Geospatial Analysis of Stroke Mortality & Hospitalization: An Overview Using Health Outcome Data
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Virginia Network for Geospatial Health Research
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Place Matters

...it is space not time that hides consequences from us.
Abraham Verghese: Urbs in Rure

Types of Spatial Analysis

1. Traditional GIS
   A. Query and display
   B. Buffering
   C. Overlay

2. Spatial Statistics
   A. Hot spot analysis
   B. Spatial pattern analysis
   C. Spatial Regression
Multilevel Spatial Analysis: Social Determinants of Health & Neighborhood Effects

From: After
To: Beside
Aggregation

Low Education in Virginia

US ~ Stroke Hospitalization Rates
Pop Ages 65+, Medicare Beneficiaries, 2000-2006

Source: http://apps.nccd.cdc.gov/giscvh2/Results.aspx
Distribution of Health Care Providers

Stroke System of Care Regions ~ Board Certified Neurologists * Primary Stroke Centers (PSC) & Comprehensive Stroke Centers (CSC) in Virginia's Rural and Urban Areas

* Physician data from the Virginia Board of Medicine, Doctor Profile Database for January 2010 (www.vahealthprovider.com).
HotSpot Analysis & Scan Statistics
Examining Spatial Patterns

• Hot Spot Analysis Getis Ord Gi*
  – Used to identify clusters of features with values significantly higher or lower than the overall study area mean
  – Z score is calculated
    • High Z = hot spot (surrounded by other high Z)
    • Low z = cold spot (surrounded by other low Z)

ESRI, “Understanding Spatial Statistics in ArcGIS.” Transcript, 2006
Virginia
Hot Spot Analysis ~ Relative Risk
Arterial Ischemic Stroke (AIS)
Hospitalization (Primary Diagnosis) Discharged Data
Ages 35 Years & Over by ZIP Code
State Standard - (Adjusting for Age)
2005~2009

* Data Source: Virginia Health Information, Hospital Discharged Data
2005-2009 Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Stroke Discharged Data which have been age-adjusted Virginia Standard Population. Relative Risks take into account SatScan adjustments based on distribution within contiguous area.
Virginia
Hot Spot Analysis ~ Average Distance Travelled Arterial Ischemic Stroke (AIS) Hospitalization (Primary Diagnosis) Discharged Data Ages 35 Years & Over by ZIP Code
State Standard - (Adjusting for Age)
2005~2009

* Data Source: Virginia Health Information, Hospital Discharged Data 2005-2009 Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Stroke Discharged Data which have been age-adjusted Virginia Standard Population. Relative Risks take into account SatScan adjustments based on distribution within contiguous area.
Virginia
Arterial Ischemic Stroke (AIS) ~ 35 Years & Over
Hospitalization (Primary Diagnosis) Discharge Data *
SaTScan Cluster Analysis (Global)
2005~2009

Cluster #2
Observed 992
Expected 610
RR 1.23

Cluster #1
Observed 30439
Expected 25012
RR 1.23

* Data Source: Virginia Health Information, Hospital Discharge Data 2005-2009. Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-9 Codes, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436. Data have been age-adjusted, to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia
Arterial Ischemic Stroke (AIS) ~ 35 Years & Over
Hospitalization (Primary Diagnosis) Discharge Data *
SaTScan Cluster Analysis (50 Miles Radius)
2005~2009

* Data Source: Virginia Health Information, Hospital Discharge Data
2005-2009. Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-9 Codes, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436. Data have been age-adjusted, to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia
Arterial Ischemic Stroke (AIS) ~ 35 Years & Over
Hospitalization (Primary Diagnosis) Discharge Data *
SaTScan Cluster Analysis (25 Miles Radius)
2005~2009

<table>
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<th>Cluster</th>
<th>Radius**</th>
<th>LLR</th>
<th>Obs.</th>
<th>Exp.</th>
<th>RR</th>
<th>P value</th>
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</table>

** Miles

* Data Source: Virginia Health Information, Hospital Discharge Data 2005-2009. Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-9 Codes, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436. Data have been age-adjusted, to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia

Stroke Mortality ~ Indirect Standardization for Ages 35 Years & Over

SaTScan Cluster Analysis (Global)

2005~2009


Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-10 Codes, I60 ~ I69. Data have been age-adjusted, to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia
Stroke Mortality ~ Indirect Standardization for Ages 35 Years & Over
SaTScan Cluster Analysis (50 Miles)
2005~2009

Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-10 Codes, I60 ~ I69. Data have been age-adjusted, to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia

Stroke Related Recurrent Admission ~ 35 Years & Over
Based on 2008 AIS Admissions Cohort
Hospitalization Discharge Data *
Space-Time Permutation Analysis ~ Retrospective
1994~2007

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<tr>
<th>Cluster #</th>
<th>Start Date</th>
<th>End Date</th>
<th>Observed</th>
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<td>42</td>
<td>23.15</td>
<td>1.81</td>
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</table>

* Data Source: Virginia Health Information, Hospital Discharge Data 2004-2008. Analysis based on SatScan (v8.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-9 Codes, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436. Data have been age, sex & race-adjusted to the 2008 Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia Stroke Hospitalization Rate / 100,000 (Arterial Ischemic Stroke) by ZIP Code 2005~2009

* Data Source: Virginia Health Information, Hospital Discharge Data 2005-2009. Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-9 Codes, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436. Data have been age-adjusted to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Virginia
Kriging Analysis
Average Distance Traveled for Stroke Hospitalization (Arterial Ischemic Stroke) by ZIP Code
2005-2009

Distance in Miles
- 0 - 12.88
- 12.88 - 17.26
- 17.26 - 30.14
- 30.14 - 68.05
- 68.05 - 179.61

* Data Source: Virginia Health Information, Hospital Discharge Data 2005-2009. Analysis based on SatScan (v9.0, 2009) clustering algorithms developed by Martin Kulldorf for NCI. Data represent Primary Diagnosis Stroke Discharges for ICD-9 Codes, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436. Data have been age-adjusted to Virginia State Standard Population. Relative Risk Ratios take into account SatScan adjustments based on Poisson distributions within contiguous area.
Spatial Analysis

Regression
Analytic Process

Select Variables
- Dependent Variable
- Independent (exploratory) variables

Explore Spatial Patterns
- Histogram
- Scatter Plot Matrix
- Spatial Autocorrelation
- Hot Spot Analysis

Regression Analysis
- Ordinary Least Squares Regression
- Geographically Weighted Regression
Ordinary Least Squares Regression (OLS)

• Global regression technique
• Single equation to represent overall relationship between variables
• OLS will indicate spatially significant explanatory variables
• Remove non-significant variables, explore other explanatory variables
• Run several iterations of OLS
Ordinary Least Squares Regression (OLS)

• Six (6) diagnostic indicators
  – Coefficients have the expected sign
  – Check for redundancy (VIF>7.5)
  – Coefficients are statistical significance
  – Residual are normally distributed
  – AIC & Adjusted R-Squared values
  – Relationships across the area do not vary significantly
Selecting Variables for Spatial Regression

- Percent Below Federal Poverty Level
- Percent Below High School Education
- Average Distance Travelled in Miles
- Percent Pop 65 & Over
- Primary Care Providers Total FTEs
Using OLS to test hypotheses
Virginia
Exploring Spatial Variation
Stroke Hospitalization Rate ~ 2005-2009
Geographically Weighted Regression (GWR)

Local R-Square
- 0.04 - 0.21
- 0.22 - 0.33
- 0.34 - 0.44
- 0.45 - 0.54
- 0.55 - 0.63
- 0.64 - 0.71
- 0.72 - 0.81
- 0.82 - 0.88
- 0.89 - 0.94
- 0.95 - 0.99

* Data Source: Virginia Health Information, Hospital Discharge Data
Dependent Variable: Stroke Hospitalization Rate
Independent Variables: PctPoverty, Pct 65 & Over, Average Distance to Care, PCP FTEs, Length of Stay
Modeled Relationship Across the Study Area

- Percent 65 & Over Spatial Variation
- Average Distance Coefficient Spatial Variation
- Percent Poverty Coefficient Spatial Variation
- Average Length of Stay Coefficient Spatial Variation
- Total Primary Care Providers Total FTEs Coefficient Spatial Variation
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