Mapping Geographic Areas of High and Low Drug Adherence in Patients Prescribed Continuing Treatment for Acute Coronary Syndrome After Discharge

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Study Objective. To determine the feasibility of using geographic information system (GIS) technology to identify geographic areas of high and low adherence to cardiovascular drug therapy for treatment of acute coronary syndrome (ACS) in patients discharged from a university-affiliated hospital.

Design. Retrospective analysis.

Data Source. A registry of patients admitted to and discharged from a large university-affiliated medical center for the treatment of ACS.

Patients. A total of 1081 adults distributed over 300 census tracts who were discharged between April 1999 and December 2004 with a diagnosis of an ACS event of unstable angina or acute myocardial infarction.

Measurements and Main Results. Data were collected on patient demographics, home addresses, and adherence to four classes of drugs—statins, angiotensin-converting enzyme inhibitors, β-blockers, and aspirin—at 6–12 months after discharge for the ACS index event. A GIS program was used to map patient addresses and adherence data to geographic coordinates. Hot Spot Analysis was used to determine the existence of any spatial clustering patterns in adherence rates. The analysis was performed at the census tract level by using the percentage of nonadherent patients within a census tract to represent adherence for the people living within that tract, standardized by the number of residents in a census tract aged 40 years or older. Hot Spot Analysis identified unique geographic areas of high, neutral, and low adherence in the southeast area. Highly adherent census tracts were primarily located in and around the city where the university hospital and clinics are located. Areas of low adherence were located to the west, southwest, and southeast of the city. All other census tracts were considered neutral in adherence rates.

Conclusion. Mapping geographic areas of drug adherence is feasible with use of GIS technology, with spatial mapping able to detect areas of varying levels of adherence. Future research should examine local-level factors associated with low adherence, which can be used to derive tailored, locally relevant interventions to improve long-term drug adherence.

Key Words: geographic information system, GIS, medication persistence, medication adherence, cardiovascular disease, acute coronary syndrome, ACS.
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Acute coronary syndrome (ACS) encompasses several clinical conditions, including ST-segment elevation myocardial infarction (STEMI), non–ST-segment elevation myocardial infarction

(NSTEMI), and unstable angina. In 2004, the American College of Cardiology and the American Heart Association published evidence-based guidelines for the treatment of ACS.[1] Based on evidence from randomized controlled trials, four classes of drugs are recommended for the treatment of patients with ACS: angiotension-converting enzyme (ACE) inhibitors, β-blockers, statins, and antiplatelet drugs. Since the publication of these guidelines, changes in pharmacologic therapy and interventions for ACS have significantly reduced the number of in-hospital deaths, cardiogenic shock, recurrent myocardial infarction, and heart failure in patients with STEMI and NSTEMI.[2]

On discharge, these drugs should be continued to prevent secondary cardiovascular events. However, nonadherence is very common in patients with cardiovascular disease, often leading to increased mortality and hospitalizations.[3–5] Nonadherence has been shown to significantly increase the likelihood of death within 1 year after a myocardial infarction.[6] For example, higher rates of death and acute myocardial infarction were observed in patients who prematurely stopped treatment with clopidogrel.[7]

There are many patient-specific factors that contribute to nonadherence, some of which include age and race-ethnicity, polypharmacy, frequency of drug changes, socioeconomic status, access to medical care, out-of-pocket drug cost, lack of prescription drug insurance, and poor communication between patients and health care providers.[8–13] In addition, beliefs and attitudes about illness and drugs influence adherence to drug regimens.[8, 14] Patients may alter their drug regimens based on their perceptions of the effectiveness of the drugs, the constraints of everyday life, and any adverse effects they experience.[15, 16]

The focus of research on medication-taking behavior has been on patient-level factors. Identification of these important variables often leads to development of patient-centered interventions tailored to the patient's specific needs. An approach to modifying behavior used in the public health arena is to target populations and their environments rather than individuals.[17] Researchers are beginning to examine the environment in which individuals live in an attempt to identify determinants of illness, as well as the existence of modifiable risk behaviors in populations. Individuals of low socioeconomic position are at greater risk of developing cardiovascular disease, and those living in deprived neighborhoods have lower survival rates after an acute myocardial infarction.[18, 19]

Individual factors associated with nonadherence may also be linked to an individual's neighborhood or community. Social characteristics of residential environments are associated with the conduct of healthy behaviors.[20] Evidence supports the concept that residential neighborhoods play a role in determining individual behaviors linked to health outcomes, which primarily have been studied in diet and exercise.[21, 22] It may be hypothesized that medication-taking behavior is also linked to neighborhood or geographic characteristics. Recent studies have documented that drug prescribing and adherence vary based on geography. For example, adherence to drugs used for the treatment of diabetes mellitus varies by region in which the patient lives in the United States.[23] Other studies have documented geographic variation in the prescribing of drugs such as opiates and antiretroviral treatment.[24, 25]

A relatively new analytic technique, spatial epidemiology, combines the disciplines of geography, statistics, and epidemiology.[26] Among the tools used in these analyses are mapping computer programs. Programs known as geographic information systems (GIS) are capable of not only mapping any type of data that can be linked to an address, or geocoded, but also performing statistical analyses that examine spatial relationships between variables. Related to drug therapy, GIS technology has been used to study variations in prescribing controller asthma drugs, based on clinical guidelines, for pediatric patients with asthma.[27] A GIS program was used successfully to assess the impact of a large-scale distribution program for nicotine replacement therapy in New York City.[28] In addition, GIS was proven to be a useful tool to detect local patterns of opiate drug prescribing and use. Such was the case in a study that tracked opiate prescribing and use in New Mexico.[29]

There may be a link between medication-

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taking behavior and neighborhood or geographic area characteristics. A new approach to identifying population or spatially associated, community-based variables may be the use of GIS technology. The first step in assessing the usefulness of GIS is to test the feasibility of mapping drug adherence in an effort to identify variations based on geography. Once the feasibility is established, further work can begin to determine the neighborhood or spatially related factors that are associated with adherence variation. Data that can be used for these analyses would include census data, population survey data such as the Behavioral Risk Factor Surveillance System available from the Centers for Disease Control and Prevention, or locally obtained information including health system infrastructure.

The purpose of this study was to determine the feasibility of using GIS technology to document geographic areas of high and low drug adherence in patients who were discharged from a large university-based hospital with continuing treatment related to ACS. To date, there are relatively few studies using GIS technology to assess drug adherence on a community or neighborhood level.

Methods

The Acute Coronary Syndrome Patient Registry

This retrospective study used data obtained from a registry of patients admitted to and discharged from a large university-affiliated medical center for the treatment of ACS. The registry uses data obtained from patients' medical records as well as a telephone follow-up survey of the patients obtained 6–12 months after discharge. All patients aged 18 years or older who were discharged between April 1999 and December 2004 with the documented discharge diagnosis of an ACS event—unstable angina or acute myocardial infarction—were eligible for inclusion in the registry. Inclusion criteria were documentation of unstable angina or myocardial infarction using standard criteria such as electrocardiogram changes, cardiac enzyme level changes, and patient-reported symptoms. Other inclusion criteria were the ability to understand English and communicate verbally by telephone.

Registry data included demographic and clinical characteristics such as age, sex, education, and comorbid conditions. The address where the patient lived at the time of the index ACS event was also documented. Drug data in the registry included a complete list of drugs prescribed at the time of discharge, obtained from the medical record. Another list of drugs obtained by patient self-report during the follow-up survey was also documented in the registry. Four cardiac-specific drug categories were derived from the lists and included β-blockers, ACE inhibitors, statins, and aspirin.

Determination of continuation of the cardiac-specific drugs was made by comparing the list of drugs prescribed at discharge for the index ACS event with the list of drugs reported by the patient at the time of the telephone survey.[30] Patients who discontinued any one of the four drugs were classified as nonadherent.

Patients who were admitted multiple times during the study time frame were counted once, and their most recent address and adherence data were used for this analysis.

Mapping Process

A GIS program was used to map patient addresses and adherence data to geographic coordinates on a base map. The GIS integrates hardware, software, and data to allow a user to store, analyze, manipulate, and present geographically referenced information, and it allows investigators to visualize and interpret data in ways that reveal relationships, patterns, and trends in the form of maps and reports. The program contains a structured database from which maps can be generated, allowing the user to view geographic features and relationships, and it usually contains a statistical package for processing geographic information. The software used for this study was ArcGIS, version 9.3.1 (Esri Data Systems; Environmental Systems Research Institute, Inc., Redlands, CA).

A spreadsheet that included patient addresses and adherence data was merged with census tract data and a base map of Michigan to form a map that contained analyzable attributes. The merging process included ensuring a complete match of all addresses to known places on the census tract map. Mismatches were reconciled through observation of closeness to known addresses on the map layer. Patient data associated with addresses that could not be reconciled were removed.

Analysis

A drug adherence value was determined for each registry patient for the four classes of drugs used in this study (β-blockers, ACE inhibitors, statins, and antiplatelet drugs). Drugs documented

as prescribed at discharge and self-reported as taken at the follow-up survey were considered persistently taken, and that drug class was coded as adherent. A value of 1 was then assigned to that drug class. A value of 0 was assigned if a drug was prescribed at discharge but the patient indicated at the time of the follow-up survey that the drug was not taken. The final value for adherence for each patient was deter-mined by summing the adherence score for each drug class prescribed at discharge and dividing by the number of drug classes prescribed. Being adherent to all classes of drugs prescribed at discharge was considered a value of 1.0, whereas being nonadherent to all classes of drugs prescribed at discharge resulted in a value of 0.0.

During the geocoding phase, one or more patients from the registry were assigned to a census tract based on their home address listed in the ACS registry. The value for drug adherence assigned to a specific census tract was the average of the adherence scores of the registry patients assigned to that census tract. An assumption for this study is that people in the registry are similar to those who live in the census tract in which they reside. It is important to realize that census tracts can vary substantially in demographics and that the registry patient may not be similar demographically to the mean age and sex of their assigned census tract. To standardize based on age, the mean adherence value derived for individual census tracts was divided by the number of people living in the census tract aged 40 years or older. Forty years of age was chosen as this is the age at which increased monitoring and assessment of cardiovascular risk factors begins based on guidelines.[31]

Hot Spot Analysis was used to determine existence of any spatial patterns to drug adherence. The Getis-Ord Gi* statistic was calculated for the census tract adherence value, resulting in a Z score and a p value. The Z score indicates where high and low values cluster spatially. A statistically significant hot spot (individual or grouping of census tracts) will have a high value that is surrounded by other census tracts with high values. A statistically significant cold spot will have a low value that is surrounded by other tracts with low values. In this study, hot spots are areas of higher adherence, whereas cold spots

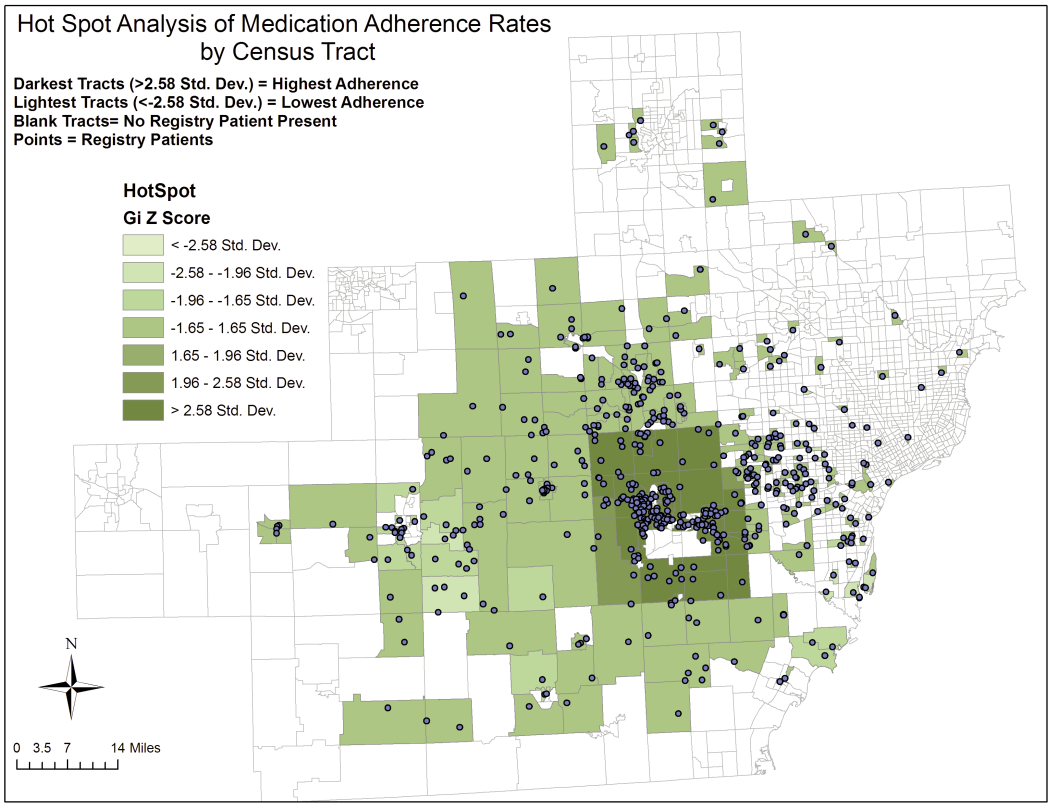

Figure 1. Map of southeast Michigan census tracts, including distribution of registry patients and delineation of census tracts by high and low adherence (Hot Spot Analysis).

are areas of lowest adherence. Analyses were conducted at the census tract level by using the percentage of nonadherent patients within a census tract as a representation of the overall adherence rate of that tract. For the analyses, we used a spatial weights matrix file with polygon contiguity in which neighbors were defined as tracts sharing a common edge. Census tracts without represented neighbors (census tracts without at least one ACS registry patient) and tracts that did not share a common border were removed because the spatial analyses we used were dependent on tracts having neighbors. Census tracts without a registry patient were also excluded from analysis.

Once areas of high, neutral, and low adherence or persistence were identified, the mean ± SD of the standardized adherence value for tracts grouped as high, neutral, or low adherence values were determined. Because of the process by which hot and cold spots are identified, values for adherence in represented census tracts are not assumed to be independent of each other. Therefore, comparative testing was not undertaken, since traditional statistical methods require the units of analysis to be independent from each other.

Results

A total of 2877 people were listed in the ACS registry between April 1999 and December 2004. Of these, 1101 had traceable addresses. Lack of a traceable address was the main reason why 1776 registry patients were not analyzed in this study. This may have been due to a mismatch between registry patient and the hospital system used to retrieve the addresses, or addresses given by the patients that were recorded at the time of hospitalization were either incorrect or were documented incorrectly. We were unable to confirm the number of cases associated with each of these common reasons for lack of traceable addresses. Of the 1101 patients with traceable addresses, 1081 had complete drug data at discharge and from the follow-up survey. Reasons for lack of drug data were not ascertained. The 1081 patients were distributed over 300 census tracts in southeastern Michigan. Patients' mean ± SD age was 63.4 ± 13.3 years, and 712 (65.9%) were male.

A comparison was performed between patients in the geocoded group (1081 patients) and those in the nongeocoded group (1776 patients). The adherence rate for patients in the group with addresses and adherence data was significantly higher compared with those who had adherence rates available but no geocodable address (0.75 ± 0.25 vs 0.69 ± 0.27, $p<0.001$). In addition, patients in the geocoded group were younger by 1 year compared with those in the nongeocoded group (mean ± SD age 63.3 ± 13.6 vs 64.3 ± 13.9 yrs, $p=0.04$). Finally, the sex of the patients was not significantly different between the geocoded and nongeocoded groups ($p=0.11$).

Figure 1 is a map of the area included in this analysis along with location of registry patients within the census tracts within these counties. It should be noted that the area is primarily located in Washtenaw, Jackson, Livingston, Monroe, Oakland, Lenawee, and Wayne counties in southeastern Michigan. Geographically, the University of Michigan Hospital, the source of hospital care for the index ACS event, is centrally situated in Washtenaw county, which is bordered by the other six counties.

Hot Spot Analysis was able to delineate unique geographic areas of high, neutral, and low adherence in the southeast Michigan area (Figure 1). High-adherence census tracts were primarily located in and around the city of Ann Arbor, the location of the university hospital and clinics. The areas with low adherence were located to the west, southwest, and southeast of the city of Ann Arbor, roughly incorporating the Jackson county-city area, city of Adrian, and city of Monroe. All other census tracts were considered neutral in adherence rates.

The mean ± SD adjusted adherence rates for the three categories of census tracts were as follows: high adherence 0.00063 ± 0.0019, neutral adherence 0.00041 ± 0.0023, and low adherence 0.00036 ± 0.00019.

Discussion

The results of this feasibility study show that there is a spatial effect associated with adherence to drug therapy in patients who had recently been discharged after an ACS event. It appears that GIS technology may be a useful technique to identify geographic areas of varying rates of adherence. This is important as a first step in developing population-based assessment of drug adherence by using GIS technology. One important issue yet to be resolved is the representativeness of the people mapped in a geographic unit to the rest of the people who live there. Further research is necessary to document that these representative individuals are similar to the at-risk population of that area. Some census tracts included only one or two registry patients.

The assumption was that these individuals represent all people aged 40 years or older in that census tract. Therefore, a limitation of this study is the representativeness of the registry patients to the at-risk population of their assigned census tract. It is also important to note that this study was limited geographically, assessing people living in the greater Ann Arbor area of Michigan and extending to areas of southeastern Michigan. Further research would be necessary to test the technology in much larger geographic areas. It does demonstrate that, at the local level, assessments of geographic variation in adherence are possible.

Health is now understood to be influenced on multiple levels, including the community and societal influences.[32, 33] In addition to further work to validate GIS technology to assess adherence at a population level, research must also be conducted using mixed methods to identify local beliefs and attitudes toward drug therapy, along with identifying common local barriers to accessing prescribed drugs. This would provide local public health practitioners and policymakers the opportunity to develop tailored interventions that are meaningful to a local population.

Several limitations in the study design and data require discussion. The patient registry included only patients treated for ACS at a single, large, university-based hospital in southeastern Michigan. Patients treated at other local hospitals were not included in this study. Local effects related to hospital and health system characteristics, such as discharge counseling and follow-up communication with community providers, as well as provision of local community health programs targeting patients with ACS, were not assessed. Future research could identify not only patient and population characteristics, but also the differences in local health systems procedures that may be associated with local population health beliefs, attitudes, and practices.

Another limitation of the study was the fact that many patients in the ACS registry did not have addresses that we could geocode and map. Unfortunately, this is an inherent problem when using a registry or database that was built for other purposes. We were not able to determine why addresses were not able to be mapped, but only able to state that they were missing. Future research in this area should include prospective data collection efforts that would preemptively ensure the accuracy and completeness of addresses obtained from subjects in the study sample.

The method of determining drug adherence should also be discussed as a limitation of the study. Most measures of adherence or persistence with prescription drugs are at best surrogates for actual taking of the drug. We used a method that included identification of drugs prescribed at discharge coupled with self-report of the drugs taken at the time of a relatively short-term (< 12 mo) follow-up. Other methods for determining adherence would include pharmacy claims data, capture of drug container openings by using an electronic surveillance method, or use of a standardized, validated self-report instrument. Future research may use mixed methods to assess adherence as an attempt to improve the measurement procedure.

Another limitation related to our method of determining adherence is that reasons for discontinuation of a drug were not obtained for all patients. For example, drugs discontinued by a physician's order due contraindications or adverse effects would have been classified as the nonadherent drug category. Future research should include assessment of patient-reported reasons for nonadherence.

Despite the limitations, this study demonstrated the potential of using GIS technology to identify geographic areas of relatively lower drug adherence. Mapping drug adherence by using a GIS program may be a useful tool that public health practitioners, local health care providers, and researchers can use to identify local geographic areas where adherence is not optimal. Through further qualitative and quantitative studies, interventions developed by using locally relevant information on barriers to appropriate use of prescribed drugs may have a higher success rate than using generalized interventions to improve drug adherence in a community. Targeting communities with poor adherence may prove cost-effective compared with interventions for individual patients. Some examples of community interventions would be educating patients with health announcements over local radio or in newspapers, as well as educating health professionals on the importance of maintaining good communication with patients in their area. These strategies would target not only patients, but also the social network that includes local friends, acquaintances, and family members whose influence has been shown to positively affect compliance with medical recommendations.[34]

Conclusion

This study has demonstrated the feasibility of

using GIS technology to study drug adherence. Spatial mapping can be used to detect areas of low drug adherence. Using this information, health professionals may identify geographic areas that, once an understanding of the local contextual effects associated with poor adherence are identified, could help develop target interventions to specific areas rather than using general population interventions or one-on-one individual approaches.

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