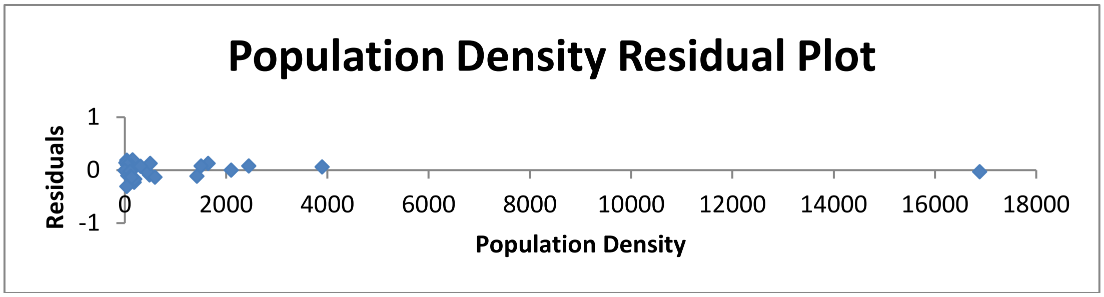
Residual Output **Probability Output**

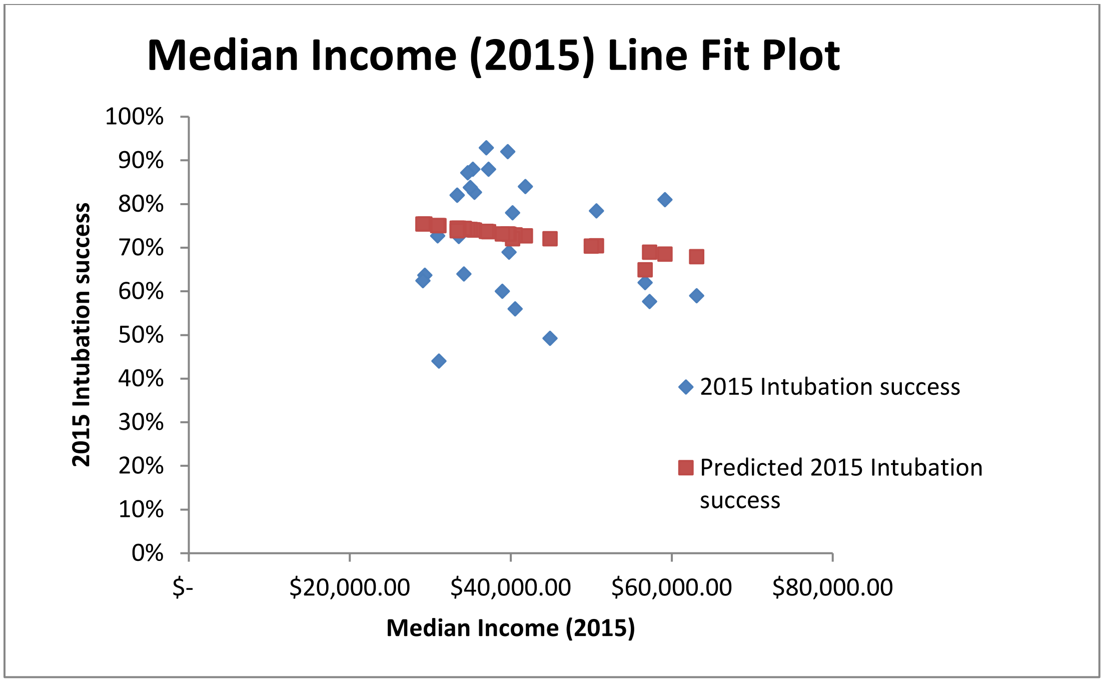
Observation	*Predicted 2015 Intubation Success*	*Residuals*	*Standard Residuals*		*Percentile*	*2015 Intubation Success*
1	0.67976882	-0.08976882	-0.690737319		1.785714286	0.44
2	0.685160321	0.124839679	0.960594394		5.357142857	0.4923
3	0.689913753	-0.112913753	-0.868828878		8.928571429	0.56
4	0.649548685	-0.029548685	-0.227366025		12.5	0.577
5	0.704043962	0.080056038	0.616001116		16.07142857	0.59
6	0.703819243	0.000880757	0.006777095		19.64285714	0.6
7	0.720156167	-0.227856167	-1.753267545		23.21428571	0.62
8	0.727000352	0.112999648	0.869489812		26.78571429	0.6241
9	0.72946181	-0.16946181	-1.303944918		30.35714286	0.6372
10	0.720225305	0.059774695	0.459943805		33.92857143	0.64
11	0.730459693	-0.040459693	-0.311322127		37.5	0.69
12	0.731862097	0.188137903	1.447650435		41.07142857	0.7047
13	0.73182441	-0.13182441	-1.014339278		44.64285714	0.726
14	0.736852726	0.143147274	1.10146446		48.21428571	0.7274
15	0.737360325	0.191639675	1.474595254		51.78571429	0.74
16	0.740641648	0.086458352	0.665264515		55.35714286	0.78
17	0.741363691	0.138636309	1.066754282		58.92857143	0.7841
18	0.741910796	0.095689204	0.73629245		62.5	0.81
19	0.741421333	0.130178667	1.001675902		66.07142857	0.82
20	0.743638515	-0.003638515	-0.027997007		69.64285714	0.8203
21	0.743641343	-0.103641343	-0.797481175		73.21428571	0.8271
22	0.744883465	-0.018883465	-0.145301166		76.78571429	0.8376
23	0.744772128	0.075527872	0.58115858		80.35714286	0.84
24	0.739036114	0.080963886	0.622986662		83.92857143	0.8716
25	0.750436432	-0.310436432	-2.388691637		87.5	0.88

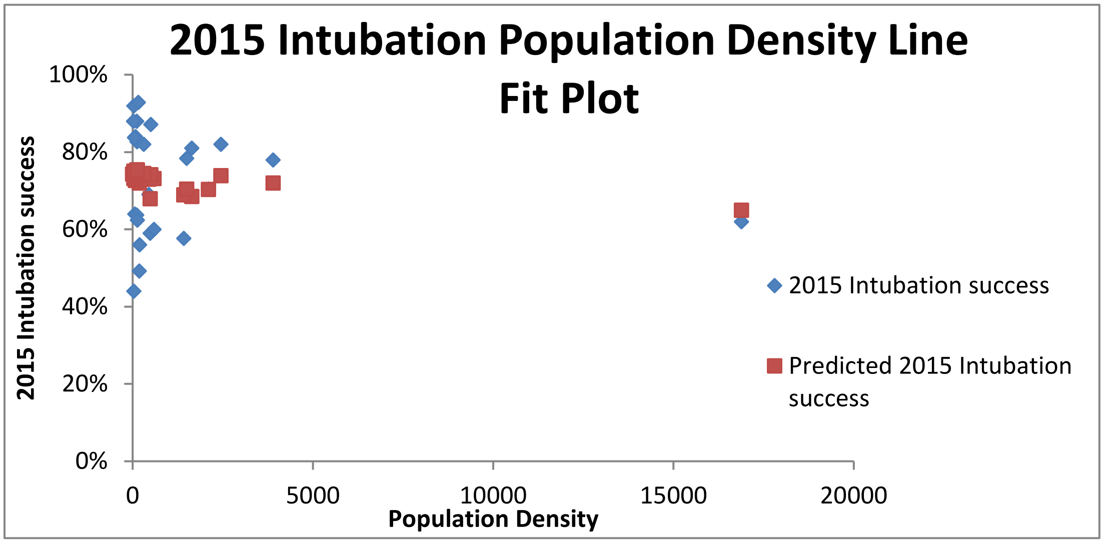
Residual Output **Probability Output**

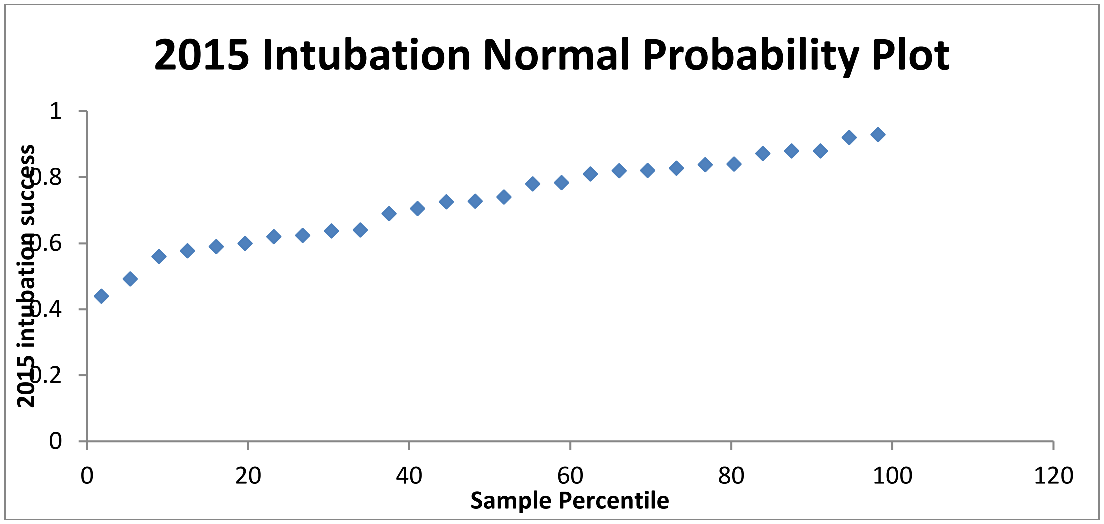
Observation	*Predicted 2015 Intubation Success*	*Residuals*	*Standard Residuals*		*Percentile*	*2015 Intubation Success*
26	0.750614041	-0.023214041	-0.17862332		91.07142857	0.88
27	0.75408051	-0.11688051	-0.899351586		94.64285714	0.92
28	0.754502314	-0.130402314	-1.003396782		98.21428571	0.929

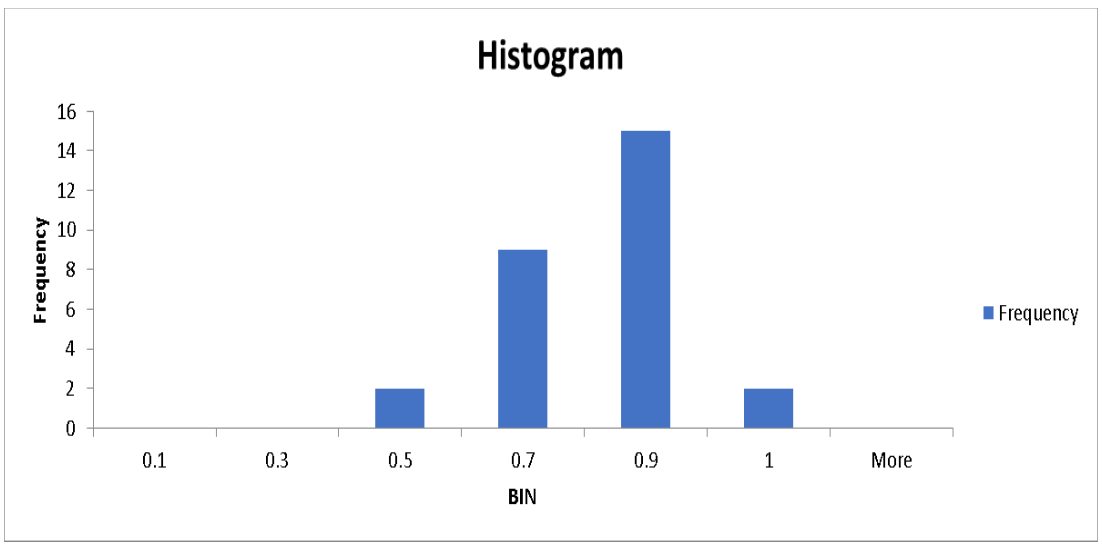

Median Income (2015) Residual Plot
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Residuals
$-
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Median Income (2015)


Population Density Residual Plot
1
0
-1
Residuals
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Population Density


Median Income (2015) Line Fit Plot
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2015 Intubation success
$-
$20,000.00
$40,000.00
$60,000.00
$80,000.00
Median Income (2015)
2015 Intubation success
Predicted 2015 Intubation success


2015 Intubation Population Density Line Fit Plot
100%
80%
60%
40%
20%
0%
2015 Intubation success
0
5000
10000
15000
20000
Population Density
2015 Intubation success
Predicted 2015 Intubation success


2015 Intubation Normal Probability Plot
2015 intubation success
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Sample Percentile


Histogram
Frequency
16
14
12
10
8
6
4
2
0
0.1
0.3
0.5
0.7
0.9
1
More
BIN
Frequency

APPENDIX G. 2016 ORAL TRACHEAL INTUBATION SUCCESS RATES BY LEMSA

<table>
<tr><th colspan="3">Regression Statistics</th></tr>
<tr><td>Multiple R</td><td>0.179310066</td><td rowspan="5">Fitted line plot for median income and 2016 intubation success display a
decreasing linear trend, so the higher the income, the less likely you will have
100% success.
The histogram appears to be normally distributed.
Residuals show an outlier
Y = .750561 - .00000054*Median Income - .000005*Population Density
HO: There is no relationship between the dependent and independent (X and Y) variables

HA: There is a relationship between the dependent and independent variable
α: Reject region = .05
Fail to reject the null hypothesis
Conclude: there is no statistically significant relationship between 2016 intubation
success and median income or population density.</td></tr>
<tr><td>R Square</td><td>0.0321521</td></tr>
<tr><td>Adjusted R Square</td><td>-
0.048501892</td></tr>
<tr><td>Standard Error</td><td>0.109616962</td></tr>
<tr><td>Observations</td><td>27</td></tr>
</table>

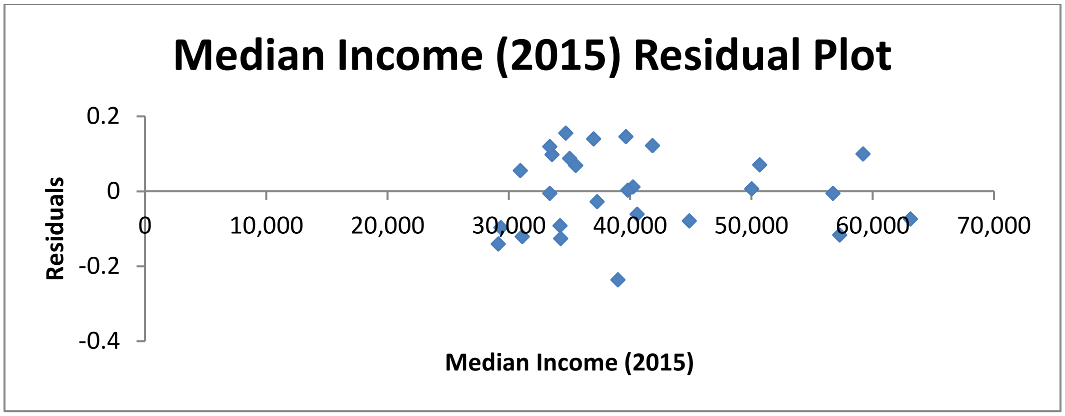
ANOVA

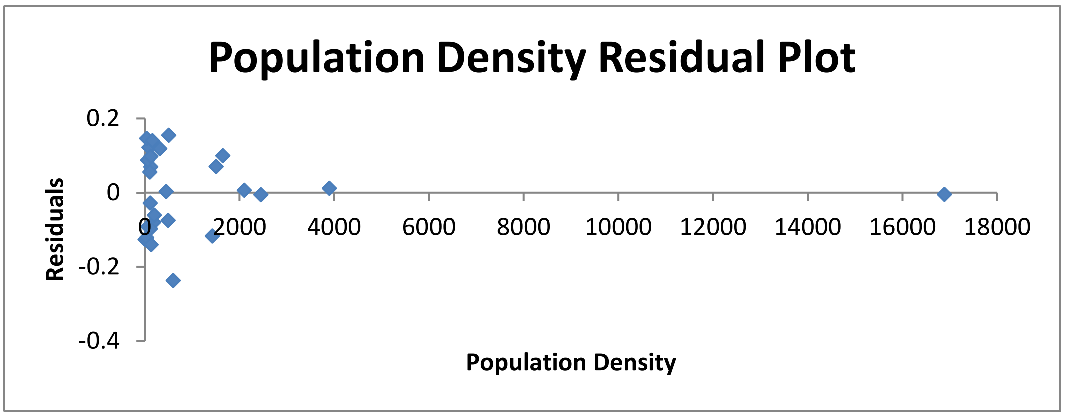
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.009580077	0.004790038	0.398642388	0.675593319
Residual	24	0.288381079	0.012015878		
Total	26	0.297961156			

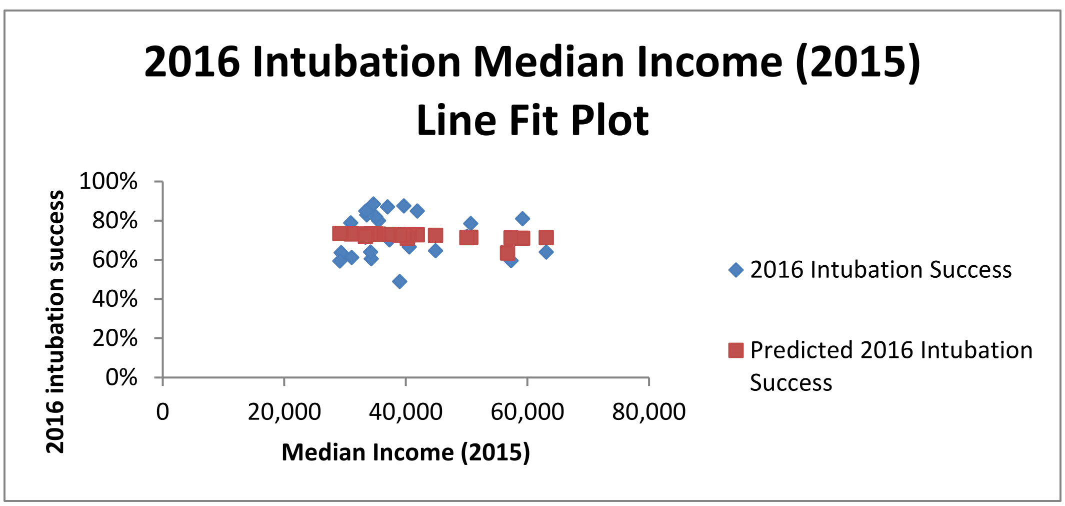
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.750561064	0.098740351	7.601361069	7.70497	0.546770994	0.954351133
Median Income (2015)	-5.36112E-07	2.47261E-06	- 0.216820091	0.830181087	-5.63933E-06	4.56711E-06
Population Density	-5.03728E-06	7.27794E-06	- 0.692129296	0.495498542	-2.00582E-05	9.98366E-06

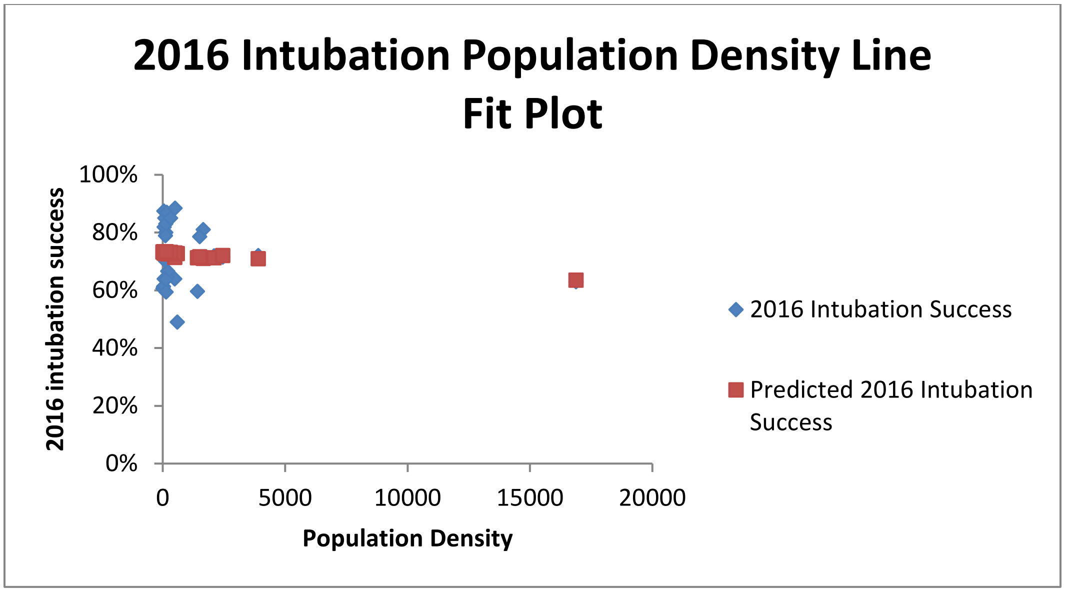
Residual Output **Probability Output**

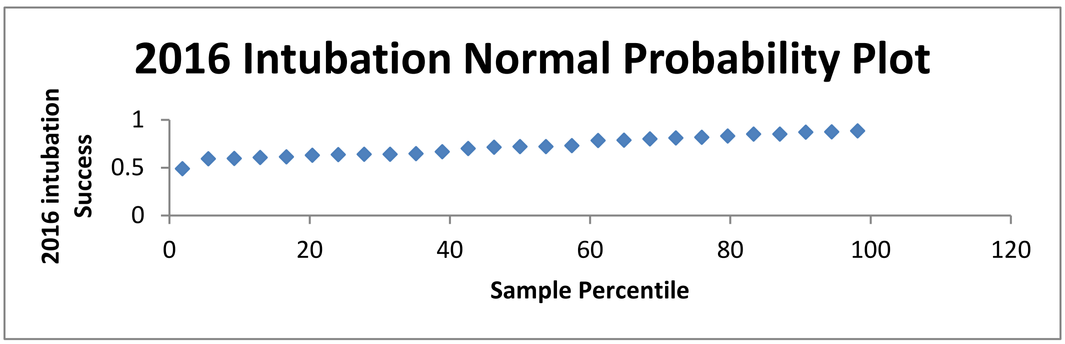
Observation	*Predicted Intubation Success*	*Residuals*	*Standard Residuals*	*Percentile*	*2016 Intubation Success*
1	0.714248696	-0.074248696	-0.705004881	1.851851852	0.49
2	0.710521862	0.099478138	0.944563027	5.555555556	0.5939
3	0.712682611	-0.116482611	-1.10602359	9.259259259	0.5962
4	0.635091663	-0.005091663	-0.04834627	12.96296296	0.6061
5	0.715812022	0.070187978	0.666447628	16.66666667	0.6125
6	0.71314653	0.00645347	0.061276867	20.37037037	0.63
7	0.725565931	-0.079365931	-0.753593958	24.07407407	0.637
8	0.727704924	0.122295076	1.161214	27.77777778	0.64
9	0.727798856	-0.061198856	-0.581094277	31.48148148	0.64
10	0.70933804	0.01166196	0.110732434	35.18518519	0.6462
11	0.726943777	0.003056223	0.029019391	38.88888889	0.6666
12	0.729091022	0.145908978	1.3854323	42.59259259	0.702
13	0.726641803	-0.236641803	-2.246956981	46.2962963	0.7147
14	0.730005685	-0.028005685	-0.265919072	50	0.7196
15	0.729940216	0.140059784	1.329893135	53.7037037	0.721
16	0.730894577	0.069105423	0.656168564	57.40740741	0.73
17	0.73150265	0.08759735	0.831752776	61.11111111	0.786
18	0.729427458	0.155172542	1.47339152	64.81481481	0.7889
19	0.732156684	-0.126056684	-1.196931154	68.51851852	0.8
20	0.731902946	-0.091902946	-0.872635196	72.22222222	0.81
21	0.731935964	0.098064036	0.93113587	75.92592593	0.8191
22	0.731085092	0.118914908	1.129118691	79.62962963	0.83
23	0.720318317	-0.005618317	-0.053346938	83.33333333	0.85
24	0.73368881	-0.12118881	-1.150709807	87.03703704	0.85
25	0.733442763	0.055457237	0.526576561	90.74074074	0.87
26	0.734238953	-0.097238953	-0.92330155	94.44444444	0.875
27	0.734272148	-0.140372148	-1.332859089	98.14814815	0.8846

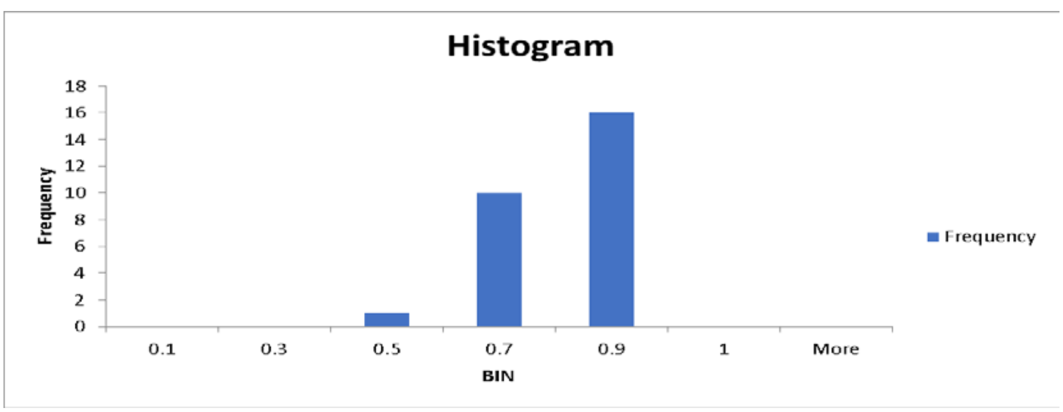

Median Income (2015) Residual Plot
0.2
0
-0.2
-0.4
Residuals
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
Median Income (2015)


Population Density Residual Plot
0.2
0
-0.2
-0.4
Residuals
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Population Density


2016 Intubation Median Income (2015) Line Fit Plot
100%
80%
60%
40%
20%
0%
2016 intubation success
0
20,000
40,000
60,000
80,000
Median Income (2015)
2016 Intubation Success
Predicted 2016 Intubation Success


2016 Intubation Population Density Line Fit Plot
2016 intubation success
100%
80%
60%
40%
20%
0%
0
5000
10000
15000
20000
Population Density
2016 Intubation Success
Predicted 2016 Intubation Success


2016 Intubation Normal Probability Plot
2016 intubation Success
1
0.5
0
0
20
40
60
80
100
120
Sample Percentile


Histogram
Frequency
18
16
14
12
10
8
6
4
2
0
0.1
0.3
0.5
0.7
0.9
1
More
BIN
Frequency

APPENDIX H. 2015 12-LEAD ECG COMPLIANCE BY LEMSA

Regression Statistics		
Multiple R	0.331700299	Residuals show an outlier: which is San Francisco Y = .568343 - .00000585*Median Income - .00000514*Population Density HO: There is no relationship between the dependent and independent (X and Y) variables HA: There is a relationship between the dependent and independent variable α: Reject region = .05 Fail to reject the null hypothesis Conclude: There is no statistically significant relationship between median income, population density, and 2015 12-lead ECG compliance.
R Square	0.110025088	
Adjusted R Square	0.04156548	
Standard Error	0.186186851	
Observations	29	

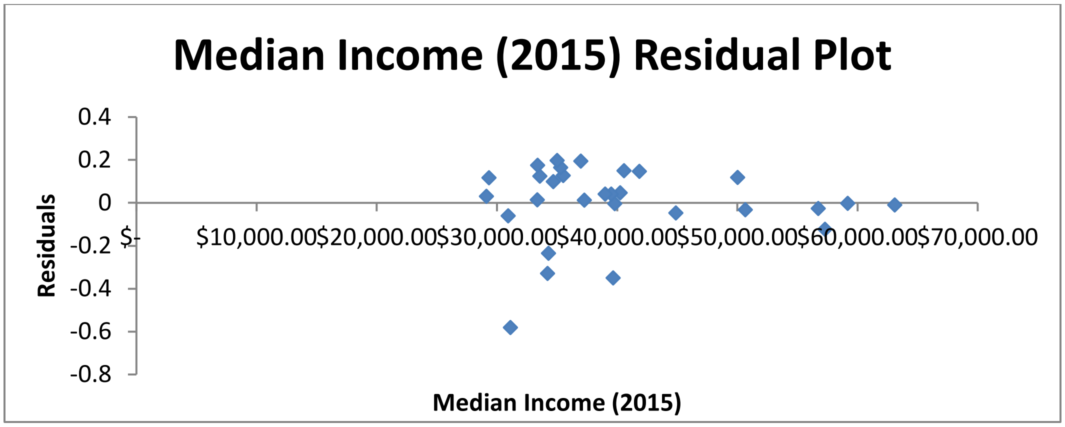
ANOVA

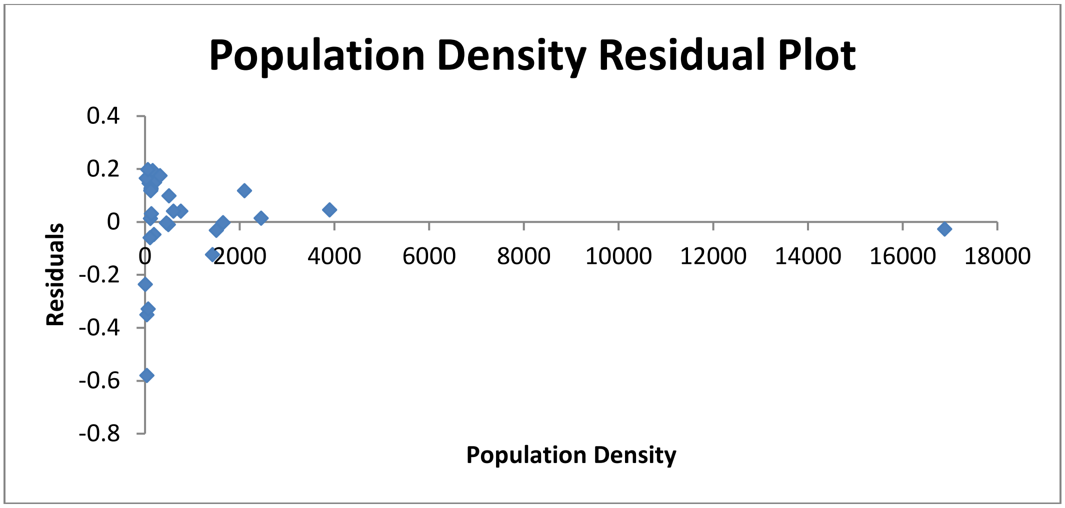
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.111425687	0.055712843	1.607153333	0.219740918
Residual	26	0.901304126	0.034665543		
Total	28	1.012729813			

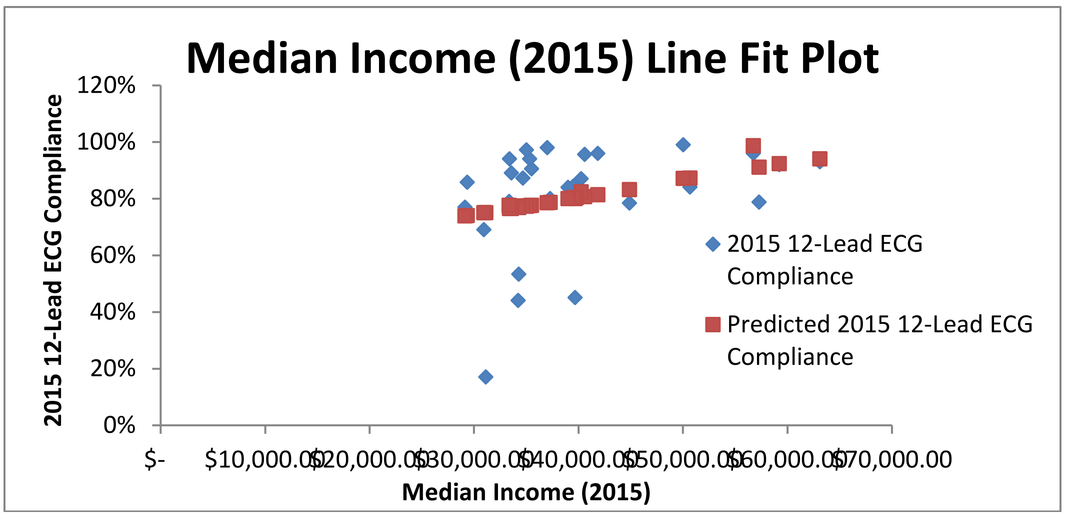
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.568343487	0.166267014	3.418257618	0.002086413	0.226576745	0.91011023
Median Income (2015)	5.84804E-06	4.18658E-06	1.396853104	0.174267678	-2.7576E-06	1.44537E-05
Population Density	5.14002E-06	1.23524E-05	0.416116385	0.680739714	-2.02506E-05	3.05307E-05

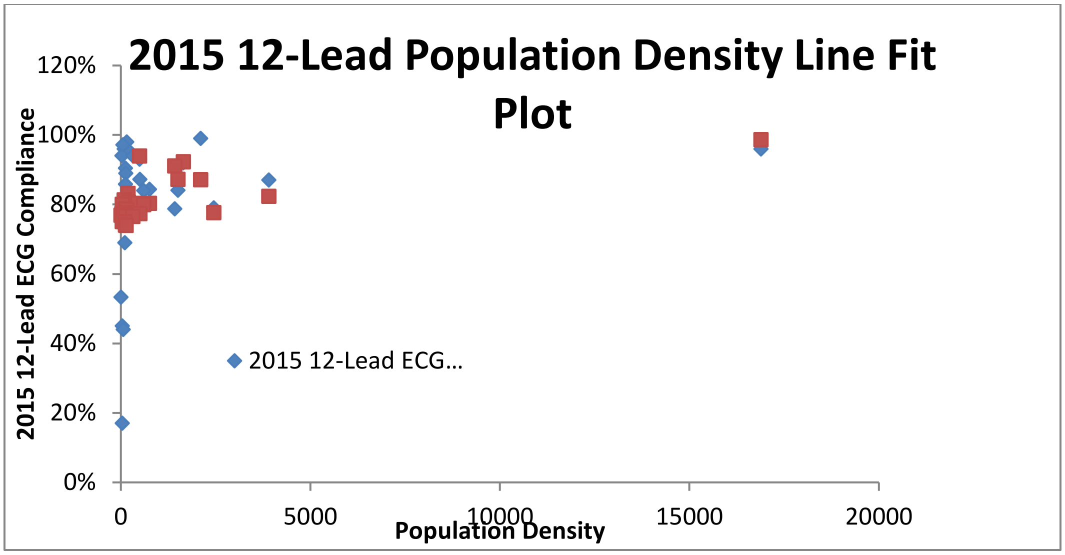
Residual Output **Probability Output**

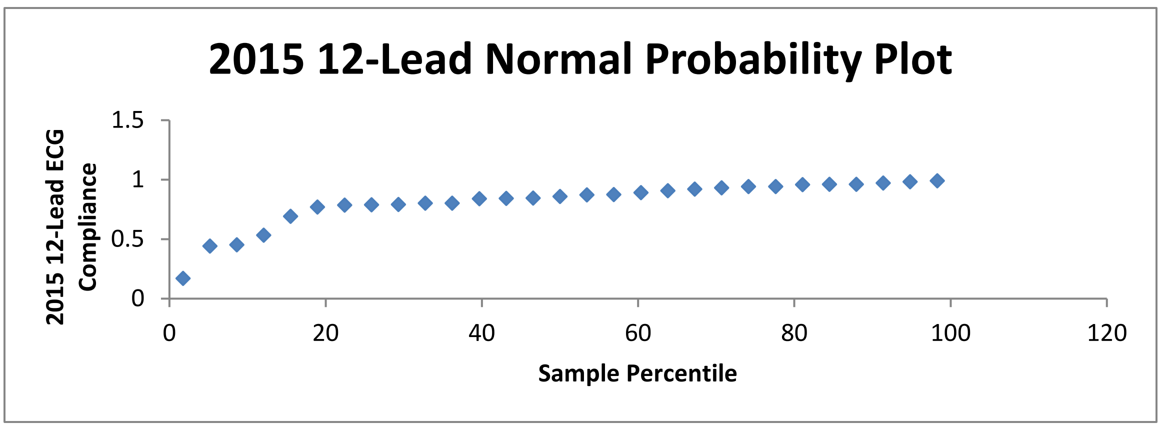
Observation	*Predicted 2015 12-lead ECG compliance*	*Residuals*	*Standard Residuals*	*Percentile*	*2015 12-lead ECG compliance*
1	0.939942404		-0.055415945	1.724137931	0.17
2	0.922975953	-0.002975953	-0.016587057	5.172413793	0.44
3	0.910640926	-0.123540926	-0.688579655	8.620689655	0.45
4	0.986851263	-0.026851263	-0.149660798	12.06896552	0.5332
5	0.872386894	-0.031586894	-0.176055771	15.51724138	0.69
6	0.871735321	0.118264679	0.659171459	18.96551724	0.77
7	0.831746564	-0.047546564	-0.265010129	22.4137931	0.7842
8	0.813517825	0.146482175	0.81644722	25.86206897	0.7871
9	0.806636702	0.149363298	0.832505727	29.31034483	0.79
10	0.823735343	0.046264657	0.257865169	32.75862069	0.8
11	0.803416853	-0.009942404	-0.019044505	36.20689655	0.8
12	0.800504875	-0.350504875	-1.953607884	39.65517241	0.84
13	0.803309458	0.040590542	0.226239372	43.10344828	0.8408
14	0.79943118	0.04056882	0.226118298	46.55172414	0.8439
15	0.786902175	0.013097825	0.073003306	50	0.8581
16	0.785442292	0.194557708	1.084405666	53.44827586	0.87
17	0.776668578	0.128031422	0.713608319	56.89655172	0.8723
18	0.774933745	0.165066255	0.920029251	60.34482759	0.89
19	0.773390183	0.198309817	1.105318784	63.79310345	0.9047
20	0.773767916	0.098532084	0.549187957	67.24137931	0.92
21	0.768843539	-0.235643539	-1.313405629	70.68965517	0.93
22	0.76871336	-0.32871336	-1.832148585	74.13793103	0.94
23	0.765234021	0.124765979	0.695407731	77.5862069	0.94
24	0.765137467	0.174862533	0.974630732	81.03448276	0.956
25	0.77609205	0.01390795	0.077518698	84.48275862	0.96
26	0.750452679	-0.580452679	-3.235267211	87.93103448	0.96
27	0.749834382	-0.059834382	-0.333498702	91.37931034	0.9717
28	0.740463494	0.117636506	0.655670213	94.82758621	0.98
29	0.739292558	0.030707442	0.171153972	98.27586207	0.99

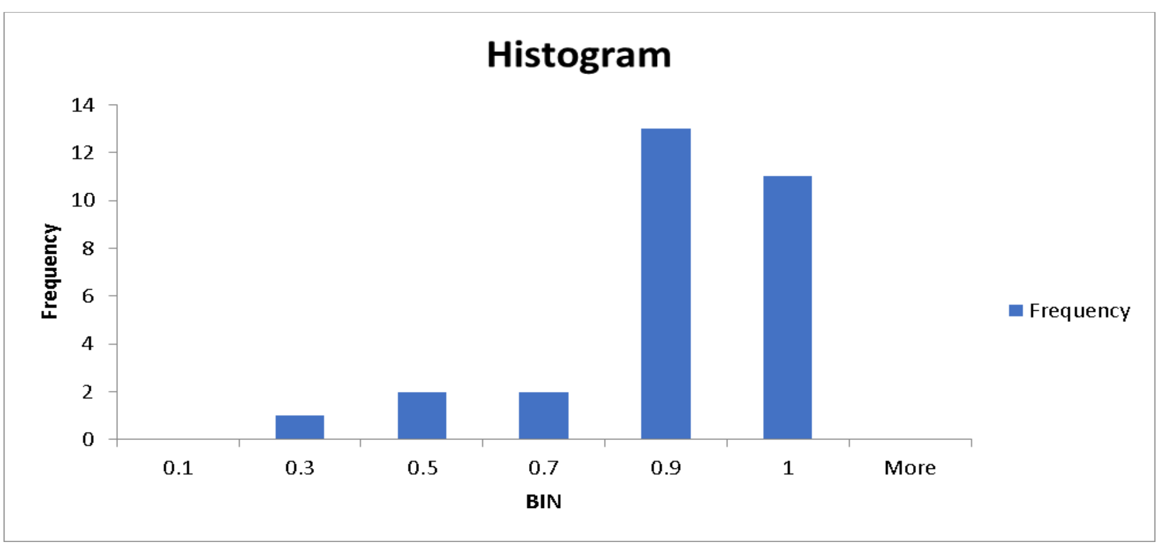

Median Income (2015) Residual Plot
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Residuals
$-
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Median Income (2015)


Population Density Residual Plot
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Residuals
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Population Density


Median Income (2015) Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
2015 12-Lead ECG Compliance
$-
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Median Income (2015)
2015 12-Lead ECG Compliance
Predicted 2015 12-Lead ECG Compliance


2015 12-Lead Population Density Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
2015 12-Lead ECG Compliance
2015 12-Lead ECG...
0
5000
10000
15000
20000
Population Density


2015 12-Lead Normal Probability Plot
1.5
1
0.5
0
2015 12-Lead ECG Compliance
0
20
40
60
80
100
120
Sample Percentile


Histogram
14
12
10
8
6
4
2
0
Frequency
0.1
0.3
0.5
0.7
0.9
1
More
BIN
Frequency

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APPENDIX I. 2016 12-LEAD ECG COMPLIANCE BY LEMSA

Regression Statistics		
Multiple R	0.327300985	Residuals show an outlier: which is San Francisco
R Square	0.107125935	Y = .466867 - .00000868*median income - .0000016*population density
Adjusted R Square	0.03569601	
Standard Error	0.239379565	HO: There is no relationship between the dependent and independent (X and Y) variables
Observations	28	HA: There is a relationship between the dependent and independent variable. α: Reject region = .05 Fail to reject the null hypothesis Conclude: there is no statistically significant relationship between 2016 12-lead ECG compliance.

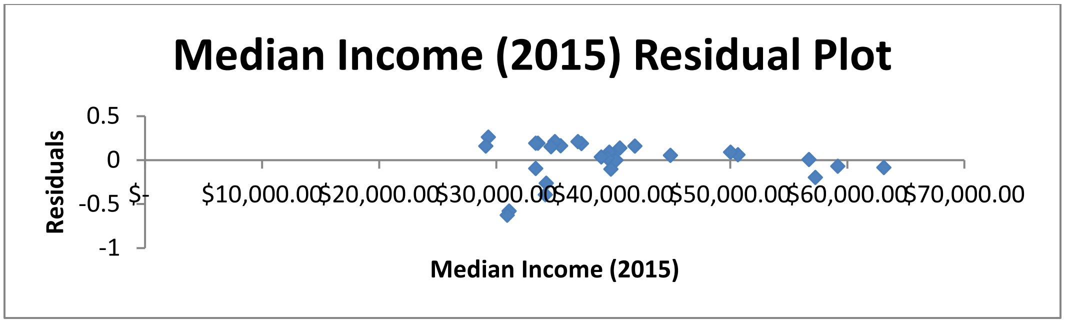
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.171877319	0.08593866	1.499734663	0.242592632
Residual	25	1.432564402	0.057302576		
Total	27	1.604441721			

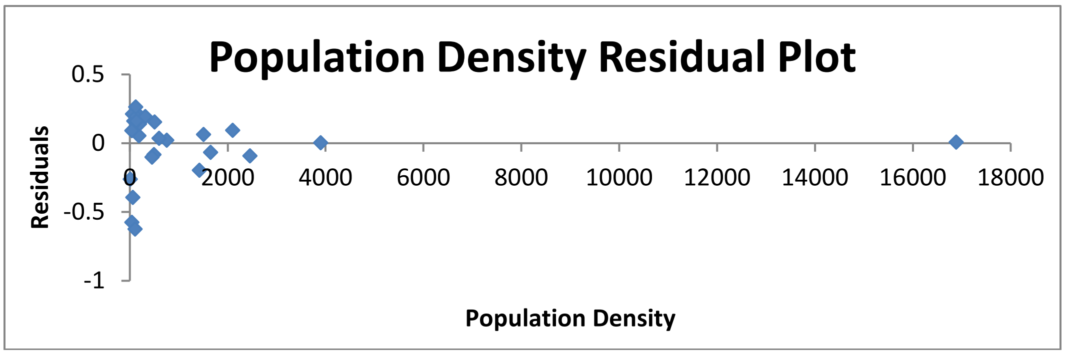
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.466866893	0.215366099	2.167782652	0.039899225	0.023312109	0.910421676
Median Income (2015)	8.68439E-06	5.39953E-06	1.608361217	0.120313363	-2.43614E-06	1.98049E-05
Population Density	-1.62022E-06	1.58889E-05	-0.101971921	0.91959246	-3.43441E-05	3.11036E-05

Residual Output Probability Output

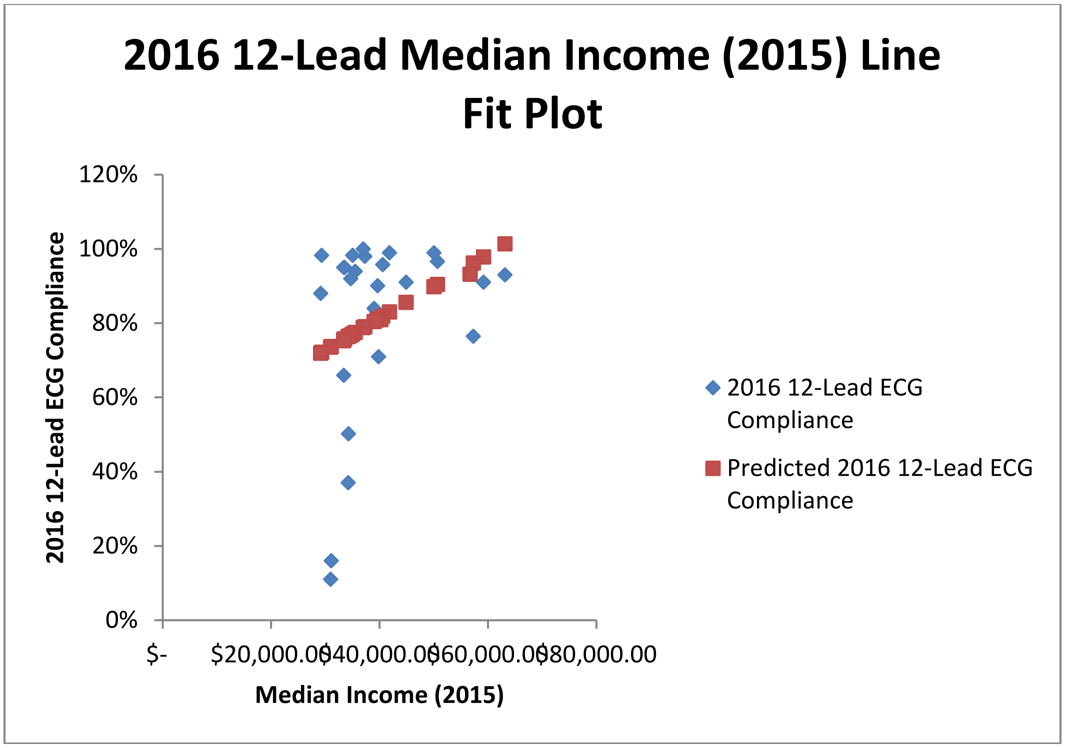
Observation	*Predicted 2015 12-lead ECG Compliance*	*Residuals*	*Standard Residuals*	*Percentile*	*2015 12-lead ECG Compliance*
1	1.014141678	-0.084141678	-0.365288479	1.785714286	0.11
2	0.978241893	-0.068241893	-0.296261947	5.357142857	0.16
3	0.96201149	-0.19711149	-0.855729974	8.928571429	0.37
4	0.932103633	0.007896367	0.034280894	12.5	0.502
5	0.904438981	0.061561019	0.267257935	16.07142857	0.66
6	0.89794869	0.09205131	0.39962696	19.64285714	0.71
7	0.856304106	0.054095894	0.234849212	23.21428571	0.7649
8	0.830182482	0.159817518	0.693823789	26.78571429	0.812
9	0.818875952	0.138524048	0.60138138	30.35714286	0.8306
10	0.810033048	0.001966952	0.008539229	33.92857143	0.84
11	0.811763446	-0.101763446	-0.441790741	37.5	0.88
12	0.811249572	0.089850428	0.390072161	41.07142857	0.9011
13	0.808807405	0.021792595	0.094609284	44.64285714	0.91
14	0.804492285	0.035507715	0.154151422	48.21428571	0.9104
15	0.790375946	0.189524054	0.822790259	51.78571429	0.92
16	0.787804121	0.212195879	0.921216587	55.35714286	0.93
17	0.775079149	0.164920851	0.715979144	58.92857143	0.94
18	0.770833919	0.212266081	0.921521359	62.5	0.94
19	0.767259629	0.152740371	0.663099418	66.07142857	0.95
20	0.764562859	-0.262562859	-1.139877279	69.64285714	0.95
21	0.763831153	-0.393831153	-1.709758896	73.21428571	0.9574
22	0.758084834	0.191915166	0.833170914	76.78571429	0.966
23	0.756199211	0.193800789	0.841357065	80.35714286	0.9799
24	0.75268297	-0.09268297	-0.402369214	83.92857143	0.9831
25	0.736940541	-0.576940541	-2.504700844	87.5	0.9831
26	0.735408881	-0.625408881	-2.715118871	91.07142857	0.99
27	0.72136562	0.26173438	1.13628056	94.64285714	0.99
28	0.719476508	0.160523492	0.696888671	98.21428571	1

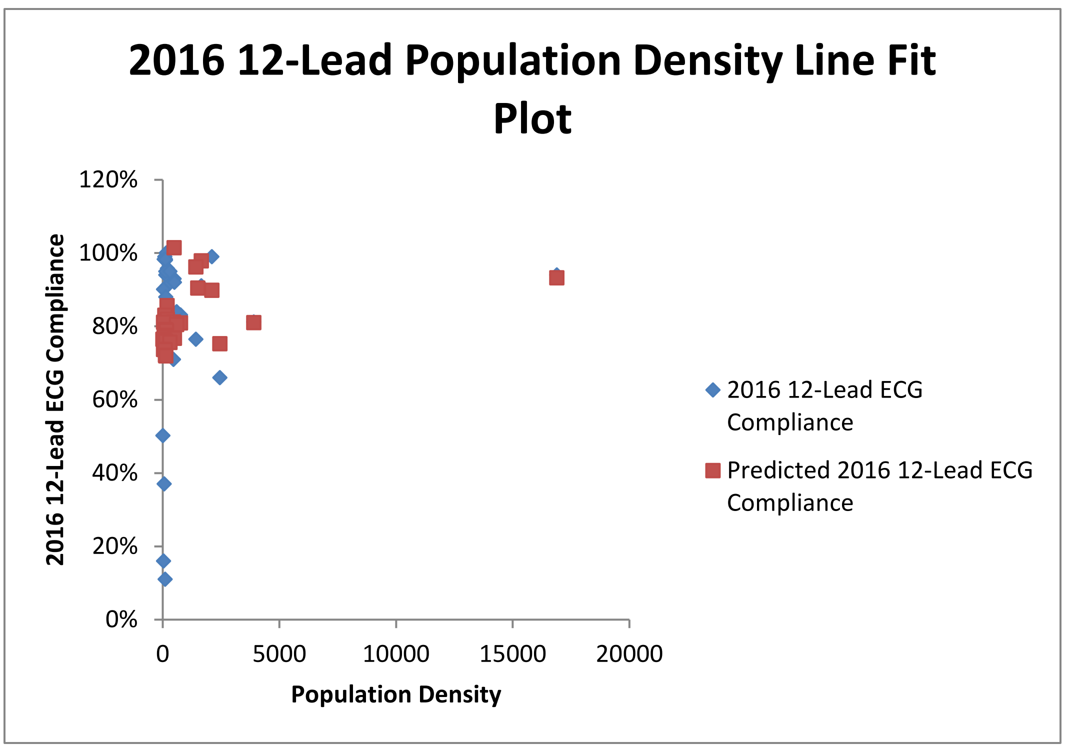


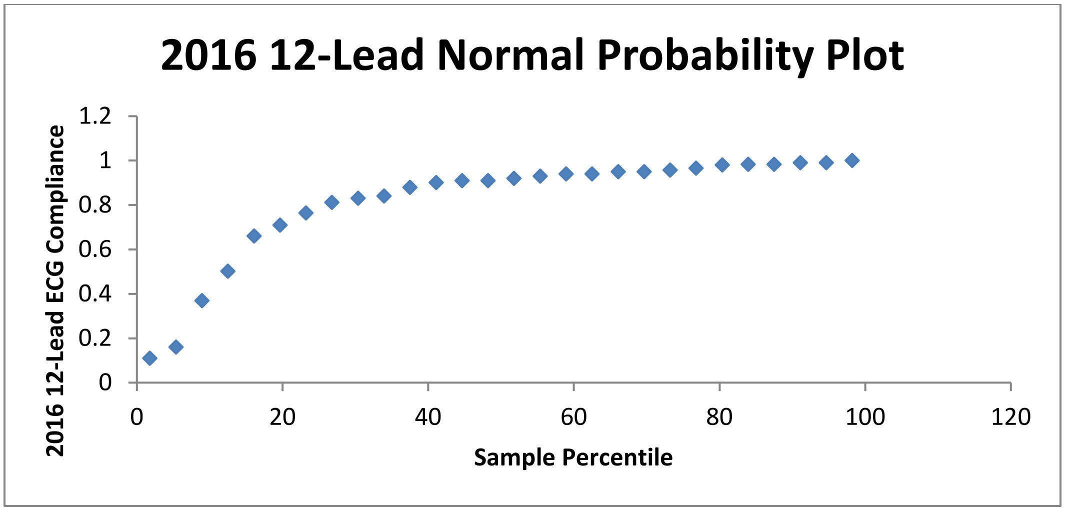
Median Income (2015) Residual Plot
Residuals
0.5
0
-0.5
-1
$-
$10,000.00
$20,000.00
$30,000.00
$40,000.00
$50,000.00
$60,000.00
$70,000.00
Median Income (2015)

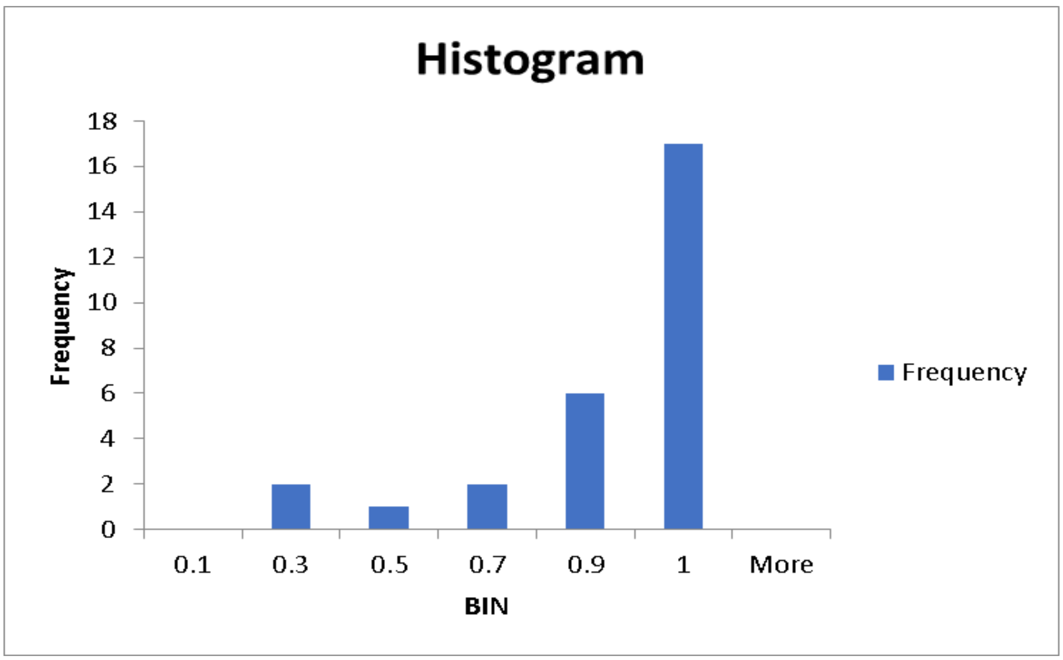


Population Density Residual Plot
Residuals
0.5
0
-0.5
-1
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Population Density


2016 12-Lead Median Income (2015) Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
2016 12-Lead ECG Compliance
$-
$20,000.00
$40,000.00
$60,000.00
$80,000.00
Median Income (2015)
2016 12-Lead ECG Compliance
Predicted 2016 12-Lead ECG Compliance


2016 12-Lead Population Density Line Fit Plot
120%
100%
80%
60%
40%
20%
0%
2016 12-Lead ECG Compliance
0
5000
10000
15000
20000
Population Density
2016 12-Lead ECG Compliance
Predicted 2016 12-Lead ECG Compliance


2016 12-Lead Normal Probability Plot
2016 12-Lead ECG Compliance
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Sample Percentile


Histogram
Frequency
18
16
14
12
10
8
6
4
2
0
0.1
0.3
0.5
0.7
0.9
1
More
BIN
Frequency

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APPENDIX J. CARDIAC ARREST SURVIVAL T-TEST (GROUP A CALIFORNIA GROUP B LONDON AMBULANCE)

London Ambulance Service 2016 Patient Characteristics, Response Times, and Outcomes[126]	Number of Patients	+Survived to Discharge
Barking & Dagenham	101	5.9%(6/101)
Barnet	200	4.6%(9/196)
Bexley	141	7.9%(11/139)
Brent	193	6.7%(13/193)
Bromley	162	10.1%(16/158)
Camden	129	13.2%(17/129)
Central London	139	15.0%(20/133)
City & Hackney	148	12.4%(18/146)
Croydon	195	8.6%(16/186)
Ealing	175	7.0%(12/173)
Enfield	183	9.4%(17/181)
Greenwich	138	8.9%(12/135)
Hammersmith & Fulham	89	13.6%(12/88)
Haringey	122	12.5%(15/120)
Harrow	130	18.5%(24/130)
Havering	157	7.2%(11/152)
Hillingdon	154	7.8%(12/153)
Hounslow	126	11.3%(14/124)
Islington	117	10.4%(12/115)
Kingston	83	6.1%(5/82)
Lambeth	167	10.4%(17/163)
Lewisham	130	10.2%(13/128)
Merton	85	13.3%(11/83)
Newham	149	7.7%(9/142)

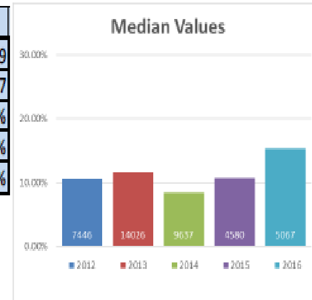
126 Source: London Ambulance Service, *Cardiac Arrest Annual Report: 2016/2017*.

London Ambulance Service 2016 Patient Characteristics, Response Times, and Outcomes[126]	Number of Patients	+Survived to Discharge
Redbridge	160	11.1%(17/153)
Richmond	94	6.8%(7/91)
Southwark	142	7.9%(11/140)
Sutton	115	12.4%(14/113)
Tower Hamlets	118	11.4%(13/114)
Waltham Forest	154	5.9%(9/152)
Wandsworth	119	6.9%(8/116)
West London	118	12.3%(14/114)

	2016 Value	2016 Denom.
Los Angeles County	29.71%	2376
*Contra Costa County	28.90%	76
*San Luis Obispo County	26.00%	58
*Riverside County	19.00%	562
*Ventura County	15.40%	272
*Santa Barbara County	14.00%	208
*San Francisco	10.00%	493
*Alameda County	9.16%	960
*Napa County	6.45%	62
Central California		
*Coastal Valleys		
El Dorado County		
Imperial County		
Inland Counties		
*Kern County		
Marin County		
Merced County		
*Monterey County		
Mountain Valley		
North Coast		
Northern California		
Orange County		
Sacramento County		
San Benito County		
*San Diego County		
San Joaquin County		
*San Mateo County		
Santa Clara County		
*Santa Cruz County		
Sierra-Sacramento Valley		
Solano County		
Tuolumne County		
Yolo County		

An (*) denotes LEMSAs participating in the CARES Registry
Empty grey cells indicate no value reported

Measure ID	CAR-4
Response Count	9
Denominator Total	5067
Submission Rate (n=33)	30.30%
Average	17.62%
Median	15.40%



Of the 9 LEMSAs reporting these data for 2016, the median percentage of patients that had survived an out of hospital cardiac arrest and were discharged from the hospital was 15.40%. This measure yielded the lowest number of responses from LEMSAs because of the difficulties in obtaining hospital outcome data. Values vary widely, depending on multiple factors. Accurate measure of this outcome is an important future quality improvement goal and supports the need to develop exchange of health information with hospitals. The California summary data from the CARES registry show the hospital discharge rate for OOHCA at 10.5% with the national average of 10.3%. Values for a particular system should be used to track improvements. An important refinement to this measure is the functional status on discharge.

2016 Out Of Hospital Cardiac Arrest Survival to Hospital Discharge by California LEMSA[127]

[127] Source: Core Measures 2016 Data.

Data Summary			
	A	B	Total
n	9	32	41
- ΣX	146.81000(	313.39999(	460.20999(
- ΣX^2	2827.6881	3375.6799(	6203.3681
SS	432.8908	306.3188	1037.6792
mean	16.3122	9.7937	11.2246

Results

$Mean_a - Mean_b$	t	df
6.5185	+3.97	39

P		
P	one-tailed	0.00015
	two-tailed	0.000300

For independent samples, these results pertain to the "usual" t-test, which assumes that the two samples have equal variances.

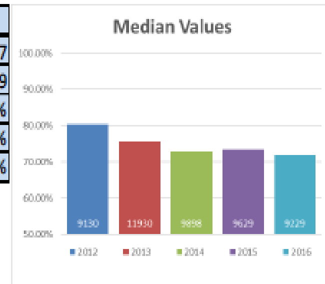
Cardiac Arrest Survival t-Test (Group A: California Group B: London Ambulance)

APPENDIX K. INTUBATION SUCCESS RATE T-TEST: CALIFORNIA AND LONDON AMBULANCE SERVICE

	2016 Value	2016 Denom.
San Joaquin County	88.46%	338
San Benito County	87.50%	8
Santa Barbara County	87.00%	82
Riverside County	85.00%	1201
San Luis Obispo County	85.00%	74
Monterey County	83.00%	
Sierra-Sacramento Valley	81.91%	398
San Mateo County	81.00%	374
Mountain Valley	80.00%	125
Kern County	78.89%	595
Contra Costa County	78.60%	300
Ventura County	73.00%	63
Orange County	72.10%	315
Alameda County	71.96%	756
Los Angeles County	71.47%	1360
Coastal Valleys	70.21%	47
Yolo County	66.66%	18
Napa County	64.62%	65
Inland Counties	64.00%	1491
Marin County	64.00%	85
Central California	63.70%	460
San Francisco	63.00%	308
North Coast	61.25%	160
Northern California	60.61%	33
Santa Clara County	59.62%	208
Merced County	59.39%	293
Santa Cruz County	49.00%	72
El Dorado County		
Imperial County		
Sacramento County		
San Diego County		
Solano County		
Tuolumne County		

Empty grey cells indicate no value reported

Measure ID	SKL-1
Response Count	27
Denominator Total	9229
Submission Rate (n=33)	84.85%
Average	72.26%
Median	71.96%



Of the 27 LEMSAs reporting these data for 2016, the median percentage of successful endotracheal intubations (within 2 attempts) was 71.96% Endotracheal intubation success rate by paramedics in the field vary widely from 49.00-88.46% with an average of 72.26%, depending on methods, population and protocol.

Other methods of airway management have recently been shown to be as effective as intubation. It is important to monitor this measure to verify skill maintenance, especially at a time when endotracheal intubation is being used less often.

2016 California Intubation Success Rate by LEMSA[128]

128 Source: Core Measures 2015 Data.

Cardiac Arrest Monthly Report

5. Usage of advanced airway devices

Station Group	Number of patients*	Advanced airway device utilised successfully**		End-Tidal CO_2 measured				$EtCO_2$ not measured (no reading or trace)	
				Reading and/or $EtCO_2$ trace		Reading with no $EtCO_2$ trace			
	n	n	%	n	%	n	%	n	%
Homerton	14	12	86%	10	83%	2	17%	0	0%
Newham	30	26	87%	24	92%	2	8%	0	0%
Romford	27	22	81%	18	82%	4	18%	0	0%
North East	**71**	**60**	**85%**	**52**	**87%**	**8**	**13%**	**0**	**0%**
Camden	20	20	100%	17	85%	3	15%	0	0%
Edmonton	34	31	91%	25	81%	6	19%	0	0%
Friern Barnet	17	17	100%	14	82%	3	18%	0	0%
North Central	**71**	**68**	**96%**	**56**	**82%**	**12**	**18%**	**0**	**0%**
Brent	30	25	83%	24	96%	1	4%	0	0%
Fulham †	17	16	94%	14	88%	2	13%	0	0%
Hanwell	26	22	85%	18	82%	4	18%	0	0%
Hillingdon	19	18	95%	16	89%	2	11%	0	0%
Westminster	6	6	100%	5	83%	1	17%	0	0%
North West	**98**	**87**	**89%**	**77**	**89%**	**10**	**11%**	**0**	**0%**
Bromley †	18	16	89%	10	63%	6	38%	0	0%
Deptford	38	35	92%	25	71%	10	29%	0	0%
Greenwich	32	27	84%	23	85%	4	15%	0	0%
South East	**88**	**78**	**89%**	**58**	**74%**	**20**	**26%**	**0**	**0%**
Croydon	14	13	93%	11	85%	2	15%	0	0%
New Malden	12	11	92%	10	91%	1	9%	0	0%
St Helier	8	7	88%	7	100%	0	0%	0	0%
Wimbledon †	14	13	93%	8	62%	4	31%	1	8%
South West	**48**	**44**	**92%**	**36**	**82%**	**7**	**16%**	**1**	**2%**
PAS and VAS	1	1	100%	1	100%	0	0%	0	0%
Other LAS $	28	28	100%	20	71%	8	29%	0	0%
LAS-Wide	**405**	**366**	**90%**	**300**	**82%**	**65**	**18%**	**1**	**<1%**

Key:
† Percentages do not equal 100% due to rounding.
$ Training, Hazardous Area Response, Special Events and Tactical Response Units are reported as "Other LAS".

2018 London Ambulance Service Intubation Success Rate by LAS Station Group[129]

129 Source: London Ambulance Service, *Cardiac Care Pack 2016–2017*.

t-Test: Independent or Correlated Samples

Data Summary

	A	B	Total
n	27	20	47
$\sum X$	1950.95	1833	3783.95
$\sum X^2$	143950.159	168729	312679.159
SS	2979.5705	734.55	8034.9552
mean	72.2574	91.65	80.5096

Results

$Mean_a - Mean_b$	t	df	P one-tailed	P two-tailed
-19.3926	-7.24	45	<.0001	<.0001

Intubation Success Rate t-test (Group A: California, Group B: London Ambulance Service)

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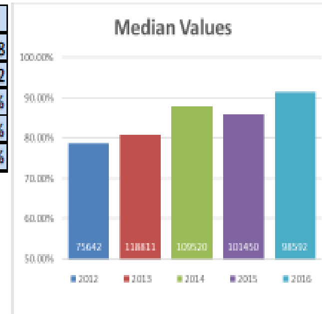
APPENDIX L. TWELVE-LEAD ECG COMPLIANCE T-TEST, CALIFORNIA AND LONDON AMBULANCE SERVICE

	2016 Value	2016 Denom.
Santa Barbara County	100.00%	89
Alameda County	99.00%	3698
San Luis Obispo County	99.00%	542
Central California	98.31%	5568
Sierra-Sacramento Valley	98.31%	4251
Coastal Valleys	97.99%	1142
Contra Costa County	96.60%	3511
Yolo County	95.74%	774
Monterey County	95.00%	
Riverside County	95.00%	9287
Mountain Valley	94.00%	1927
San Francisco	94.00%	2767
Marin County	93.00%	583
San Joaquin County	92.00%	2776
Napa County	91.04%	569
San Mateo County	91.00%	1877
San Benito County	90.11%	91
Merced County	88.00%	2436
Santa Cruz County	84.00%	901
San Diego County	83.06%	11058
Orange County	81.20%	2185
Santa Clara County	76.49%	3173
Ventura County	71.00%	1846
Los Angeles County	66.00%	16544
Northern California	50.20%	512
Inland Counties	37.00%	14476
North Coast	16.00%	1278
Kern County	11.00%	4731
El Dorado County		
Imperial County		
Sacramento County		
Solano County		
Tuolumne County		

Empty grey cells indicate no value reported

Measure ID	ACS-2
Response Count	28
Denominator Total	98592
Submission Rate (n=33)	87.88%
Average	81.57%
Median	91.52%



Of the 28 LEMSAs reporting these data for 2016, the median number of patients receiving 12-Lead ECG in the field for complaints of chest pain or discomfort suggestive of cardiac origin was 91.52%.

The reported values for this measure ranged greatly from 11-100%, but there was moderate consistency in this measure with most LEMSAs reporting 80-100% compliance. Low values more likely represent data and methodological issues rather than actual performance. This measure is of importance with the widespread development of STEMI centers. Field EKG for chest pain or cardiac concerns represents a patient-centered practice that is in line with national guidelines and recommendations. It is now standard of care to perform prehospital 12 lead ECG with interpretation in the field to identify STEMI patients. The draft STEMI regulations define "STEMI Patient" as one with characteristic symptoms of myocardial ischemia in association with persistent ST-Segment Elevation in ECG and that "The STEMI system policies shall address ... identification of STEMI patients through the use of pre-hospital 12-lead ECG..." The American Heart Association has stated that the national goal is for consistent recording and analysis of "in the field ECG." Thirty of 33 LEMSAs have developed STEMI systems and currently include field ECG in their management protocol.

2016 ACS Prehospital 12-lead ECG Compliance by California LEMSA[130]

[130] Source: Core Measures 2015 Data.

2. Care Bundle provision and ECG strips submission

Group Station	Number of patients	Full Care Bundle (or exceptions*)		Aspirin & GTN given		Analgesia given		Two pain assessments made		ECG strips submitted	
		n	%	n	%	n	%	n	%	n	%
Homerton	**16**	9	56%	15	94%	11	69%	15	94%	14	88%
Newham	**22**	15	68%	20	91%	17	77%	21	95%	20	91%
Romford	**19**	15	79%	18	95%	16	84%	19	100%	18	95%
North East	**57**	39	68%	53	93%	44	77%	55	96%	52	91%
Camden	**15**	10	67%	15	100%	11	73%	14	93%	14	93%
Edmonton	**17**	15	88%	17	100%	15	88%	17	100%	17	100%
Friern Barnet	**16**	10	63%	15	94%	12	75%	14	88%	14	88%
North Central	**48**	35	73%	47	98%	38	79%	45	94%	45	94%
Brent	**37**	33	89%	37	100%	33	89%	37	100%	37	100%
Fulham	**19**	12	63%	16	84%	14	74%	19	100%	18	95%
Hanwell	**13**	9	69%	13	100%	9	69%	12	92%	13	100%
Hillingdon	**9**	8	89%	9	100%	8	89%	9	100%	8	89%
Westminster	**9**	5	56%	9	100%	5	56%	9	100%	9	100%
North West	**87**	67	77%	84	97%	69	79%	86	99%	85	98%
Bromley	**16**	14	88%	16	100%	14	88%	16	100%	16	100%
Deptford	**25**	17	68%	24	96%	18	72%	25	100%	25	100%
Greenwich	**18**	12	67%	17	94%	14	78%	17	94%	16	89%
South East	**59**	43	73%	57	97%	46	78%	58	98%	57	97%
Croydon	**9**	8	89%	9	100%	8	89%	9	100%	9	100%
New Malden	**8**	6	75%	8	100%	6	75%	8	100%	8	100%
St Helier	**13**	11	85%	12	92%	12	92%	12	92%	12	92%
Wimbledon	**10**	10	100%	10	100%	10	100%	10	100%	10	100%
South West	**40**	35	88%	39	98%	36	90%	39	98%	39	98%
PAS & VAS	**6**	5	83%	6	100%	5	83%	6	100%	6	100%
Other LAS $	**12**	9	75%	11	92%	11	92%	11	92%	12	100%
LAS-Wide	**309**	**233**	**75%**	**297**	**96%**	**249**	**81%**	**300**	**97%**	**296**	**96%**

Key:
* Valid exceptions are taken from UK Ambulance Services Clinical Practice Guidelines and LAS policy. Certain exceptions used by the LAS differ from those used nationally, therefore there may be a difference between locally and nationally reported figures.
$ Training, Hazardous Area Response, Special Events and Tactical Response Units are reported as "Other LAS".

2018 London Ambulance Service ECG strip submission rate by LAS Group Station[131]

131 Source: London Ambulance Service, *Cardiac Care Pack 2016–2017*.

Data Summary			
	A	B	Total
n	28	25	53
- ΣX	2283.56	2398	4681.5599
- ΣX^2	202286.997	230508	432794.997
SS	16049.6303	491.84	19266.6192
mean	81.5557	95.92	88.3313

Results

$Mean_a - Mean_b$	t	df
-14.3643	-2.9	51

P		
	one-tailed	0.0027465
	two-tailed	0.005493

12-lead ECG for suspected acute coronary syndromes compliance t-test.
(Group A: California, Group B: London Ambulance Service)

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APPENDIX M. DIRECT TRANSPORT TO STEMI-RECEIVING CENTER FOR STEMI PATIENTS: T-TEST FOR CALIFORNIA AND LONDON AMBULANCE SERVICE

	2016 Value	2016 Denom.
Marin County	100.00%	68
Santa Barbara County	100.00%	189
Santa Clara County	100.00%	224
San Diego County	99.86%	721
San Luis Obispo County	99.00%	120
Napa County	98.86%	88
Alameda County	98.00%	603
Orange County	97.80%	138
San Mateo County	97.00%	270
Yolo County	96.58%	117
Ventura County	96.10%	154
Santa Cruz County	96.00%	46
Sierra-Sacramento Valley	95.51%	312
Los Angeles County	94.66%	543
Monterey County	93.00%	
Central California	92.75%	207
Riverside County	84.00%	1418
Inland Counties	83.00%	739
Kern County	82.35%	17
Merced County	78.49%	2436
Northern California	65.22%	23
San Francisco	64.00%	217
San Benito County	40.00%	15
Contra Costa County	12.47%	3511
Coastal Valleys	0.00%	272
Mountain Valley	0.00%	206
El Dorado County		
Imperial County		
North Coast		
Sacramento County		
San Joaquin County		
Solano County		
Tuolumne County		

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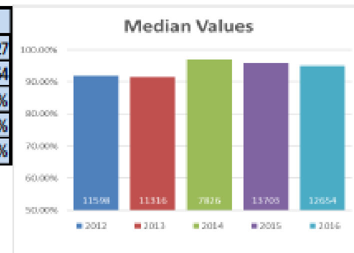
Measure ID	ACS-5
Response Count	27
Denominator Total	12654
Submission Rate (n=33)	84.85%
Average	79.41%
Median	95.09%



Of the 27 LEMSAs reporting these data for 2016, the median percentage of patients appropriately transported directly to a STEMI center was 95.09%, consistent with median in 2015.

Direct transport of patients to a STEMI centers with percutaneous coronary intervention (PCI) capability will vary by geography and availability of resources in a given area. Lower values would be expected in a rural area that may not have an established STEMI system or one that can be accessed rapidly in a neighboring LEMSA.

Several LEMSAs with measures below 90% have well-developed STEMI systems, implying poor data quality or potential protocol violations.

27 of 33 LEMSAs have STEMI Receiving Center.

Direct Transport to Designated STEMI Receiving Center for Suspected STEMI Patients by California LEMSA[132]

[132] Source: Core Measures 2015 Data.

3. Patient destination

Group Station	Number of patients	Direct to Heart Attack Centre		A&E			
				With valid reason		Without valid reason	
		n	%	n	%	n	%
Homerton	16	16	100%	0	0%	0	0%
Newham	22	22	100%	0	0%	0	0%
Romford	19	18	95%	1	5%	0	0%
North East	57	56	98%	1	2%	0	0%
Camden	15	15	100%	0	0%	0	0%
Edmonton	17	15	88%	1	6%	1	6%
Friern Barnet	16	16	100%	0	0%	0	0%
North Central	48	46	96%	1	2%	1	2%
Brent	37	35	95%	2	5%	0	0%
Fulham	19	19	100%	0	0%	0	0%
Hanwell	13	13	100%	0	0%	0	0%
Hillingdon	9	9	100%	0	0%	0	0%
Westminster	9	9	100%	0	0%	0	0%
North West	87	85	98%	2	2%	0	0%
Bromley	16	16	100%	0	0%	0	0%
Deptford	25	24	96%	1	4%	0	0%
Greenwich	18	18	100%	0	0%	0	0%
South East	59	58	98%	1	2%	0	0%
Croydon	9	9	100%	0	0%	0	0%
New Malden	8	8	100%	0	0%	0	0%
St Helier	13	13	100%	0	0%	0	0%
Wimbledon	10	9	90%	0	0%	1	10%
South West	40	39	98%	0	0%	1	2%
PAS & VAS	6	6	100%	0	0%	0	0%
Other LAS $	12	11	92%	1	8%	0	0%
LAS-Wide	309	301	97%	6	2%	2	1%

Key:
$ Training, Hazardous Area Response, Special Events and Tactical Response Units are reported as "Other LAS".

2018 London Ambulance Service Direct to "Heart Attack Centre" Transport by LAS Group Station[133]

133 Source: London Ambulance Service, *Cardiac Care Pack 2016–2017*.

Data Summary			
	A	B	Total
n	25	20	45
$\sum X$	1965.7900(	1956	3921.79
$\sum X^2$	178456.35(	191574	370030.35(
SS	23883.1431	277.2	28242.871(
mean	78.6316	97.8	87.1509

Results

$Mean_a - Mean_b$	t	df			
-19.1684	-2.7	43	P	one-tailed	0.0049375
				two-tailed	0.009875

(Group A: California, Group B: London Ambulance Service)

Direct Transport to Designated STEMI Receiving Center (U.K. Equivalent) for STEMI Patients' T-Test.

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