ACCESS TO CARDIAC REVASCULARIZATION SERVICES FOR RURAL PATIENTS WITH MYOCARDIAL INFARCTION

A thesis by

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Presented to the Department of Public Health and Preventive Medicine

and the Oregon Health and Science University School of Medicine

in partial fulfillment of the requirements for the degree of

Master of Public Health

April 2006

School of Medicine

Oregon Health and Science University

CERTIFICATE OF APPROVAL

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ACKNOWLEDGEMENTS

I wish to thank the following individuals for their support and assistance in completing this project:

My thesis committee:	Cynthia Morris, PhD, MPH; Advisor and Chair
	Greg Larsen, MD
	Dongseok Choi, PhD
GIS analysis:	Mark Bosworth
	Molly Vogt
ICD-9 coding:	Bonnie Lowe
OAHHS data:	Tara Harben
And especially, my wife:	Jamie L. Z. Riley

ABSTRACT

Background: For rural patients with non-ST-segment elevation myocardial infarction (NSTEMI), the closest Local Hospital (LH) often does not offer cardiac revascularization procedures. In late 2002, national treatment guidelines were revised to recommend a primary strategy of routine early coronary angiography and cardiac revascularization for patients with NSTEMI. Rural patients with MI presenting to a LH would require transfer to a Referral Center (RC) that performs cardiac revascularization in order to meet these guidelines. We compared the proportions of rural patients that received care in a RC versus a LH and the proportion that did or did not undergo a cardiac procedure during the time periods before and after the guideline revisions.

Methods: We used the Oregon Association of Hospitals and Health Systems discharge database to analyze patients from rural Southwest Oregon with a primary ICD-9 discharge diagnosis of acute MI either before (1999-2002) or after (2003-2004) the guideline revisions. We created a geographic information system (GIS) to measure the distance from each patient's ZIP code of residence to the closest hospital. We selected patients for whom the closest hospital *did not* offer cardiac revascularization. For these rural patients, we then used our GIS to measure the distance to the closest Referral Center that did offer these services.

Results: Of the 3238 total patients in our sample, the proportion discharged from a RC increased from 59.5% in 1999-2002 to 69.4% in 2003-2004 ($p<0.001$). This increase remained statistically significant in a multiple logistic regression model that adjusted for possible confounders, including age, gender, co-morbidity, and insurance status. We also found that there was a significant interaction between time period (before or after the guideline revisions) and the distance from a patient's residence to the closest RC. Before the guideline revisions, the odds that a rural patient living 100 miles away from a RC would receive care in a RC were less than half those of a patient living only 50 miles away (OR = 0.41; 0.25-0.66). But after the guideline revisions, this disparity actually worsened (OR = 0.29; 0.17-0.49). The proportion of patients in our cohort that underwent a cardiac procedure increased from 60.5% in 1999-2002 to 71.2% in 2003-2004 ($p<0.001$). In the multiple logistic regression model for the cardiac procedure outcome, however, we did not find that distance to the closest RC was a significant predictor of whether or not a patient underwent a cardiac procedure.

Conclusions: Following the release of national treatment guidelines recommending routine coronary angiography and revascularization for patients with NSTEMI, there were significant increases in the proportion of rural patients who received care in a hospital that could perform cardiac revascularization and in the proportion of patients that actually underwent a cardiac procedure. After these guideline revisions, there was evidence that rural patients who are more geographically isolated may face an increasing disparity in access to receiving care in hospitals that perform cardiac revascularization procedures. However, there was no statistically significant evidence of such a disparity with regard to whether or not a patient actually underwent a cardiac procedure.

INTRODUCTION

Coronary heart disease (CHD) is a major cause of morbidity and mortality in the United States, directly affecting the lives of more than 13 million Americans (American Heart Association, 2006). One out of every five deaths can be attributed to CHD, and it is a major underlying cause of disability from chronic angina and heart failure. In addition to its impact on the lives and well being of individuals, CHD also accounts for a significant financial burden on the country as a whole. The total direct and indirect costs related to CHD for 2006 are estimated to be 142.5 billion dollars. More than half of the prevalent cases of CHD are related to myocardial infarction (MI). It is estimated that over 850,000 people will have a first or recurrent MI this year. More than 25% of patients will die within one year of their first MI. Of those who survive that period, over 20% of men and 40% of women will subsequently develop disability from heart failure within the next six years. Given these statistics, treatment strategies aimed at reducing the morbidity and mortality that are associated with MI have received a great deal of attention.

A myocardial infarction results from the acute obstruction of one of the coronary arteries, which are the blood vessels that supply the heart muscle with blood and oxygen. There are two general categories of MI: ST-segment elevation MI (STEMI) and non-ST-segment elevation MI (NSTEMI) (Joint Committee for the Redefinition of Myocardial Infarction, 2000). These categories are distinguished by the presence or absence of specific characteristics on a patient's electrocardiogram. The type (STEMI versus NSTEMI) and severity of an MI are related to the location and relative degree of the coronary artery obstruction. Compared to patients with NSTEMI, patients with STEMI are more likely to have complete occlusion of blood flow in a more proximal location of the coronary artery. As a result, patients with STEMI also tend to have a higher morbidity and mortality. Approximately one third to one half of acute myocardial infarctions can be classified as STEMI, with the remainder being NSTEMI (Perschbacher *et al*, 2004; Roe *et al*, 2005; Rogers *et al*, 2000; Rothwell *et al* 2005). Both types result in ischemic necrosis of the myocardial tissue that is downstream from the area of obstruction. This leads to the release of cardiac biomarkers (e.g. troponin) from the dying cells of the heart muscle into the systemic circulation. Abnormal elevations of these biomarkers can then be detected in blood tests, which are used as part of the criteria for diagnosing a myocardial infarction.

For patients with either STEMI or NSTEMI, the coronary arteries can be evaluated using diagnostic coronary angiography in order to locate the area of obstruction that caused the infarction. Percutaneous coronary intervention (PCI) can then be used to "re-open" the obstructed coronary artery and restore blood flow in an effort to reduce further ischemic damage to the affected area of myocardium. Thus, PCI is one type of "cardiac revascularization procedure." Alternatively, some patients may instead be referred for coronary artery bypass graft (CABG) surgery as a means of revascularization. For most patients who suffer an acute MI, however, PCI is used as the initial method of cardiac revascularization (Roe *et al*, 2005; Rogers *et al*, 2000). But due to the rare possibility of a complication during the PCI procedure that would necessitate emergency CABG surgery, PCI is usually only performed in hospitals where this surgery is also available.

Numerous trials have shown the benefits of immediate PCI in the acute treatment of patients with STEMI. A recent meta-analysis confirmed the superiority of PCI over medical therapy with thrombolytic agents for STEMI patients in the proper clinical setting (Keeley *et al*, 2003). For patients with NSTEMI, an approach of routine cardiac catheterization with revascularization if indicated (a routine "early invasive strategy") has also been advanced. Recent years have witnessed significant procedural improvements in the utilization of PCI to treat patients with MI. Upon the foundation of balloon angioplasty, such advances have included the use of intra-coronary stents and the administration of adjunctive pharmacologic agents. The addition of these measures has helped to increase the success of PCI in treating the acute MI, and also to reduce a patient's risk of recurrent cardiac events in the future.

In the setting of these modern PCI advancements, the FRISC II and TACTICS-TIMI 18 randomized clinical trials provided evidence that a routine early invasive strategy can improve cardiovascular outcomes for patients with NSTEMI (Bach *et al*, 2004; Cannon *et al*, 2001; Wallentin *et al*, 2000). The time frame in which study patients assigned to the routine early invasive strategy actually underwent cardiac catheterization has varied in different trials. Although patients with NSTEMI do not undergo immediate cardiac catheterization (as is recommended for patients with STEMI), advocates of a routine early invasive strategy generally recommend that this be performed within 48 hours after hospital admission, or at least prior to the patient being discharged to home.

As clinical trial data have accumulated to show the benefits of PCI in various settings, the American College of Cardiology (ACC) and American Heart Association (AHA) have progressively expanded their recommendations for its use in treating patients with acute MI. The 1999 *ACC/AHA Guidelines for the Management of Patients with Acute Myocardial Infarction* gave a Class I recommendation (indicating general agreement and supporting evidence that a treatment is useful and effective) for the use of PCI as an alternative to thrombolytic therapy in patients with STEMI (Ryan *et al*, 1999). At that time, however, a routine early invasive strategy was given only a Class IIb recommendation (indicating a divergence of opinion and less evidence to support the usefulness of a treatment) for NSTEMI patients whose symptoms had resolved and who were clinically stable. Instead, cardiac catheterization following NSTEMI was given a Class I recommendation only for those patients who had recurrent angina or evidence of hemodynamic instability. Other patients were recommended to undergo a non-invasive stress test following their MI, with referral for cardiac catheterization only if this test was markedly positive despite maximum medical therapy. This treatment approach was later termed an "early conservative strategy."

In September of 2000, the ACC/AHA released new recommendations specifically for the treatment of patients with unstable angina and NSTEMI (Braunwald *et al*, 2000). These guidelines gave a Class I recommendation to a routine early invasive strategy as an equally acceptable alternative to an early conservative strategy. With the additional support from the findings of TACTICS-TIMI 18, however, the guidelines for the treatment of NSTEMI were updated in 2002 to give preference to a routine early invasive strategy instead of an early conservative strategy for *all* NSTEMI patients (as defined by elevation of the troponin biomarker) without contraindication to cardiac catheterization and revascularization (Braunwald *et al*, 2002). These guideline updates were first announced in March of 2002 and subsequently published in October of that year. Given that patients with NSTEMI account for approximately one-half to two-thirds of all cases of acute MI, the evolution of the national treatment guidelines for this condition in recent years has resulted in a substantial increase in the proportion of patients for whom routine cardiac catheterization is recommended as the preferred treatment strategy.

Such treatment strategies, however, may not be equally available to all patients. It is difficult for smaller hospitals to maintain the staff, facilities, and patient volume that would make it feasible for them to provide these advanced cardiac procedures. This is particularly relevant for patients living in rural areas, as there is a low likelihood that the hospital closest to their place of residence will offer these services. Among the hospitals included in the Medicare Cooperative Cardiovascular Project, only 4.4% of rural hospitals had the capacity to perform PCI and only 2.2% had the capacity to perform cardiac surgery (Baldwin *et al*, 2004). This compared to 38.7% and 33.4% of urban hospitals that offered these cardiac revascularization procedures, respectively.

Previous studies have shown the likelihood that a patient with an acute MI will receive cardiac catheterization is lower if the hospital where the patient initially presents does not offer this procedure (Blustein, 1993; Every *et al*, 1993; Petersen *et al*, 2003). In order to receive the currently recommended treatment strategy for NSTEMI, such patients would require transfer to a referral hospital that performs cardiac revascularization procedures. Unlike patients living in urban areas, however, rural patients may live a considerable distance from the nearest hospital that offers these services. A recent study reported that the median distance to the closest hospital offering PCI for rural patients in the U.S. is 27.8 miles (Nallamothu *et al*, 2006). This compares to a median distance of only 3.5 miles for patients in urban areas. Additional data indicate that the utilization of PCI may decrease as the distance from a patient's residence to the hospital offering those services increases. Gregory et al studied a cohort of New Jersey residents with acute MI in regard to the relationship between the utilization of cardiac revascularization procedures and the distance from a patient's residence to the closest hospital offering those services. They found that the likelihood of PCI utilization decreased in a linear fashion with increasing distance. They found a similar relationship for CABG utilization (Gregory *et al*, 2000).

Compared to patients from urban areas, previous studies have shown disparities in the likelihood that rural patients with acute MI will receive recommended therapies. Sheikh and Bullock compared rural and urban hospitals in Kansas for their compliance with six different quality of care guideline recommendations from the ACC/AHA (Sheikh and Bullock, 2001). Each of these treatment guidelines could be accomplished medically, without the need for advanced cardiac procedures. Nevertheless, they found that "ideal patients" (i.e. those without any contraindications to the given therapy) in urban hospitals were more likely to receive four of these six recommended treatments than were patients in rural hospitals. Baldwin and colleagues reported similar findings in a national sample of Medicare patients with acute MI (Baldwin *et al*, 2004). In addition, they found that after adjusting for other factors, patients with acute MI who were initially admitted to rural hospitals had a higher 30-day mortality than did those patients admitted to urban hospitals.

Given that the ACC/AHA treatment guidelines for the care of patients with NSTEMI now call for the routine use of advanced cardiac procedures, rural hospitals that do not offer these procedures cannot directly follow these guidelines. Therefore, rural patients who receive their care in the local rural hospital that is closest to their place of residence may face increasing disparities in access to the currently recommended level of care. One way to overcome this disparity would be for these rural hospitals to routinely transfer such patients to larger referral hospitals that offer cardiac catheterization and revascularization procedures. Over the period of time that the treatment guidelines have evolved to recommend a routine early invasive strategy, however, the way in which access to these advanced cardiac procedures may have changed for rural patients with MI is not currently known. Also unknown is whether or not these relationships may vary according to the distance from a rural patient's place of residence to the closest referral hospital that offers cardiac revascularization services.

The region of southwest Oregon is uniquely suited for studying such issues of access to advanced cardiac services for rural patients with MI. The six counties in this area cover more than 17,000 square miles and have a total population of fewer than 800,000 people (U.S. Bureau of the Census, 2000). Though predominantly rural, this region is bordered to the north and south by cities designated as "Urbanized Areas" in the 2000 U.S. Census. Each of these two cities, Eugene and Medford, has a hospital that offers cardiac revascularization procedures, including both PCI and CABG. The smaller hospitals located in the more rural areas within this region, however, do not offer such procedures. Thus, these two "Referral Centers" in Eugene and Medford are the closest hospitals where a rural patient living in this area who suffered an acute MI could receive a cardiac revascularization procedure.

We designed our study to focus on rural patients with acute MI who do not have ready access to cardiac revascularization services. Therefore, we selected those patients from within this region of southwest Oregon for whom the hospital that is closest to their place of residence (i.e. their "Local Hospital") *does not* offer cardiac revascularization procedures. We analyzed the change over time in the proportion of these patients that ultimately received care in a Referral Center during the course of their initial hospitalization for an acute MI. We also analyzed the proportion of these patients that underwent an advanced cardiac procedure (i.e. diagnostic coronary angiography with or without cardiac revascularization).

Our main hypothesis was that the proportion of rural patients that received care in a Referral Center and the proportion that underwent an advanced cardiac procedure had both increased following the revisions to the national treatment guidelines recommending a routine early invasive strategy as the preferred treatment approach for patients with NSTEMI. However, we also hypothesized that there would be a greater increase in these proportions for those rural patients that lived closer to a Referral Center compared with those rural patients living farther away. By examining the impact of distance on these relationships, we sought to determine the extent to which disparities in access to recommended care may be increasing for patients who are more geographically isolated.

SUBJECTS AND METHODS

Patients:

The patient data used in this analysis came from the Oregon Association of Hospitals and Health Systems (OAHHS) discharge database. Annual discharge data is submitted by each of the OAHHS members, which include all hospitals in the state of Oregon except for the two federal Veterans Administration hospitals, the state psychiatric hospital, and one physician-owned hospital in Portland. This database is maintained for the OAHHS by COMPdata (Naperville, Illinois), a data collection and management company. Each individual hospital submits records for all of its patient discharges directly to COMPdata. COMPdata then assesses the records for accuracy, compiles the discharge data for each hospital, and makes the full discharge database available for review by the other OAHHS members. Each discharge record in the database includes the patient's age, gender, ZIP code, primary and secondary ICD-9 discharge diagnosis codes, principal and secondary ICD-9 procedure codes, discharge status (i.e. was the patient discharged to home, a skilled nursing facility, deceased, etc.), insurance status, and the name of the hospital from which the patient was discharged. The are no unique patient identifiers in this database.

Using these records, we identified those patients aged 18 years and older who had a primary discharge diagnosis of acute myocardial infarction (ICD-9 codes 410.0-410.9) during the years 1999-2004. We excluded any codes with the fifth digit "2" (i.e. 410.x2), as this signifies a readmission for subsequent care following an acute MI within the previous 8 weeks. We also excluded all those patients for whom the discharge status was anything other than "Home or Self Care." This prevented the double counting of patients who were transferred to another hospital for additional care. This also excluded those patients who died during their hospitalization or who were discharged to a skilled nursing facility, as this group of patients would be more likely to have contraindications to cardiac catheterization. We then selected those patients for whom their ZIP code of residence was within our geographic Region of Interest, and for whom the closest hospital did not offer cardiac revascularization procedures. The methods by which we defined our Region of Interest and selected the patient ZIP codes for inclusion are described below in the *Geographic Information System* section.

Hospitals:

The hospitals included in our analysis were those non-federal acute care hospitals located within our Region of Interest that discharged at least one patient meeting our selection criteria during the study period. Patients who met our other selection criteria but were discharged from an Oregon hospital that was outside of our Region of Interest (<1.5% of the total patients for the study period) were also excluded.

The two hospitals in this area that offered cardiac revascularization procedures were located in Eugene and Medford. Eugene is located on the northern border of our Region of Interest and Medford is on its southern border. Thus, for all of those patients living within our Region of Interest, these are the two closest hospitals in which they could receive cardiac revascularization services. Therefore, we identified Eugene and Medford as **Referral Centers**.

There were eight other hospitals within our Region of Interest that met our hospital selection criteria but did not perform cardiac revascularization procedures. We identified these as **Local Hospitals**. They were located in the communities of Bandon, Coos Bay, Coquille, Florence, Gold Beach, Grants Pass, Reedsport, and Roseburg. At the beginning of the study period in 1999, Roseburg had a second hospital in operation that was subsequently closed in early 2000. As both this hospital and the one that remains in operation in Roseburg shared similar characteristics with regard to the cardiology services that they provided, we considered discharge from either of these facilities to be an equivalent outcome. In addition, a small number of patients (<1% of the total patient cohort for each year) were discharged from a second hospital located in Medford that is independent of the Referral Center in Medford. This second hospital performs diagnostic coronary angiography but does not perform cardiac revascularization procedures. For the purposes of our study, we chose to treat patients discharged from this hospital as having an equivalent outcome to being discharged from any of the other Local Hospitals.

A physician who was either the medical director or a practicing cardiologist at each of the Local Hospitals was contacted in order to determine the Referral Center to which they usually transferred patients with acute MI in need of additional care, and the usual method and route of transfer. They were also asked about any cardiology services (such as outpatient clinics) that were provided in their community.

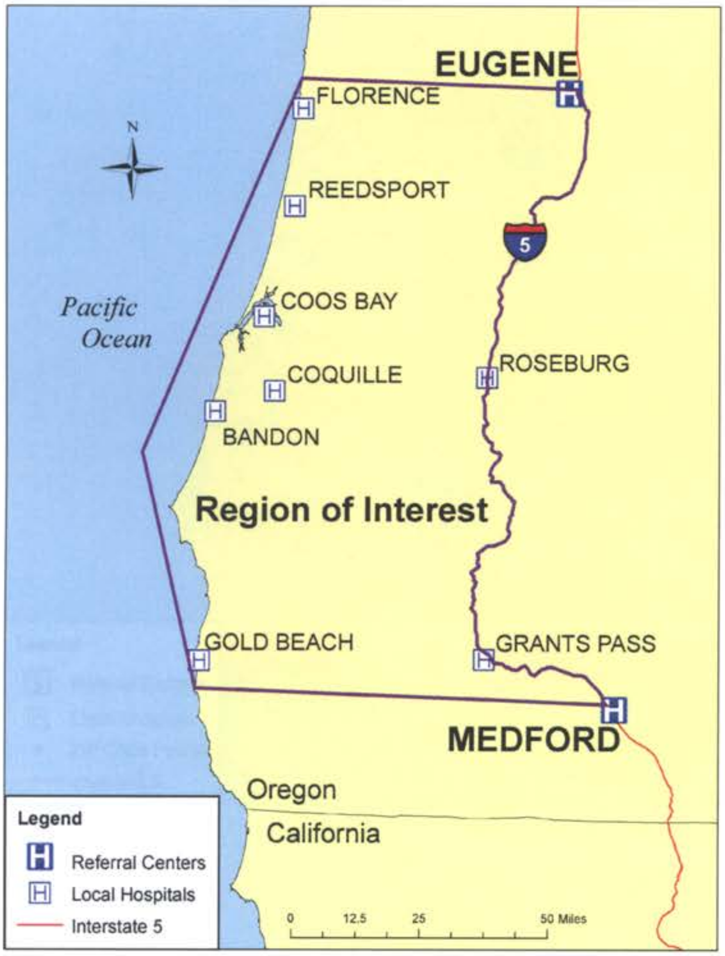
Geographic Information System:

A geographic information system (GIS) is a sophisticated map that allows for the integration and analysis of data with regard to a spatial frame of reference (Melnick, 2002). Characteristics or outcomes related to an individual patient can be geographically linked to where that patient lives and to other locations of interest, such as the nearest healthcare facilities. These various data points can then be examined for their geographic relationships. As such, GIS is particularly useful for studying the geographic variables that influence access to health care services, and it has been applied to the study of a variety of these issues (Birkmeyer *et al*, 2003; Kansagra *et al,* 2004; Nallamothu *et al*, 2006; Peleg and Pliskin, 2004; Scott *et al*, 1998).

We created our GIS using ArcGIS version 9.1 from Environmental Systems Research Institute, Inc (ESRI, Redlands, California). The data used in our map layers came from the proprietary geographic data issued by ESRI with the ArcGIS 9.1 release. These layers included U.S. States, U.S. Cities, U.S. ZIP Code Areas, U.S. ZIP Code Points, U.S. Hospitals, and U.S. Highways. Our map was projected in the NAD83 Oregon Lambert Projection, which is the official map projection for the state of Oregon.

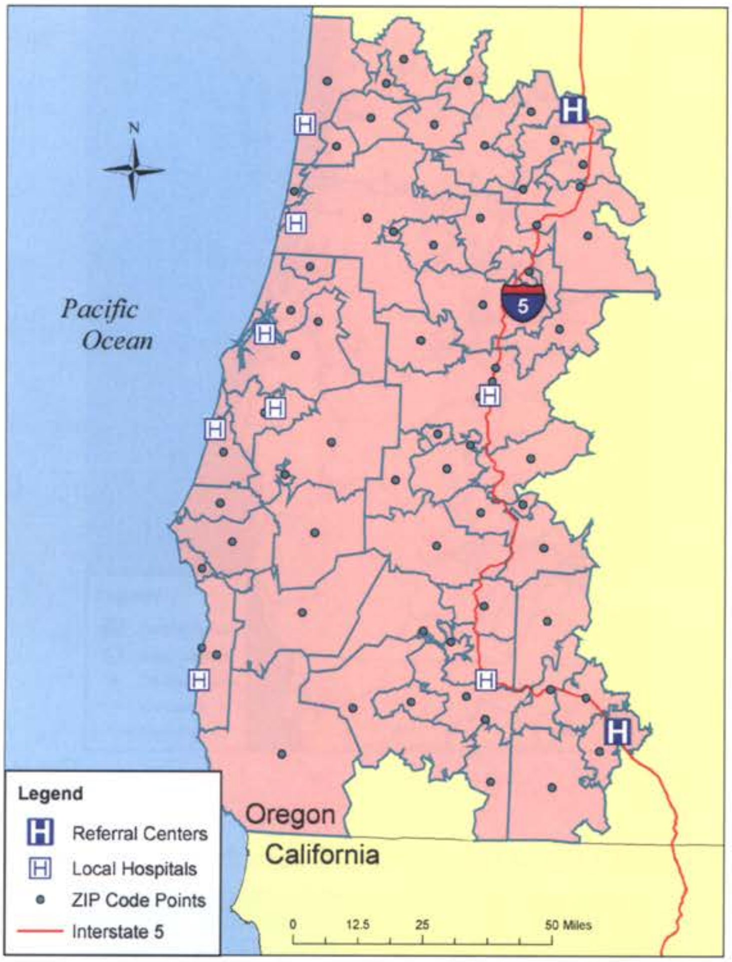
In order to select those patients that would be served predominantly by the hospitals within our Region of Interest, we identified an area of Southwest Oregon that was bounded by our two Referral Center hospitals, the interstate highway that connects them, and the Oregon coast (**Figure 1**). Specifically, our borders were the latitude of Eugene to the north, the latitude of Medford to the south, Interstate 5 to the east, and the Pacific Ocean to the west.

FIGURE 1: Borders of our Region of Interest.



We defined our Region of Interest to include all those ZIP code areas that were either partially or entirely contained by these borders (**Figure 2**). For each of the ZIP code areas that were included in our Region of Interest, we identified the point at the geometric center of the area. As such, each ZIP code area had a corresponding ZIP code point, which was then used for the subsequent measurement of distances. We also included those ZIP code points within our Region of Interest that corresponded to post office box locations. These points did not have a corresponding ZIP code area.

FIGURE 2: ZIP code areas and ZIP code points included in our Region of Interest.



We connected the ZIP code points to the network of major roads in this region by creating the shortest possible straight-line segment that would link a point to its nearest roadway (**Figure 3**). We used the Network Analyst extension for ArcGIS 9.1 to measure the distance over major roadways from each of these ZIP code points to the closest hospital (**Figure 4**). We then selected those ZIP codes for which the closest hospital *did not* offer cardiac revascularization procedures (i.e. the closest hospital *was not* a Referral Center). We identified these as the **Rural ZIP Codes**.

FIGURE 3: ZIP code points connected to the network of major roads.

FIGURE 4: Route from each ZIP code point to the Closest Hospital.

Finally, we measured the distance over major roadways from each of these Rural ZIP Codes to the closest hospital that *did* offer cardiac revascularization procedures (i.e. the closest Referral Center) (**Figure 5**). In determining the routes to the closest Referral Center, we placed barriers over two roadways that were included in the ESRI U.S. Highways map layer, but were actually remote roads that would not commonly be used for patient transport.

FIGURE 5: Route from each Rural ZIP Code to the closest Referral Center.

As the hospital in Roseburg performs diagnostic coronary angiography but does not perform cardiac revascularization procedures, we also used a similar process in order to select those ZIP codes from within our Region of Interest for which the closest hospital did not offer diagnostic coronary angiography (i.e. the closest hospital was not in Eugene, Medford, or Roseburg). We identified this group as the **Non-Roseburg Rural ZIP Codes**.

Statistical Analysis:

We assessed two separate primary outcomes for patients who lived in one of the Rural ZIP Codes and met our other selection criteria. Our first primary outcome was whether a patient was ultimately discharged to home from a Local Hospital or from a Referral Center. We termed this the "**Discharge Hospital Outcome**." Our second primary outcome was whether or not a patient underwent coronary angiography, with or without cardiac revascularization, during their hospitalization. This was assessed from the discharge database by determining if the patient's discharge record listed one or more of the ICD-9 procedure codes for diagnostic coronary angiography (88.50 and 88.53-88.58), PCI (36.01-36.07 and 36.09), or CABG (36.11-36.17 and 36.19). We termed this the "**Cardiac Procedure Outcome**."

We performed univariate logistic regression analyses in order to compare the individual patient variables for the two groups within each of our primary outcomes. We performed the Chi-square test for trend for binomial proportions across the six years of our study (1999-2004) for each outcome. We also performed a Chi-square test to compare the proportion of patients with each of these primary outcomes during the time periods before (1999-2002) and after (2003-2004) the October, 2002, release of the revised guidelines recommending a routine early invasive approach. As a means of comparison with a non-rural population for the Cardiac Procedure Outcome, we used the same discharge database to analyze this outcome in the cohort of patients who had a ZIP code of residence in Eugene or Medford, who met our other selection criteria, and who were discharged from the Referral Center in the city in which they lived.

We performed a multiple logistic regression analysis for both of our primary outcomes using the covariates of time period before or after the guideline revisions, gender, age, patient co-morbidity level, type of insurance, closest Local Hospital, closest Referral Center, and distance to the closest Referral Center. "Time Period" was a dichotomous variable defined as before (1999-2002) or after (2003-2004) release of the guideline revisions. "Gender" was a dichotomous variable. "Age" was a continuous variable in one-year increments. "Insurance Type" was a categorical variable divided into 4 groups: Group 1 had Medicare; Group 2 had private insurance; Group 3 had Medicaid; and Group 4 was self-pay, self-insured, or medically indigent. Patient "Co-Morbidity Level" was a categorical variable representing the patient's Charlson Comorbidity Index calculated by the method of D'Hoore (D'Hoore, 1996). This method assigns each patient with a comorbidity level of 0-4, which is determined from the secondary ICD-9 diagnosis codes listed in the patient's discharge record. Higher numbers correlate with increased inpatient mortality. "Closest Local Hospital" and "Closest Referral Center" were categorical variables.

The variable of "Referral Distance" represented the distance over major roadways from the patient's ZIP code of residence (located by its corresponding ZIP code point) to the closest Referral Center. This variable was evaluated in three different ways. In the first method, the measured distance over major roadways was analyzed as a continuous variable in miles. In the second method, distance was analyzed as a categorical variable by dividing patients into tertiles of increasing distance to the closest Referral Center (i.e. closest, middle, and farthest). All but one of the eight Local Hospitals reported that their patients were predominantly transferred to the Referral Centers by ground transport (i.e. in ambulances traveling over major roadways). Due to its relative geographic isolation, however, the hospital in Gold Beach predominantly transfers its patients by air, which is generally a 20 minute flight to the nearest Referral Center compared to a 150 mile ground transport distance. Because of this, our third method for evaluating the Referral Distance variable was for all of the patients for whom Gold Beach was the closest Local Hospital to be included in the "closest" tertile, with the remaining patients again assigned to tertiles according to their measured distance over major roadways. As many patients shared the same ZIP code of residence, this resulted in multiple patients with the identical measured distance to the closest Referral Center. Therefore in both of our strategies for creating tertiles of increasing distance, we were unable to divide the patients exactly into thirds. We instead selected break points in the distance values that resulted in the three groups being as equally sized as possible.

In addition to the baseline variables listed above, we also assessed for the potential interactions of Age by Gender, Age by Insurance Type, and Time Period by Referral Distance. We added all three interaction terms to the main effects model containing each of our baseline variables. We then performed a backward stepwise selection for removal of the non-significant interaction terms. All of the baseline variables were retained in our final model, regardless of statistical significance.

We repeated the multiple logistic regression analyses for both of our primary outcomes using only those patients from the Non-Roseburg Rural ZIP Codes. For all of our tests, we used $p<0.05$ as the cutoff value for statistical significance. All statistical analyses were performed using SPSS version 14.0 (Chicago, Illinois).

RESULTS

Over the course of the six years included in our study (1999-2004), a total of 3238 patients meeting our selection criteria were discharged to home following hospitalization for an acute MI. The characteristics of these patients are shown in **Table 1**. In the overall sample, the mean age was 68.7 years, and nearly two-thirds of the patients were male. The mean co-morbidity level was 0.77. Two-thirds of the patients were covered by Medicare and one quarter were covered by private insurance.

Table 1 also shows the patient characteristics within each outcome category for our two primary outcomes. Patients who were discharged from a Referral Center or who underwent a cardiac procedure tended to be younger, had a higher proportion of males, and had a lower co-morbidity level. Coos Bay, Grants Pass, and Roseburg were the closest Local Hospitals for the largest number of patients. Eugene was the closest Referral Center for a slightly larger proportion of patients than was Medford. In the univariate analyses, patients discharged from a Referral Center or receiving a cardiac procedure had a slightly greater mean distance to the closest Referral Center than did their respective comparison groups. Each of the comparisons of the individual variables for the two primary outcomes was highly statistically significant ($p<0.001$) by univariate logistic regression analysis, with the exception of the Closest Referral Center variable for the Discharge Hospital Outcome ($p = 0.867$).

Table 1: Patient Characteristics and Univariate Comparisons

Variables		Total Sample (n = 3238)	Discharge Hospital Outcome		Cardiac Procedure Outcome	
			Local Hospital (n = 1207)	Referral Center (n = 2031)	No Cardiac Procedure (n = 1165)	Cardiac Procedure (n = 2073)
Age	Mean	68.7	73.7	65.8	74.6	65.4
	Median	70	75	66	76	66
			p <0.001		p <0.001	
Gender (%)	Male	2057 (63.5)	679 (56.3)	1378 (67.8)	658 (56.5)	1399 (67.5)
	Female	1181 (36.5)	528 (43.7)	653 (32.2)	507 (43.5)	674 (32.5)
			p <0.001		p <0.001	
Co-Morbidity Level (%)	0	1479 (45.7)	363 (30.1)	1116 (54.9)	326 (28.0)	1153 (55.6)
	1	1200 (37.1)	494 (40.9)	706 (34.8)	489 (42.0)	711 (34.3)
	2	426 (13.2)	263 (21.8)	163 (8.0)	260 (22.3)	166 (8.0)
	3	83 (2.6)	52 (4.3)	31 (1.5)	54 (4.6)	29 (1.4)
	4	50 (1.5)	35 (2.9)	15 (0.7)	36 (3.1)	14 (0.7)
	Mean	0.77	1.09	0.58	1.13	0.57
			p <0.001		p <0.001	
Insurance Type (%)	Medicare	2133 (65.9)	998 (82.7)	1135 (55.9)	991 (85.1)	1142 (55.1)
	Private	814 (25.1)	148 (12.3)	666 (32.8)	121 (10.4)	693 (33.4)
	Medicaid	160 (4.9)	41 (3.4)	119 (5.9)	32 (2.7)	128 (6.2)
	Self-Pay	131 (4.0)	20 (1.7)	111 (5.5)	21 (1.8)	110 (5.3)
			p <0.001		p <0.001	
Closest Local Hospital (%)	Bandon	97 (3.0)	27 (2.2)	70 (3.4)	29 (2.5)	68 (3.3)
	Coos Bay	520 (16.1)	209 (17.3)	311 (15.3)	217 (18.6)	303 (14.6)
	Coquille	173 (5.3)	66 (5.5)	107 (5.3)	70 (6.0)	103 (5.0)
	Florence	191 (5.9)	36 (3.0)	155 (7.6)	47 (4.0)	144 (6.9)
	Gold Beach	229 (7.1)	34 (2.8)	195 (9.6)	49 (4.2)	180 (8.7)
	Grants Pass	1040 (32.1)	426 (35.3)	614 (30.2)	464 (39.8)	576 (27.8)
	Reedsport	147 (4.5)	43 (3.6)	104 (5.1)	46 (3.9)	101 (4.9)
	Roseburg	841 (26.0)	366 (30.3)	475 (23.4)	243 (20.9)	598 (28.8)
			p <0.001		p <0.001	
Closest Referral Center (%)	Eugene	1825 (56.4)	678 (56.2)	1147 (56.5)	607 (52.1)	1218 (58.8)
	Medford	1413 (43.6)	529 (43.8)	884 (43.5)	558 (47.9)	855 (41.2)
			p = 0.867		p <0.001	
Referral Distance	Mean	80.5	76.8	82.7	77.1	82.5
			p <0.001		p <0.001	

P-values represent the univariate logistic regression analysis for each variable within the given primary outcome.

The relative size and annual patient volume of the eight Local Hospitals and two Referral Centers from our Region of Interest are shown in **Table 2**. The three largest Local

Hospitals according to number of staffed beds and number of total discharges per year were located in Coos Bay, Grants Pass, and Roseburg. The Discharge Accuracy

Table 2: Hospital Characteristics

Hospital Location	Staffed Beds	Discharges Per Year	Discharge Accuracy	Practicing Cardiologist?	Diagnostic Angiography?
Local Hospitals:					
Bandon	18	349	99.4%	No	No
Coos Bay	129	8,464	96.1%	No	No
Coquille	15	660	96.8%	No	No
Florence	21	1,431	98.2%	Weekly Clinic	No
Gold Beach	24	774	91.3%	Monthly Clinic	No
Grants Pass	98	7,800	97.6%	Full Time	No
Reedsport	49	597	98.5%	No	No
Roseburg	153	10,170	99.4%	Full Time	Yes
Referral Centers:					
Eugene	423	26,221	97.1%	Full Time	Revascularization
Medford	276	15,008	97.6%	Full Time	Revascularization

Staffed Beds: Number of staffed beds in 2004 as reported by the OAHHS.

Discharges Per Year: Average number of yearly discharges (1999-2004) reported by each hospital for all diagnoses.

Discharge Accuracy: Average percentage of agreement between number of yearly discharges reported by each hospital and number of discharge records that were sufficient for inclusion in the discharge database (1999-2004).

Practicing Cardiologist: Whether or not there is a cardiologist who provides services in the community where the Local Hospital is located. The weekly cardiology clinic in Florence is staffed by cardiologists from the Referral Center in Eugene. The monthly clinic in Gold Beach is staffed by cardiologists from the Referral Center in Medford.

Diagnostic Angiography: Whether or not the Local Hospital performs diagnostic coronary angiography. By definition, none of the Local Hospitals perform cardiac revascularization procedures, but both of the Referral Centers provide these services.

represents the percentage of agreement between the number of total discharges that each hospital reported and the corresponding number of discharge records found to be sufficiently accurate for inclusion in the discharge database that was compiled by COMPdata. There was greater than 90% accuracy for the discharge records from all of the hospitals included in the study, and all but one (Gold Beach) had greater than 96% accuracy. Two of the Local Hospitals (Grants Pass and Roseburg) are served by full-time cardiologists. Two others have periodic outpatient cardiology clinics provided in their community, but do not have full-time cardiology staffing for hospitalized patients. Roseburg is the only Local Hospital that performs diagnostic coronary angiography.

Table 3 shows the number and proportion of patients within each of the primary outcomes by year. The proportion of patients discharged from a Referral Center increased from 57.1% in 1999 to 71.1% in 2004 (p for trend <0.001). This is shown graphically in **Figure 6**. The proportion of patients receiving a cardiac procedure increased from 58.2% in 1999 to 74.3% in 2004 (p for trend <0.001) (**Figure 7**).

TABLE 3: Primary Outcomes by Year

Year	**1999** (n = 534)	**2000** (n = 543)	**2001** (n = 564)	**2002** (n = 544)	**2003** (n = 559)	**2004** (n = 494)
Discharge Hospital Outcome (p for trend <0.001)						
Local Hospital (%)	229 (42.9)	231 (42.5)	204 (36.2)	221 (40.6)	179 (32.0)	143 (28.9)
Referral Center (%)	305 (57.1)	312 (57.5)	360 (63.8)	323 (59.4)	380 (68.0)	351 (71.1)
Cardiac Procedure Outcome (p for trend <0.001)						
No Cardiac Procedure (%)	223 (41.8)	223 (41.1)	203 (36.0)	213 (39.2)	176 (31.5)	127 (25.7)
Cardiac Procedure (%)	311 (58.2)	320 (58.9)	361 (64.0)	331 (60.8)	383 (68.5)	367 (74.3)

FIGURE 6: Rural ZIP Codes Discharge Hospital Outcome

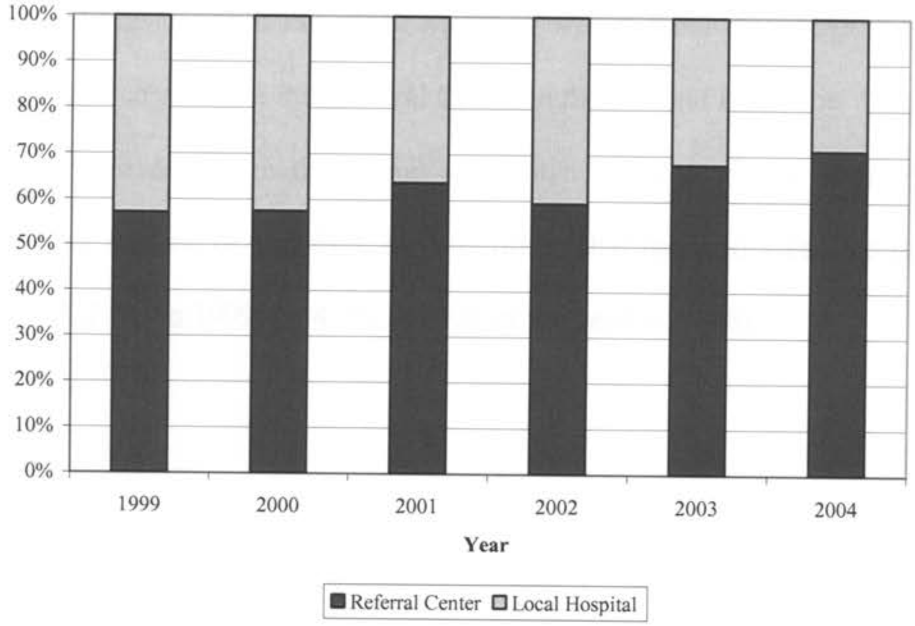
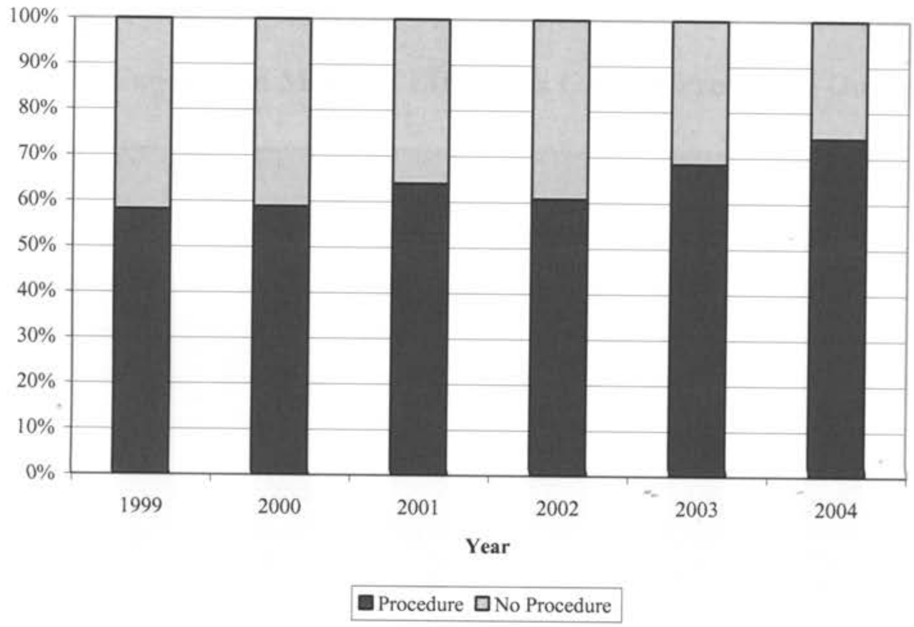


FIGURE 7: Rural ZIP Codes Cardiac Procedure Outcome

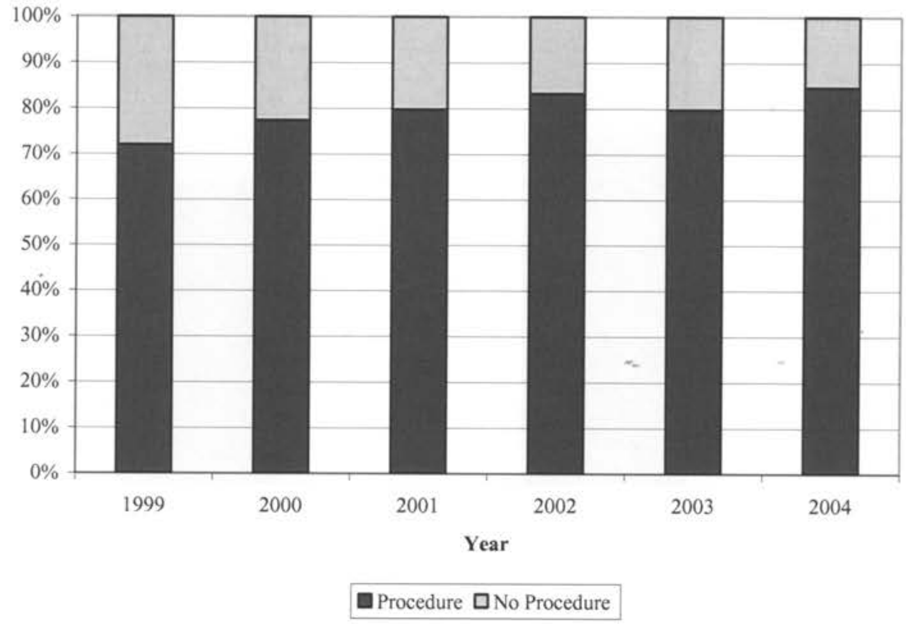


As a means of comparison for the secular trends in cardiac procedure use among rural patients, we also analyzed the Cardiac Procedure Outcome in a non-rural population. For this comparison, we selected those patients from the OAHHS discharge database who had a ZIP code of residence in Eugene or Medford, who met our other selection criteria, and who were discharged from the Referral Center in their city of residence. The Cardiac Procedure Outcome data from this group are shown in **Table 4** and **Figure 8**. For patients living in Eugene or Medford, the proportion that received a cardiac procedure increased from 72.0% in 1999 to 84.7% in 2004 (p for trend = 0.008).

TABLE 4: Cardiac Procedure Outcome in Patients from Eugene and Medford

Year	1999 (n = 254)	2000 (n = 195)	2001 (n = 253)	2002 (n = 246)	2003 (n = 263)	2004 (n = 249)
Cardiac Procedure Outcome (p for trend = 0.008)						
No Cardiac Procedure (%)	71 (28.0)	44 (22.6)	51 (20.2)	41 (16.7)	53 (20.2)	38 (15.3)
Cardiac Procedure (%)	183 (72.0)	151 (77.4)	202 (79.8)	205 (83.3)	210 (79.8)	211 (84.7)

FIGURE 8: Eugene and Medford ZIP Codes Cardiac Procedure Outcome



For the patients from Rural ZIP Codes, **Table 5** and **Figures 9 and 10** show the proportions for both of the primary outcomes according to the time period before (1999-2002) or after (2003-2004) the guidelines were revised to recommend a routine early invasive strategy. The proportion of patients discharged from a Referral Center increased from 59.5% before the guideline revisions to 69.4% afterwards (p <0.001). Likewise, the proportion of patients who underwent a cardiac procedure increased from 60.5% to 71.2% (p <0.001).

TABLE 5: Primary Outcomes by Time Period

	Before Guideline Revisions (1999-2002)	**After Guideline Revisions** (2003-2004)
Discharge Hospital Outcome (p <0.001)		
Local Hospital %	40.5	30.6
Referral Center %	59.5	69.4
Cardiac Procedure Outcome (p <0.001)		
No Cardiac Procedure %	39.5	28.8
Cardiac Procedure %	60.5	71.2

FIGURE 9: Rural ZIP Codes Discharge Hospital Outcome

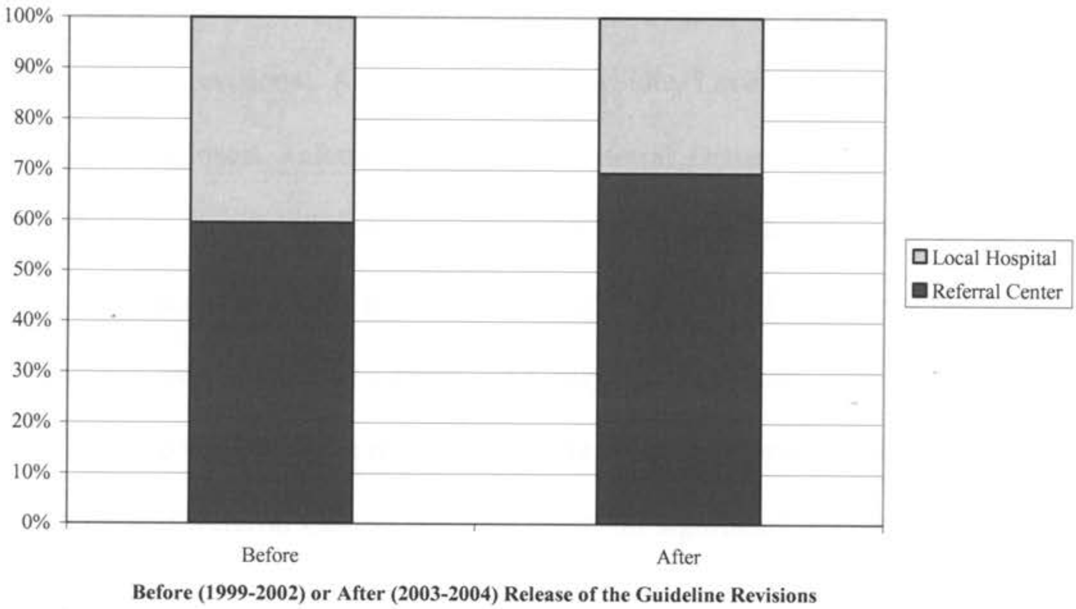
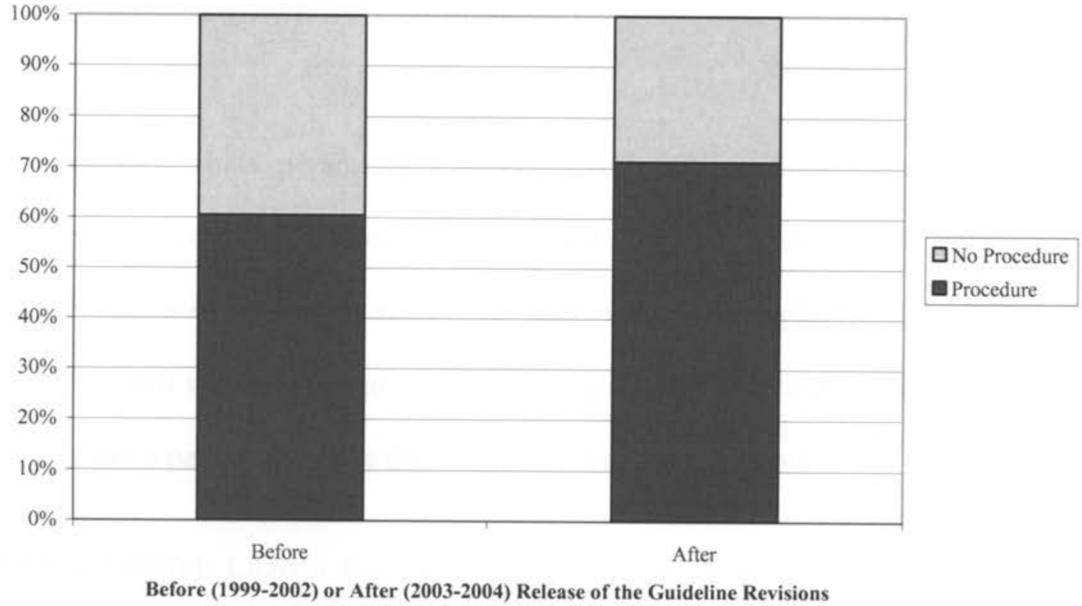


FIGURE 10: Rural ZIP Codes Cardiac Procedure Outcome



Our multiple logistic regression models allowed us to evaluate the effect of the individual variables on each of our primary outcomes while controlling for other potentially confounding covariates. The main effects model for all Rural ZIP Codes using the Discharge Hospital Outcome included the baseline variables of Time Period (before or after the guideline revisions), Age, Gender, Co-Morbidity Level, Insurance Type, Closest Local Hospital, Closest Referral Center, and Referral Distance. We first evaluated Referral Distance as a continuous variable. All but one of the variables in the main effects model was a statistically significant ($p<0.05$) predictor of whether or not a patient was discharged from a Referral Center. The only non-significant variable was Closest Referral Center ($p = 0.256$). We retained all of the variables from this main effects model (including Closest Referral Center) and then tested for significant interaction terms. We evaluated the interaction terms of Age by Gender, Age by Insurance Type, and Time Period by Referral Distance. After backward stepwise removal of the non-significant interaction terms, only the Time Period by Referral Distance interaction was retained in our final model (p = 0.010).

Table 6 shows the beta, p-value, and odds ratio with 95% confidence intervals for each of the variables in our final model of the Discharge Hospital Outcome. The Nagelkerke-adjusted R square value for this model was 0.28. With the exception of Closest Referral Center, all of the variables in our final model were statistically significant predictors of whether or not a patient would be discharged from a Referral Center.

TABLE 6: Multiple Logistic Regression Model for the Discharge Hospital Outcome

Variable	Beta	p-Value	Odds Ratio	95% C.I.
Time Period (after guideline revisions compared to before)	1.071	<0.001	See text	
Referral Distance (per 1 mile increase in distance)	-0.018	<0.001	See text	
Time Period by Referral Distance Interaction	-0.007	0.010	See text	
Age (per 1 year increase in age)	-0.039	<0.001	0.96	0.95-0.97
Gender (females compared to males)	-0.192	0.024	0.83	0.70-0.97
Co-Morbidity Level (compared to Level 0)		<0.001		
Level 1	-0.589		0.56	0.46-0.66
Level 2	-1.401		0.25	0.19-0.32
Level 3	-1.454		0.23	0.14-0.39
Level 4	-2.012		0.13	0.07-0.26
Insurance Type (compared to Medicare)		<0.001		
Private Insurance	0.700		2.01	1.59-2.55
Medicaid	0.267		1.31	0.86-1.98
Self-pay	0.705		2.02	1.20-3.43
Closest Local Hospital (compared to Coos Bay)		<0.001		
Coquille	0.566		1.76	1.16-2.67
Gold Beach	2.004		7.42	3.96-13.88
Reedsport	0.064		1.07	0.61-1.85
Roseburg	-1.116		0.33	0.20-0.54
Florence	0.367		1.44	0.78-2.69
Bandon	1.217		3.38	1.85-6.17
Grants Pass	-1.507		0.22	0.09-0.56
Closest Referral Center (Eugene compared to Medford)	-0.229	0.223	0.80	0.55-1.15

After controlling for the other variables in this model, we found that patients who were female, older, or who had a higher level of co-morbidity were all less likely to be discharged from a Referral Center than were patients in their respective comparison groups. Patients with Medicare were less likely to be discharged from a Referral Center than were patients who had private insurance, Medicaid, or who were self-insured.

Patients were more likely to be discharged from a Referral Center during the time period after the guidelines were revised to recommend a routine early invasive strategy. Patients who lived closer to a Referral Center were also more likely to be discharged from a Referral Center than were patients who lived farther away. But due to the significant interaction between Time Period and Referral Distance, the effect of a patient's distance from the closest Referral Center on the likelihood of being discharged from a Referral Center differed according to the Time Period. During the time period before the guideline revisions, the odds ratio for a one-mile increase in the Referral Distance was 0.982 (0.973-0.992). During the time period after the guideline revisions, the odds ratio for a one-mile increase in the Referral Distance was 0.975 (0.965-0.986).

In order to determine the effect of a difference in the Referral Distance that is more conceptually meaningful than one mile, we calculated the odds ratios that would correspond to an increase in the Referral Distance of 50 miles. This can be thought of as a comparison of the likelihood of being discharged from a Referral Center between a patient living 100 miles away from a Referral Center with a patient living only 50 miles away. During the time period before the guidelines were revised, the odds ratio for this comparison was 0.41 (0.25-0.66). This odds ratio decreased to 0.29 (0.17-0.49) during the time period after the guidelines were revised. The decrease in the odds ratio from the time period before to the time period after the guideline revisions indicates that although the likelihood of being discharged from a Referral Center increased for rural patients as a whole after the guidelines were revised, the increase in the *odds* of this outcome was greater for patients living closer to a Referral Center than for patients living farther away. This is reflected by the observed decrease in the *odds ratio.*

As another way to conceptualize the interaction between Time Period and Referral Distance, we created a second model that analyzed Referral Distance as a categorical variable, with tertiles of increasing Referral Distance (closest, middle, farthest) in place of the continuous variable. Because there were multiple patients from each ZIP code (and, therefore, multiple patients with the same Referral Distance), the tertile break points were selected to create three groups of as equal size as possible. The mean and range of distances for each of the tertiles are shown in **Table 7**. Using this categorical variable in our main effects model, we again found all of the baseline variables (with the exception of Closest Referral Center) to be statistically significant predictors of the likelihood that a patient would be discharged from a Referral Center. We also again found a significant interaction between Time Period and Referral Distance. The odds ratios for being discharged from a Referral Center were calculated by using the "closest" tertile as the reference group. These are shown in **Table 7**. For the "middle" tertile compared to the "closest" tertile, the odds ratio decreased from 0.66 (0.38-1.13) during the time period before the guideline revisions to 0.45 (0.25-0.82) after the guideline revisions. For the "farthest" tertile compared to the "closest" tertile, this odds ratio decreased from 0.39 (0.16-0.96) before to 0.22 (0.08-0.56) afterwards. Again, this decrease in the *odds ratio* indicates that following the guideline revisions, there was a greater increase in the *odds* of being discharged from a Referral Center for patients who lived closer to a Referral Center than for patients who lived farther away.

TABLE 7: Tertiles of Increasing Distance from the Closest Referral Center

	Closest (n = 1075)	**Middle** (n = 1094)	**Farthest** (n = 1069)
Distance in miles:			
Mean	41.7	73.9	126.4
Range	17.4 – 57.2	58.0 – 89.3	98.7 – 164.1
Odds Ratio* (95% CI):			
Before Revisions	Reference	0.66 (0.38-1.13)	0.39 (0.16-0.96)
After Revisions	Reference	0.45 (0.25-0.82)	0.22 (0.08-0.56)

*Odds Ratio compared to the "closest" tertile for the likelihood of discharge from a Referral Center during the time period before (1999-2002) or after (2003-2004) the guideline revisions.

Gold Beach was the only hospital that reported the predominant use of air transport for transferring patients to the closest Referral Center. Because of its geographic location this meant the difference between a 20 minute flight compared to a ground transport distance of over 150 miles. As such, we created a second set of distance tertiles whereby those patients for whom Gold Beach was the closest Local Hospital were placed into the "closest" tertile, and all of the remaining patients were assigned to tertiles according to their measured Referral Distance. The results of the interaction between Time Period and Referral Distance were similar using this method of analysis (**Table 8**).

TABLE 8: Patients from Gold Beach Assigned to the Closest Tertile

	Closest (n = 896)	**Middle** (n = 1157)	**Farthest** (n = 1185)
Odds Ratio* (95% CI):			
Before Revisions	Reference	0.85 (0.63-1.14)	0.62 (0.37-1.05)
After Revisions	Reference	0.49 (0.31-0.77)	0.30 (0.16-0.56)

*Odds Ratio compared to the "closest" tertile for the likelihood of discharge from a Referral Center during the time period before (1999-2002) or after (2003-2004) the guideline revisions.

We next analyzed our data according to the Cardiac Procedure Outcome – whether or not a patient underwent diagnostic coronary angiography (with or without cardiac revascularization) during their initial hospitalization. **Table 9** shows the betas, p-values, and odds ratios with 95% confidence intervals for each of the baseline variables in the main effects model. In this model, the Referral Distance variable was not a statistically significant predictor of the likelihood that a patient would receive a cardiac procedure ($p = 0.072$). Gender ($p = 0.073$) and Closest Referral Center (0.888) were also not significant predictors of the outcome in this model. Because Referral Distance was not statistically significant in the main effects model, we did not test for a Time Period by Referral Distance interaction. Time Period itself, however, was a significant predictor of whether or not a patient underwent a cardiac procedure. Patients who were hospitalized during the time period after the guideline revisions were more likely to receive a cardiac procedure than were patients from the time period before the guidelines were revised. Similar to the Discharge Hospital Outcome, we found that patients who were older or who had a higher level of co-morbidity were less likely to receive a cardiac procedure than were patients in their respective comparison groups. Again, patients with Medicare were less likely to receive a cardiac procedure than were patients in any other category of Insurance Type. The Nagelkerke adjusted R square value for this model was 0.30.

TABLE 9: Multiple Logistic Regression Model for the Cardiac Procedure Outcome

Variable	Beta	p-Value	Odds Ratio	95% C.I.
Time Period (after guideline revisions compared to before)	0.561	<0.001	1.75	1.46-2.10
Referral Distance (per 1 mile increase in distance)	-0.009	0.072	0.99	0.98-1.00
Age (per 1 year increase in age)	-0.047	<0.001	0.95	0.95-0.96
Gender (females compared to males)	-0.155	0.073	0.86	0.72-1.01
Co-Morbidity Level (compared to Level 0)		<0.001		
Level 1	-0.705		0.49	0.41-0.59
Level 2	-1.470		0.23	0.18-0.30
Level 3	-1.76		0.172	0.10-0.29
Level 4	-2.33		0.10	0.05-0.20
Insurance Type (compared to Medicare)		<0.001		
Private Insurance	0.742		2.10	1.64-2.69
Medicaid	0.46		1.58	1.01-2.47
Self-pay	0.465		1.59	0.95-2.68
Closest Local Hospital (compared to Coos Bay)		<0.001		
Coquille	0.394		1.48	0.97-2.26
Gold Beach	1.368		3.93	2.11-7.30
Reedsport	0.433		1.54	0.88-2.70
Roseburg	0.252		1.29	0.78-2.12
Florence	0.580		1.79	0.97-3.30
Bandon	0.929		2.53	1.38-4.65
Grants Pass	-0.574		0.56	0.22-1.45
Closest Referral Center (Eugene compared to Medford)	0.028	0.888	1.03	0.70-1.52

Because Roseburg was the only Local Hospital that performed diagnostic coronary angiography, it was the only Local Hospital in which patients could initially follow a routine early invasive strategy (by undergoing diagnostic coronary angiography) without first having to be transferred to a Referral Center. Therefore, we also analyzed both of our primary outcomes within the subgroup of patients from the Non-Roseburg Rural ZIP Codes (i.e. those rural patients for whom Roseburg was not the closest Local Hospital). For the Discharge Hospital Outcome, we again found that all of the baseline variables were statistically significant predictors of the outcome, with the exception of Closest Referral Center. We also again found a statistically significant interaction between Referral Distance and Time Period. During the time period before the guideline revisions, the odds ratio for being discharged from a Referral Center was 0.985 (0.974-

0.997) for a one mile increase in distance. During the time period after the guideline revisions, this odds ratio decreased to 0.978 (0.966-0.991). For a 50 mile increase in distance, the corresponding odds ratios were 0.47 (0.26-0.85) during the time period before the revisions and 0.33 (0.18-0.62) afterwards. So among this subgroup of rural patients, it again appeared that the odds of being discharged from a Referral Center during the time period after the guideline revisions increased more for those patients living closer to a Referral Center than it did for patients living farther away.

We also found similar results for the Cardiac Procedure Outcome using the Non-Roseburg Rural ZIP Code patients. The Referral Distance variable was again not a statistically significant predictor of the outcome ($p = 0.166$) in the main effects model. The Closest Referral Hospital variable was also not statistically significant ($p = 0.541$) in this model, but Gender was ($p = 0.023$). As in the model using the full Rural ZIP Code patient cohort, the variables of Time Period, Age, Insurance Type, and Closest Local Hospital were again all statistically significant. They each had the same direction of effect (i.e. negative or positive) on predicting whether or not a patient would undergo a cardiac procedure as they did in the full Rural ZIP Code patient cohort. The odds ratio for the Cardiac Procedure Outcome in comparing the Time Period after the revisions to the Time Period before was 1.78 (1.44-2.20).

DISCUSSION

Over the time period from 1999 until 2004, we found a statistically significant increase in the proportion of rural patients with acute MI who received care in a hospital that performed cardiac revascularization procedures. We also found a statistically significant increase in the proportion that underwent diagnostic coronary angiography, with or without cardiac revascularization. The increases in both of these proportions were most noticeable beginning in 2003, which was the year following the release of revisions to the ACC/AHA guidelines that recommended a routine early invasive strategy as the preferred treatment approach for patients with NSTEMI.

From a temporal perspective, it is tempting to speculate that the adoption of the revised treatment guidelines by the rural hospitals in our sample was responsible in part for the observed increase in access to the recommended level of care. It is difficult, however, to know with certainty if the guideline changes were actually a cause of the observed findings or if this was merely an association. It is impossible to exclude the influence of other factors that may have resulted in these observations. It is also difficult to determine a precise time as to when the newly revised guidelines would have "taken effect." These guideline revisions were first announced in March of 2002, but were not published until October of that year. For the purposes of our analysis, we therefore chose to categorize patients in the year 2002 as being from the time period "before" the guidelines were revised. Both outcomes appeared to have a substantial increase from 2002 to 2003, but they also both continued to increase in 2004. Even if these increases were directly related to the adoption of the new guidelines, it is unclear how long it would take to reach a new plateau.

In comparing the Cardiac Procedure Outcome for rural patients to a group of patients that lived in the urbanized areas of either Eugene or Medford (i.e. patients with ready access to the Referral Center where they received their care), we also found an increase in the proportion that received a cardiac procedure over the time period of our study. There was not, however, a similar increase between 2002 and 2003 as was seen in the rural patient population. We also found that the urban patients underwent cardiac procedures in higher proportions than did the rural patients during each of the years that were included in the study. Given that both of the Referral Centers in Eugene and Medford were staffed by cardiologists who could perform cardiac catheterization and revascularization on site, it is not surprising that these procedures would be utilized more frequently in patients at these facilities. In addition, the ACC/AHA treatment guidelines for NSTEMI that were released in 2000 had recommended that a routine early invasive strategy was an equally acceptable alternative to an early conservative strategy. Thus, cardiologists at the Referral Centers would have been able to follow the Class I recommendations for NSTEMI by practicing either of these strategies beginning in 2000. But unlike physicians in the rural hospitals, they would not have had to transfer their patients to another facility in order to follow a routine early invasive strategy.

For the Discharge Hospital Outcome, we found the likelihood that a patient would receive care in a hospital offering cardiac revascularization procedures was also influenced by the distance from a patient's place of residence to the closest Referral Center. After adjusting for other confounding variables, patients living closer to a Referral Center were more likely to receive care in such a facility than were patients who lived farther away. In addition, there was a significant interaction between the effect of increasing Referral Distance and the time period before or after the revised guidelines were released. Although the likelihood of being discharged from a Referral Center improved for rural patients as a whole, the odds of this outcome increased more for patients living closer to a Referral Center than for patients living farther away. Thus, there is evidence of an increasing disparity in access to care in a Referral Center for patients who are more geographically isolated.

For the Cardiac Procedure Outcome, however, we did not find a statistically significant influence from the Referral Distance variable on the likelihood that a rural patient would receive a cardiac procedure. Because the Local Hospital in Roseburg performed diagnostic coronary angiography but did not offer cardiac revascularization services, we also examined this outcome in the subgroup of rural patients for whom Roseburg was not the closest Local Hospital. But even among this group, we did not find a significant influence from Referral Distance on the likelihood that a patient would receive a cardiac procedure.

It is unclear as to why the distance from a patient's place of residence to the closest hospital offering cardiac revascularization might have a significant impact on the likelihood of receiving care in such a hospital, but would not affect the likelihood of actually undergoing a cardiac procedure. In considering the possible explanations, it is important to remember that we had no way of assessing whether or not patients had specific contraindications to cardiac catheterization (i.e. the "appropriateness" of an early invasive strategy). Although such contraindications would be less likely in our selected group of patients that were discharged to home/self care, we would still expect a certain proportion of these patients to have other clinical factors that would preclude an early invasive strategy. Transfer to a Referral Center, however, does not only represent access to cardiac procedures. It also implies access to a higher level of subspecialty care than would be available in most rural hospitals. Thus, it is possible that distance may have played less of a role in the decision to transfer patients that were clearly candidates for cardiac catheterization and revascularization, but that it had a greater impact in patients for whom the consideration for transfer was related more to the clinical severity of their medical condition.

There are a variety of other factors related to where a patient receives care that we were unable to assess in this study. One is patient preference. It is possible that patients in more geographically isolated areas would be less likely to agree to be transferred to a Referral Center. At least part of this preference, however, may simply be related to the distance of the Referral Center from the patient's place of residence. Thus, the variable of distance would still be playing a direct role in this effect.

There are also several factors related to the individual Local Hospitals that may influence their likelihood of transferring a patient on to a Referral Center. These include the level of support services that are available in the local hospital, the individual practice styles of the physicians that work there, and the relationships that have been established between the Local Hospitals and the Referral Centers. Because of the small number of Local Hospitals in our sample, there was no way to assess for trends in any of these individual characteristics as they might relate to the outcomes. By including a categorical variable for the Closest Local Hospital in our logistic regression model, we attempted to control for each Local Hospital's unique combination of these characteristics at an aggregate level. It is important to remember, however, that the Closest Local Hospital variable for each patient was determined solely from the geographic location of the patient's ZIP code of residence. As such, this variable would also be strongly correlated with other factors that may vary with geographic location, such as socio-economic status.

It is also important to note that we were unable to assess the type or duration of care that a patient received prior to their admission at the hospital from which they were ultimately discharged to home. It is possible that patterns of care would be different for a patient who was initially admitted to a Local Hospital before being transferred on to a Referral Center compared to a patient who was transferred directly to a Referral Center after presenting to the Emergency Department of a Local Hospital. It is also possible that an ambulance service transporting a patient from their home may have bypassed the closest Local Hospital in favor of the closest Referral Center in certain situations. In addition, patients who transport themselves to a medical facility may include other factors besides just the shortest distance when deciding where to seek care. Scenarios such as these, however, would seem more likely to occur if the Referral Center was relatively close than if it was a greater distance away. Thus, distance to the closest Referral Center may still be playing an important role.

The strengths of our study include the utilization of a geographically unique setting in which to address these issues of access to care for rural patients with acute MI. Over 98% of the patients who had a ZIP code of residence from within our Region of Interest were ultimately discharged from one of the hospitals in this area. The fact that there were two different Referral Centers on opposite sides of this region allowed us to assess for any differences that may have been related to the individual characteristics of the Referral Center that was closest to a patient. Of note, we did not find Closest Referral Center to be a statistically significant variable in predicting either of our primary outcomes. Also, we were able to measure the distances between patients and the closest hospitals over the network of roads that would actually be used for patient transport, rather than just using straight-line distances.

Another strength of our study is that our database allowed us to assess these outcomes in patients of all ages. Because of its availability, Medicare data is often used to address issues of quality of care and access to health services. In our cohort, however, more than one third of the patients were younger than age 65. Even after controlling for age, we found that patients with private insurance were twice as likely to receive care in a Referral Center or to undergo a cardiac procedure than were patients with Medicare. Finally, even though our database did not include unique patient identifiers, limiting our cohort to patients who were discharged to home/self care allowed us to avoid the double counting of patients that were transferred to a second hospital during the same admission. Such double counting can be a significant limitation in the use of administrative databases for the investigation of issues that involve hospital transfers in rural patients (Westfall & McGloin, 2001).

Our study does have many of the limitations associated with the use of an administrative database. The lack of actual patient addresses meant that we had to approximate each patient's place of residence according to the center of their ZIP code area. Individual ZIP codes can have considerable variation in their size and shape. In rural areas that are more sparsely populated, ZIP codes tend to cover larger areas, thus making the center of a ZIP code area a less accurate approximation of an individual patient's address. This served to decrease the accuracy of our Referral Distance measurements. But due to the fact that our two Referral Centers were located on opposite borders of our Region of Interest, we feel that our distance measurements were sufficiently accurate to assess the effect of increasing distance from the closest Referral Center on our outcomes.

Another limitation is that the ICD-9 codes for acute MI do not distinguish between STEMI and NSTEMI. Although the revisions to the guidelines that were released in 2002 specifically referred to the treatment of NSTEMI and unstable angina, given that NSTEMI makes up one-half to two-thirds of all acute MI's, these guideline changes would have been relevant to the care of a substantial proportion of the patients in our cohort. However, it is still impossible to know what component of the change in the proportions of our two outcomes may have involved patients with STEMI.

Our database also lacks information on patient race/ethnicity and socioeconomic status. Both of these factors have been shown to influence patient access to cardiac care (Alter *et al*, 1999; Gurwitz *et al*, 2002; Schulman *et al*, 1999). Certainly there can be wide variation in socioeconomic status between rural areas, and we were unable to control directly for the influence of this variable in our analysis. With regard to race/ethnicity, however, we note that for the six counties that are completely or partially within our Region of Interest, the 2000 US census listed approximately 90% of the population as being "white persons, not of Hispanic/Latino origin." Thus, although racial/ethnic disparities are clearly important in evaluating issues of access to health care, we do not feel that they are likely to have played a significant role in the outcomes for our specific study population.

Future investigations should focus on the relationships between distance and utilization of care for rural patients with myocardial infarction in other parts of the country. There is a great deal regional variation in the use of cardiac procedures, and the findings in this study may not be representative of other areas (*Dartmouth Atlas of Health Care*, 1999). Ultimately, these issues would be best investigated by collecting primary data from patients who initially present to local rural hospitals. This would allow for the assessment of the type of care that a patient receives prior to transfer, specific clinical factors that may influence whether or not a patient is transferred, whether or not an individual patient is treated according to guideline recommendations, and, ultimately, the relationship between all of these factors and the patient's clinical outcome.

SUMMARY AND CONCLUSIONS

Over the period of time that the national treatment guidelines were revised to recommend a routine early invasive strategy for patients with NSTEMI, there was a significant increase in the proportion of rural patients with the diagnosis of acute MI who received care in a hospital that could perform cardiac revascularization. There was also a significant increase in the proportion of these patients that actually underwent a cardiac procedure. Following the release of the guideline revisions, there was evidence that rural patients who are more geographically isolated may face an increasing disparity in access to receiving care in hospitals that can perform cardiac revascularization. This potential disparity was not observed, however, with regard to whether or not a patient actually underwent a cardiac procedure.

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