Tennessee's Hospital Closures: A GIS-Informed Approach to Understanding Access to Care Effects on County-Level Mortality and Rural Communities, 2010 – 2019

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Dedication

I dedicate this dissertation to my family. First, to my husband, Don, who is an unwavering bulwark against any self-doubt. You have provided me with steadfast love and support from the time we first met and never questioned nursing as my calling as we grew into our life together. Your enthusiasm for my efforts is palpable, an attitude that has kept our family moving forward during times of stress and near exhaustion. Second, to my son Frank and daughter Lisa, I didn't always say it well, but I appreciate your sacrifices more than I can express. You have always cheered, "you go, Mom," even when I worried my academic and professional responsibilities shorted you of the attention you deserved. I genuinely hope you understand how much I love you both and appreciate everything you have done to complete our family.

To my parents, Marjorie, Howard, and Janice, I owe you more than I can ever repay. You have always believed in me, never doubting my ability to get the job done. When I was diagnosed with a life-changing illness, you encouraged me to use adversity to help others facing similar challenges. Your focus on the benefits of education stimulated a passion for learning that has carried me throughout my years. I can only hope to one day win that game of Scrabble, Mom. Dad, you left us too soon; how I wish you could have been here to see this dream come to fruition and add to your legacy of community service. Mom, I am eternally grateful for the love and dedication you showered upon me and our family; I owe my compassion for the underserved and less fortunate to your unwavering example. Janice, I will always cherish your love, kindness, and care for Dad and our entire family; you have no idea the gift you gave us.

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I first met Dr. Patricia Roberson in a statistics class my first year in the PhD program. Despite the numerical data focus of the class, I quickly learned that she has an uncanny ability to quickly assess the direction a manuscript or other written work is going and where it should wind up to make it a concise yet flowing piece of literature. Her assistance with my literature review was most beneficial, and I aspire to work with her again in the future, as we share a common love for rural and Appalachian communities.

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Abstract

Twenty Tennessee hospitals have closed since 2010, increasing the distance and travel time to care, especially for rural communities with prevailing health disparities. Associated mortality increases are concerning, especially from time-sensitive events, like heart attacks. Twenty-seven of the state's rural hospitals are considered immediate- or high-risk for closure, increasing concerns regarding future access and worsening health disparities. Nevertheless, scant studies have examined the impact of these closures on Tennesseans' health outcomes.

The Vulnerable Populations Conceptual Model (VPCM), the framework for this study, iteratively links resources, relative risk, and health status in a circular predictive model. Consequently, this study serves to answer the following overarching question: Considering Tennessee's hospital closures since 2010, what is the relationship between the state's disparate rural health outcomes and the growing distance/travel time to hospital and emergency care?

This retrospective ecological study employed a spatial generalized linear mixed-effects regression model (GLMM), using publicly available datasets from the U.S. Census Bureau, Department of Homeland Security, HRSA, the CDC, and the Tennessee Department of Health. Analyses ascertained the relationships between distance and travel times to hospital and emergency services and other environmental and human capital resources to county-level all-cause and time-sensitive mortality rates from 2010-2019.

In our bivariate analyses, access to hospital and emergency care correlated significantly with county-level mortality rates. However, the significance level diminished in the GLMMs (adjusted for county-level median household income, median age, ethnicity, rurality, and uninsured status). Nonetheless, the clinical significance of the travel time and distance to hospital and emergency care mortality effects cannot be understated, especially for the poor and underserved.

This study should inform long-term equitable resource investment to improve the health and well-being of all, especially those residing in Tennessee's rural areas. Investing in and improving the health of individual communities serves to improve their socioeconomic status and trigger a “virtuous cycle” of enhanced well-being and economic gains. This study may not be fully generalizable but provides a foundation for assessing rural health disparities nationwide. Furthermore, the spatial methodology provides an analytic platform for future health disparities research.

Keywords: hospital closures, rural, vulnerable populations, access to care, health equity

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Introduction

Hospitals are closing across the United States (U.S.) (Cecil G. Sheps Center for Health Services Research, 2020), raising concerns about the effects on patients, particularly those residing in vulnerable communities with existing health disparities. The U.S.'s hospital closure phenomenon is not entirely new, but the nation saw overall *increases* in the number of hospitals until the early 2000s (American Hospital Association Resource Center, 2014). Many of that era's hospital closures reduced redundant services (Wishner et al., 2016). Since 2010, however, hospitals and emergency rooms have closed at unprecedented rates, resulting from myriad factors culminating in financial shortfalls (Chartis Center for Rural Health, 2020). See Figure 1 for a flow-through diagram of hospital closures' causes and effects.

After reaching a bed-to-population ratio high of 4.5 beds to 1000 civilian population in 1980 (Committee on Energy and Commerce, 1983; Shi & Singh, 2019), the 2019 bed to population ratios fell to 2.4 per 1000 nationwide and 2.7 per 1000 in Tennessee (Kamal et al., 2020). The bulk of these closures has disproportionately affected rural and other vulnerable communities (Cecil G. Sheps Center for Health Services Research, 2021a). This decline in the geographic density of hospital services has cumulatively increased travel times to emergency and other needed hospital services. Since 2013, one-third of the closed hospitals were 20 or more miles from the nearest hospital (Medicare Payment Advisory Council, 2018). Additionally, from 2012 to 2018, the median distance to general inpatient services increased by 20.5 miles (and even more for less common specialist services) in affected communities (U.S. Government Accountability Office, 2020).

Notably, Tennessee's hospital closures rank the highest per capita in the U.S. (Cecil G. Sheps Center for Health Services Research, 2021a). As a result, 22 of the state's 95 counties have no inpatient hospital services, and 19 are without an emergency department (Murry et al., 2021; Pelligran, 2019). Like the nationwide trend (Cecil G. Sheps Center for Health Services Research, 2021a, 2021b), the state's rural communities have borne the burden of these closures, with some of them now lying 60 or more minutes from hospital services and emergency care (Tennessee Health Care Modernization Task Force, 2020). While hundreds of hospitals across the nation are at risk of closure (Balasubramanian & Jones, 2016), the South is home to more financially distressed hospitals (Thomas et al., 2019), and 27 of Tennessee's rural hospitals remain at immediate or high risk for closure (Miller, 2020).

Most rural U.S. residents encounter disparate health outcomes (Cecil G. Sheps Center for Health Services Research, 2021a; Gong et al., 2019; Hoffman & Holmes, 2017; Rural Health Information Hub, 2021), and the gap in comparison to urban dwellers is widening. For example, a recent study found that age-adjusted mortality differences tripled between 1999 and 2019 (Cross et al., 2021). Manifestations of these disparities include higher incidences of chronic disease, higher mortality rates, decreased access to essential health care services, and lower socioeconomic status (Rural Health Information Hub, 2021; Tennessee Hospital Association, 2021). In Tennessee, these disparities contribute to the state's ranking of 44th out of 50 states in clinical care and health outcomes (United Health Foundation, 2021). Moreover, as rural areas lose access to vital health care services (including hospital and emergency care), the risk for worsening mortality rates from time-sensitive events grows (Gujral & Basu, 2019), as do health disparities (Rural Health Information Hub, 2021).

Knowledge Gap

Research to date demonstrates that rural hospitals, many of which are critical access hospitals (CAHs) (Centers for Medicare and Medicaid Services, 2021a; Taylor, 2019), serve a vital role in providing access to care in rural and underserved communities (Ibrahim et al., 2016; Ibrahim et al., 2018; Johnston et al., 2019; Natafgi et al., 2017; Windorski et al., 2019). Accordingly, numerous rural hospital closures studies have assessed the closures' impact on access to care (Anderson et al., 2019; Burkey et al., 2017; Countouris et al., 2014; Hsia & Shen, 2011; Johnston et al., 2019; McCarthy et al., 2021; Murry et al., 2021; Romero et al., 2012; Shen & Hsia, 2012; Wishner et al., 2016). At the same time, most rural hospital health outcomes studies have assessed the quality of care delivered in these facilities (Gadzinski et al., 2013;

Ibrahim et al., 2016; Ibrahim et al., 2018; Joynt et al., 2011; Joynt et al., 2013; Lichtman et al., 2012; Natafgi et al., 2017; Windorski et al., 2019). Nevertheless, few researchers have examined rural and vulnerable community hospital closures' effects on mortality and morbidity. The scant early studies investigating the health outcomes effects of closures found few detrimental effects, as early hospital closures primarily served to reduce oversupply and redundant services (Joynt et al., 2015). However, as more hospitals close and travel times to these services accumulate, the current literature falls short on health outcomes effects, especially in understanding the impact of Tennessee's closures.

Scientific Domain - Nursing and Spatial Science

Researchers are increasingly examining the effects of hospital closures through a spatial lens (Burkey et al., 2017; Busingye et al., 2011; McCarthy et al., 2021). Again, most of these studies linked closures to changes in care access. For example, McCarthy et al. (2021) examined the effects of hospital closures nationwide (2010 – 2019) by creating 15-, 30-, 45- and 60-minute isochrones. They found that rural areas were more prone to closures, though most residents did not lose hospital services within a 60-minute drive. Yamashita and Kunkel (2010) analyzed the associations between hospital care access, socioeconomic factors, and heart disease mortality. While they found that socioeconomic and sociodemographic status mediated the access effects on heart disease mortality in Ohio, their use of straight-line (i.e., Euclidean) distances to care may have influenced their results.

Notably, geographic information system (GIS) platforms provide powerful analytic tools for integrating spatial variables (and associated social data) into descriptive and inferential statistical analyses. Moreover, nurses are increasingly joining multidisciplinary research teams (Rababah et al., 2014) to merge person- and health-related data to geospatial units as a "new way of seeing and applying the metaparadigms of nursing" (Moss & Schell, 2004, p. 150) to further practice, pedagogy, and research. While GIS is relatively new to nursing research, investigators can use this exploratory and analytic tool for visualizing health-related phenomena and diving deeper into the effects of environmental factors on health outcomes (Rababah et al., 2014). Because of this deeper analytic purpose, the Vulnerable Populations Conceptual Model (VPCM) and the Access to Care Framework (both described below) frame this study.

Theories

The Vulnerable Populations Conceptual Model

Flaskerud and Winslow (1998), nursing faculty at the University of California Los Angeles (UCLA), developed the VPCM in the late 1990s to understand health vulnerabilities and care for vulnerable patient communities. Myriad researchers (using both quantitative and qualitative methods) have used the model to identify vulnerable populations and develop community-based interventions. Nurses employ this iterative model for exploring the relationships between factors leading to vulnerability and their effects on health outcomes (Flaskerud & Winslow, 1998).

Concepts

In particular, the authors link resource availability to relative risk in terms of exposure to risk factors and health behaviors and how these factors ultimately influence health status and outcomes. However, they also emphasize the bidirectional relationship between health outcomes and relative risk. Lastly, they close the iterative loop connecting health status to resource availability. At the center of the VPCM lies research, practice, ethics, and policy analysis as ways to impact its conceptual components and care of vulnerable patients, communities, and populations. Notably, nurses routinely address these concepts (resources, risks, and outcomes) in daily clinical practice and research (American Nurses Association, 2015).

Flaskerud and Winslow (1998) promoted the VPCM's use in describing vulnerability, predicting outcomes, and developing interventions for vulnerable populations. The authors describe the three overarching concepts in detail while also outlining the sub-categories of each. For example, they break resource availability into socioeconomic and environmental resources, further delineated as human capital, social connectedness and integration, social status, and access to quality health care services. The theorists state how resource availability affects relative risk (in terms of exposure to risk factors and health behaviors) and how this risk influences health status and outcomes. However, they also emphasized the bidirectional relationship between health outcomes and relative risk. Lastly, they close the iterative loop connecting health status to resource availability.

Empirical Indicators

Flaskerud and Winslow (1998) define the VPCM concepts at the middle level of abstraction (Smith, 2018). Consequently, they define resource attributes (that allow the researcher to identify the resources for any given population) without specifying the specific resource metric (e.g., access to obstetrics care in a rural community). The nurse researcher must recognize these metrics specifically. On the other hand, the theorists suggest empirical indicators for each concept and subgroup, leaving room for interpretation and recognition of additional metrics of the population under study. While the VPCM constructs form a complete iterative circular model, others may add to the model's depth. For instance, González-Guarda et al. (2009) called for adding cultural factors to the model, while Dixon (2004) extended the VPCM in the Social Ecologic Model of Neighborhood Health to more site-specific resources within neighborhoods. However, the VPCM displays more mid-range abstractness by omitting specific locations.

Empirical indicators of the VPCM's concepts vary by the population under consideration, but common health status indicators include mortality rates, disease incidence and prevalence rates, and diagnosis delays (Leight, 2003). The theorists capture human capital resources in income and education levels, housing accommodations, and employment statistics. Flaskerud and Winslow (1998) viewed relative risk as exposure to risk factors, such as rates of obesity, smoking, seatbelt usage, and vaccination. However, they also emphasize the opposite directional correlation between health outcomes and relative risk, noting that health outcomes may increase the exposure to additional risk factors. The VPCM's authors also indicate that finding adequate indicators and correlates of vulnerability is challenging. Still, most researchers utilizing this theory employed quantitative methodologies, affirming the workable empirical metrics of the VPCM concepts (Leight, 2003).

Testability and Functionality

According to Smith (2018), functional adequacy is the "acid test" (p. 42) of middle-range nursing theory. The VPCM passes this test. Researchers have applied it to diverse environments and populations, including caregivers of the mentally ill (Copeland, 2007), inner-city assisted living residents (Decker et al., 2006), pregnant adolescent minority females (Spears et al., 2010), victims of natural disasters (Saunders, 2007), Hispanic and Mexican peoples in America (Albarran & Nyamathi, 2011; González-Guarda et al., 2009), and the elderly at risk for nursing home placement (Palmer et al., 2014). More relevant to rural hospital closures research, Samuel-Nakamura et al. (2017) identified populations with decreased access to care as vulnerable, while multiple authors have demonstrated the theory's applicability to rural populations (Dulemba et al., 2016; Leight, 2003; Rawlett, 2011; Rodehorst et al., 2006).

While researchers frequently use the model for purposes of research, Flaskerud and Winslow (1998) also point to the theory's use for developing community interventions for practice to enhance primary, secondary, and tertiary prevention, many of which are lacking in vulnerable populations. Furthermore, as nurses work to achieve social justice and equity (American Nurses Association, 2015), the VPCM enhances the functionality of professional discourse in health policy and ethics.

The Integrative-Interactive Paradigm

Most nursing theories within the integrative-interactive paradigm are systems-based theories, meaning that the system components are mutually dependent and interrelate with the broader reaching contextual or environmental system (Smith & Parker, 2015). The environmental factors lead to changes that impact the health and well-being of the person or community, but the person's responses to the contextual factors are multidimensional and subjective. Thus, these theories prompt explorations of nuanced, interdependent (i.e., reciprocal) responses to changes in the contextual elements. Peterson (2009) noted these integrative-interactive theories also concern the predictability of the resultant chance variations in health-related phenomena. Rawlett (2011) asserted that the theorists linked their VPCM to this paradigm, as numerous determinants and components interact within a community (system) to impact resources, relative risk, and health status. In other words, the health status of vulnerable populations depends upon the interactions (i.e., interplay) of resource components moderated or mediated by relative risk (Flaskerud & Winslow, 1998).

Use of the VPCM in Rural Health Services Research

As previously observed, rural populations are vulnerable in many regards (Dulemba et al., 2016; Leight, 2003; Rawlett, 2011; Rodehorst et al., 2006), making the VPCM a solid framework for rural health services research. Relative risk and health outcomes potentially ebb and flow with the availability of resources (both internal and external). Therefore, researchers may expect dwindling rural access to health care resources to increase the risk of adverse outcomes (visa vie limited access to many preventive care measures or rapid treatment for time-sensitive events). The declining health of rural populations (Rural Health Information Hub, 2021; Tennessee Department of Health, 2019) may also further affect resource availability, as remaining limited resources are required to care for a sicker population.

Accordingly, we expect health outcomes (e.g., mortality) will respond to shifts in resource availability (e.g., hospital and emergency department availability). However, the predictability of that response relies in part on the human capital, which may, in turn, affect the subjective reactions to shifts in access to care (McLaughlin & Wyszewianski, 2002). This point is where human capital (i.e., social determinants) enters the picture. While impossible to account for all response variability, prior research has confirmed the health status effects of socioeconomic factors (U.S. Department of Health and Human Services, 2021).

Khan and Bhardwaj's Access to Care Framework

Access to care is a significant construct of resource availability within the VPCM and, consequently, my research. Researchers have defined access in various ways (Aday & Andersen, 1974; MacKinney et al., 2014; Penchansky & Thomas, 1981). However, Khan and Bhardwaj (1994) distinguish between potential and realized spatial and aspatial (social) access to care.

Though developed for the geography discipline (rather than nursing), the Khan and Bhardwaj (1994) framework bears similarities to the VPCM (Flaskerud & Winslow, 1998) in specific ways. Constructs of the Access to Care Framework align with the interaction of contextual and multidimensional factors, paralleling the integrative-interactive paradigm (Khan & Bhardwaj, 1994; Smith, 2018). These geo-theorists also recognized the moderating effects of facilitators and barriers to transition access from potential to realized access, much like relative risk moderates or mediates resource effects on health outcomes. However, access to care, primarily spatial and aspatial (i.e., social) access, along with potential and realized access, is the critical dimension of Khan and Bhardwaj's framework that researchers may integrate into the VPCM resource indicators.

Notwithstanding, Khan and Bhardwaj (1994) did not extend their framework to include health outcomes. While useful (and will indeed be incorporated into defining access within my spatially informed study), spatial and aspatial potential and realized access could not serve as a proxy for health status or outcomes. Khan and Bhardwaj recognized this, as well. They explicitly stated their framework should "lead to the development of appropriate quantitative measures to *reflect specific dimensions* of the access to health care problem" (p. 73). They also advocated for future research that recognizes health care system deficiencies and leads to new system designs. Presumably, detailed rural health systems evaluations would include assessing their impact on health outcomes and health disparities.

Research Question, Purpose, and Aims

This study is commensurate with the VPCM and the Access to Care Framework and seeks to answer the following research question. Considering Tennessee's elevated hospital closure rate since 2010, what is the relationship between the state's disparate rural mortality rates and declining access to hospital and emergency care, adjusting for other environmental and human capital resources?

Accordingly, this study provides a comprehensive analysis of Tennessee's hospital closures' effects on county-level mortality rates, considering spatial and aspatial characteristics, including rurality, local resources, race/ethnicity, and socioeconomic factors. Specifically, this study aims to 1.) understand the impact of changing travel times to hospital and emergency care on county-level mortality rates in Tennessee, 2.) ascertain which social and environmental factors mediate these health outcomes effects, 3.) understand the impact of growing travel times in Tennessee on the relative risk of dying from time-sensitive events, and 4.) inform long-term policy solutions to allocate resources equitably and reduce Tennessee's rural health disparities. Notably, the community foci of the VPCM and access to care framework further enhance their use in formulating policies (i.e., interventions) to meet the needs of rural and vulnerable communities across Tennessee.

Additional Orientational Definitions

Health Equity

Health equity is the fair and unbiased opportunity to reach one's maximum health capacity and quality of life (Fawcett, 2019), achievable through just access to social determinants of health (e.g., adequate income, education, and safe housing) and health care services (Fawcett & Russell, 2001). Nurses, health care providers, policymakers, and administrators are increasingly approaching decision-making with a health equity focus. CMS's growing efforts to reach equitable solutions for rural communities lacking healthcare resources are evidence of this priority shift (Centers for Medicare and Medicaid Services, 2021b).

Rural Hospitals

For purposes of this study, we define rural hospitals per the Cecil G. Sheps Center for Health Services Research (2021b). This center describes rural hospitals as non-federal, short-term, general acute care hospitals operated as critical access hospitals or in non-metropolitan counties or urban-rural commuting areas type 4 or higher. However, we factor both urban and rural hospital closures (resulting from complete cessation of inpatient and emergency department services) into our analyses since we assess urban and rural county-level mortality rates for comparison in the study. This approach is commensurate with the closures' potential adverse health outcomes effects at bystander hospitals (Hsia & Shen, 2019).

Summary

This dissertation comprises four chapters, including this introductory chapter. The chapters that follow include three manuscripts covering the essential elements of this study. The first manuscript is a comprehensive literature review encompassing the quality of care delivered in rural hospitals and the effects of hospital closures on rural and vulnerable communities. This first manuscript identifies knowledge gaps and implications for future research and policymakers. The second manuscript presents the use of GIS-informed nursing research methodologies to assess access to care. This manuscript includes an exemplar explaining our assessment of three methods of calculating distance and travel times to hospital and emergency care as predictors of health outcomes in Tennessee. The third manuscript presents this study's GIS-based research design, metrics, data sources, analyses, results, and implications (with recommendations for policymakers). A conclusion section follows the final manuscript.

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Hospital Closures

Factors and Outcomes

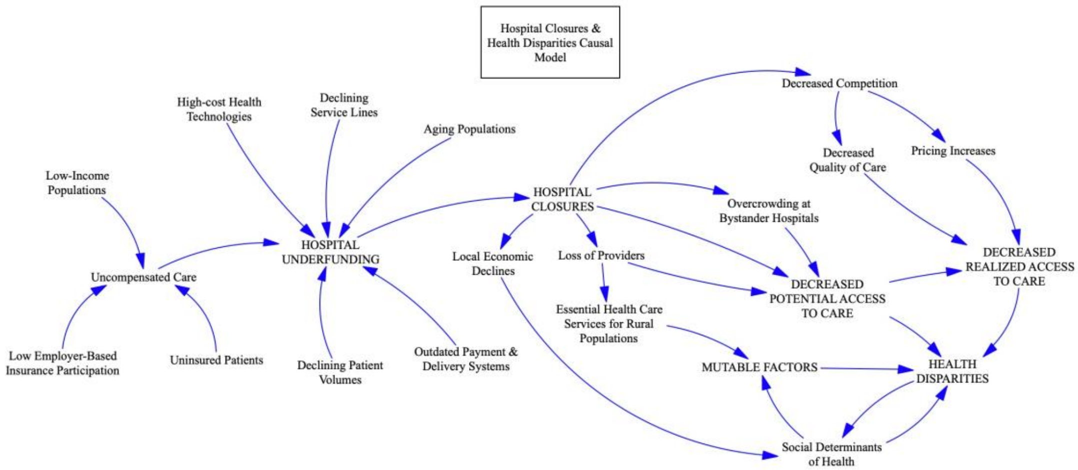

Figure 1. *Hospital closures: Factors and outcomes*

Chapter 1: Effects of U.S. Hospital and Emergency Department Closures on the Health Status of Vulnerable Rural Populations: An Integrative Literature Review

This chapter, written by Tracey Stansberry, Patricia Roberson, and Carole Myers, will be submitted for publication (target journal to be determined).

Stansberry, T., Roberson, P., & Myers, C.R. (2022). Effects of U.S. hospital & emergency department closures on the health status of vulnerable rural populations: An integrative literature review [Unpublished manuscript]. In preparation.

Abstract

Background. Hospital and emergency department closures are emblematic of America's changing health care delivery system, which often places vulnerable rural communities at further risk for poor health outcomes. Framed by the Vulnerable Populations Conceptual Model, this review aims to synthesize the existing research addressing this phenomenon.

Methods. We conducted an integrative literature review, comparing and contrasting articles via a matrix method. We identified 26 primary research studies (24 quantitative and two qualitative) through databases and ancestral searches from 2010 forward. The authors deductively coded the articles according to the constructs of the Vulnerable Populations Conceptual Model.

Results. Two overarching themes emerged from the literature: 1.) Association of rural hospitals and patient health outcomes, and 2.) Access to hospital care - effects of closures and openings on vulnerable rural populations. Subthemes reflected access to care and other resources, relative risks associated with time-sensitive health events, and health outcomes.

Conclusions. Rural hospitals provide access to essential health services and emergency care in these vulnerable, underserved communities. Their loss may increase adverse outcomes in affected communities and the overall health system. However, more data quantifying these effects and the impact of confounding factors are needed. Stakeholders from multiple disciplines must jointly address declining access to hospital and emergency care by focusing policy improvements on social determinants of health, quality assurance, innovative health care delivery systems, and sustainable rural hospital funding.

*Keywords***.** Hospitals, rural; vulnerable populations; social determinants of health; health outcomes

America's health care delivery system is quickly shifting in ways that disproportionately place vulnerable rural populations at additional risk for poor health outcomes. Driven by multiple factors, rural hospital and emergency department closures illustrate dramatic shifts in health care conveyance. Presumably, cascading impacts of rural hospital closures ensue, but little research into the effects of this change on health outcomes and social determinants exists. Framed by the Vulnerable Populations Conceptual Model (VPCM),[1] this review synthesizes the existing research about hospitals and emergency departments in vulnerable rural communities and the effects of their closures on patients.

Hospital Closures Trend

Since 2010, approximately 140 rural hospitals have closed across the United States (since 2005, the number of rural closures has exceeded 180).[2] Defining closures is somewhat inconsistent in the literature, as some hospitals convert to providing other health care services (e.g., emergency services, skilled nursing care, primary care, and behavioral health services) while others cease operations entirely. According to the Cecil G. Sheps Center for Health Services Research at the University of North Carolina (a recognized authority on U.S. hospital closures),[2] since 2005, 98 rural hospitals have closed entirely, and 83 converted to other services. Other researchers may define hospitals and closures somewhat differently, making comparisons across studies of closures challenging and complex.

Before 2010, the nation experienced net increases in the number of hospitals. In the 1940s, Congress passed the Hospital Survey and Construction Act of 1946 (i.e., the Hill-Burton Act), intending to bring the hospital beds to 1000 civilian population ratio from 3.2 up to 4.5 per 1000.[3] By 1980, communities met this goal.[4] Growth continued for a while with a net gain in the number of Medicare-participating hospitals, with openings outpacing closures by 116 from 2000 to 2010.[5] During that era, the few hospital closures that occurred had negligible effects on health outcomes.[6]

However, recent hospital closures and declining numbers of inpatient beds reduced the 2019 bed-to-population ratios from *pre*-Hill Burton levels to 2.4 per 1000 nationwide.[7] As the geographic density of hospital services continues to decline, particularly in the South, where 65% of the nation's 2020 rural hospital closures occurred,[8] travel times to emergency and other needed hospital services have increased substantially.[9] The South was home to more hospitals (920 urban, 899 rural) in 2012 – 2013 than any other geographic region of the U.S., accounting for more than 38% of the nation's 4,722 short-term acute care hospitals.[10] These numbers possibly account for the significant number of Southern hospital closures, as those with redundant services could not compete for increasingly limited financial resources, providers, and patients.[11] Other factors contributing to declining rural hospital numbers and bed-to-population ratios include shifts away from inpatient care to outpatient services, consolidated delivery arrangements, changing rural sociodemographic and economic characteristics, and lower reimbursement rates.[4,11]

Still, as more hospitals close, travel times increase cumulatively. For example, since 2013, one-third of hospital closures occurred 20 or more miles from the nearest hospital,[12] an increase from earlier years. In addition, the U.S. Government Accountability Office[9] reported that the median distance to general inpatient services for affected communities increased by 20.5 miles from 2012 to 2018 (even more for specialist services).

Rural Hospitals

Medicare has several special designations for rural hospitals, including sole community hospitals, Medicare-dependent hospitals, rural referral centers, prospective payment system (PPS) hospitals, and critical access hospitals (CAHs).[13,14] To qualify as a CAH, the facility must be in a rural area or one treated as rural, have 25 or fewer inpatient beds, have an average length of stay (LOS) per patient of 96 or fewer hours, and be 35 or more miles from the nearest hospital. CAHs made up 53.5% of rural hospitals in 2015,[10] but by 2019, they accounted for two-thirds of the nation's rural hospitals.[14] Thus, this review of rural hospital quality or loss of services will include studies of CAHs, which are particularly vital in meeting the needs of people living in underserved, vulnerable rural regions and understanding the impact of hospital closures.[2,14] For closure statistics, the Cecil G. Sheps Center defines rural hospitals as non-federal, short-term, general acute care hospitals operated as a CAH or those located in non-metropolitan counties or rural-urban commuting areas type 4 or higher.[8]

Vulnerable Populations Conceptual Model

The VPCM[1], developed by nursing faculty at the University of California Los Angeles, is a theory that describes the factors leading to the vulnerability of specific populations and predicts health outcomes as an offshoot of resource availability and altered relative risk.[1,15] This circular, iterative model integrates socioeconomic (e.g., social determinants of health [SDOH]) and environmental resources (e.g., access to quality health care). Empirical health status metrics include mortality and morbidity, while relative risk measures include exposure to risk factors (e.g., smoking) and health behaviors, such as health services utilization (or lack thereof) and vaccination uptake. In the present context of hospital and emergency department closures, we examine the impacts of resource shifts on relative risks (e.g., timely utilization of health services) and health status indicators (i.e., resultant effects on health outcomes such as mortality).

Objective

The number of hospital closures and reduced access to emergency services for patients is well documented.[2,9,16] However, the impact of these closures on health care quality and outcomes is unclear and disparate. The primary aim of this review is to synthesize the existing research about 1.) hospitals' role in providing high-quality health care resources in vulnerable rural communities, and 2.) the consequent impact of hospital and emergency department closures on relative risks for adverse outcomes and worsening health disparities compared with other populations. Given the VPCM's proposed application to future research and public policy[1] (see Figure 1.1), additional aims include informing upcoming studies of rural hospital closure effects at the state and county levels and informing impactful legislation and other policies to mitigate adverse outcomes.

Method

Integrative Review Method

Given the multidisciplinary nature of health services research, this literature review employed a modified integrative review method[17] and an organizational matrix[18] to facilitate the analysis. Integrative reviews broadly incorporate articles from diverse methodologies (experimental and non-experimental designs) and various perspectives on a phenomenon (including theory development).[17] We used a systematic search for relevant primary source data from multiple sources, as described below. After screening the articles, the primary author organized the articles in a matrix;[18] each row contained a single article, and columns comprised author/date, theoretical framework, research question, methodology and sample characteristics, analysis and results, conclusions, limitations and strengths, score, and next steps for researchers to consider. The primary author reviewed the articles for this integrative review and deductively coded the data to identify common themes and gaps in the literature,[17] using the VPCM framework.[1] Later, the second author reviewed the themes and proposed several changes. The two authors then resolved the coding differences through collegial discussions, comparing source materials.

Quality Scoring

Due to articles employing a wide range of empirical methods, this review used a simple data quality scoring system, as suggested by Whittemore and Knafl.[17] Accordingly, we assigned high or low scores for scientific rigor and data relevance. Given the non-randomized, non-interventional style of the articles, we assigned a low score for rigor unless the authors explicitly overcame these and other limitations. For example, Gadzinski and colleagues[19] utilized an observational retrospective cohort method, so we assigned a low rigor score because of the study's multiple limitations, including the use of administrative data, use of a somewhat limited and geographically asymmetrical subset of CAHs, and use of charges instead of actual payments for their cost analysis. However, we assigned a high relevance score since these authors compared post-surgical mortality rates between CAHs and non-CAHs and explained why reduced payments to struggling rural hospitals could be more problematic than beneficial.

Furthermore, we included articles about non-rural hospitals if the communities they served were vulnerable in other ways. However, we assigned a low relevance score to them. Articles were not omitted according to their scores, but those with low rigor or relevance contributed less to the final analysis.

Sampling

This review employed structured, comprehensive, and transparent selective sampling of the literature,[20] querying three databases - CINAHL, PubMed, and Scopus - in February and March 2020. The following search terms were used: TI ((hospital* OR (emergenc* AND department* OR room* or center* OR ward* OR facilit* OR service* OR ED OR ER))) AND TI ((closur* OR closing* OR shut* OR terminat* OR stop* OR "lack of access*" or "decreas* access")) AND AB ((county OR counties OR communit* OR region* OR rural)) AND AB ((death* OR mortalit* OR fatalit* OR morbidit* OR "loss of life")). The initial literature search was limited to publication dates of 2010-2020 (to identify contemporary articles); however, many of the articles published in this timeframe (and included in the review) involved retrospective analyses of data dating back into the mid-1990s. Additional inclusion criteria were articles found in peer-reviewed journals and written in English. Ancestral sources identified from bibliographies[17] were also allowed. We assumed articles examining closures of specific departments within hospitals (other than emergency departments) were beyond the scope of this review and excluded them from the analysis. However, the final dataset included studies examining the type of care and outcomes in existing facilities, as they factor into resource availability and potentially affect health outcomes if their quality or accessibility shift.

The final search diagram (see Figure 1.2) reflects an initial yield of 164 articles. Twenty-three duplicates were removed. One hundred forty-one articles were then screened, 99 of which we removed for not fully meeting inclusion criteria. Forty-two articles were further screened; 19 were removed having met exclusion criteria (international or non-research articles). In July 2021, we updated the dataset to include three additional articles identified from bibliographies and other sources. The final sample included two qualitative studies and 24 quantitative studies. Notably, one study[21] was available only as a conference abstract. Still, we included it, given its focus and implications for the research phenomenon.

Results

Summary of Papers

The authors stated theories and conceptual frameworks for three articles identified for this review.[22-24] These included Yamashita and Kunkel's[24] use of Andersen's classic behavioral model of health care, as well as Hsia and Shen's[22] and Shen and Hsia's[23] use of study data to inform their development of conceptual frameworks to understand the effects of emergency department closures on patient care at bystander hospitals (the nearest available facility offering similar services) and effects of delayed care. However, an implicit recognition of underserved and vulnerable populations was noted throughout the remaining 23 studies. In total, 17 studies examined the effects of access to care or the effects of hospital and emergency department closures or openings.[6,21-36] Nine articles reported the comparative effects of health outcomes in hospitals and emergency departments based upon facility type (e.g., rural vs. non-rural, CAHs vs. non-CAHs).[19,37-44] See Table 1.1 for a summary of papers, including quality scores. Because most CAHs exist in rural areas, we classified them as rural for this analysis.

Twenty-three quantitative studies employed retrospective designs, often using large datasets and incorporating large sample sizes.[6,19,21-29,33-44] On the lower end, one study comprised 1,438 survey respondents,[30] while another assessed age-adjusted heart disease mortality in 88 counties (though these counties represented more than 11 million residents).[24]

On the upper end, one study assessed hospital closure effects on 32,485,906 Medicare beneficiaries in 2,847 hospital service areas,[6] while another involved 66,585,996 weighted patient-years for 11,581 beneficiaries.[38] As expected, the two qualitative studies had smaller sample sizes, one with 16 key informants and 44 focus group participants[31] and the other with 37 focus group participants.[32] One quantitative study[35] utilized prospective optimization modeling and retrospective analyses. Alternatively, another quantitative study involved a descriptive survey of patients affected by a hospital and emergency room closure.[30] Ten studies employed geographic information systems, zip code, and census data to compute drive times or other spatial effects on outcomes.[22-28,33-35] The two studies by Romero et al.[30,31] were reported separately as part of a more extensive mixed-methods study, so we analyzed the quantitative and qualitative manuscripts separately. Individual quantitative and qualitative articles were weighted equally in this analysis.

As the review proceeded, commonalities reflecting the concepts from the VPCM were noted across the studies' dependent variables (DVs), independent variables (IVs), and covariates (CVs). Most of the IVs reflected resource availability or relative risk,[6,19,22-29,33-35,39-44] while the DVs reflected health status in terms of mortality and morbidity,[6,19,21-24,27-29,33,37-40,42-44] LOS,[6,19,37] readmission rates,[6,22,39,40,44] overall cost,[6,19,39] and other adverse events. However, one study[36] assessed the impact of changing hospital resources on the availability of other resources, namely physician supply. Mortality rate metrics were either disease- or procedure-specific deaths or all-cause mortality. CVs most often reflected relative risk metrics (i.e., demographics, diagnoses, or SDOH).[6,19,23,24,27-29,33,36,37,40-44] Timelines for retrospective reviews of hospital and emergency department closures most often included data from the late 1990s to 2016.[6,21-25,27-32,36] Two studies from the updated sample examined more recent data.[34,35]

After reviewing the purpose and findings of the studies, two overarching themes emerged from the data: 1.) Association of rural hospitals and patient health outcomes, and 2.)

Access to hospital care - effects of closures and openings on vulnerable rural populations. Subthemes framed according to the VPCM constructs follow below.

Theme 1: Association of Rural Hospitals and Patient Health Outcomes

We found that many articles focused on rural hospitals' health outcomes. Most articles revealed favorable effects, but several noted unfavorable outcomes. Assume these institutions provide an acceptable level of care; commensurate with the VCPM[1], the loss of these facilities would adversely affect the health outcomes of the people they serve.

Favorable Outcomes

Much of the data regarding the quality of rural hospitals and CAHs are favorable. Ibrahim and associates[39,40] and Gadzinski and colleagues[19] found that CAHs performed better or comparably compared with non-CAHs in post-surgical inpatient mortality rates, serious complications, and LOS. Furthermore, Natafgi et al.[41] found no significant difference between CAHs and comparably sized PPS non-CAHs in four states (Colorado, North Carolina, Vermont, and Wisconsin) on surgical patient safety indicators. The findings were not without caveats. These researchers found higher rates of re-operation and readmissions and higher costs for specific procedures at CAHs.[19,39,40] The authors concluded that CAHs provide quality surgical care to underserved patients in remote and rural locations but that these facilities may benefit from additional resources for post-operative care.[19,39-41]

Additionally, patients stabilized at CAHs before transfers to Level I trauma centers tended to fare better than those transferred directly to Level I trauma centers.[37] Thus, the researchers concluded that CAHs fill gaps in rural coverage and may reduce unnecessary transfers to Level I trauma centers for less severe injuries and illnesses, potentially accruing significant savings to the health care system.

Unfavorable Outcomes

On the other hand, Joynt, Harris, et al.[43] and Joynt, Orav, et al.[42] studied quality indicators at large numbers of CAHs and non-CAHs for acute myocardial infarction, congestive heart failure, and pneumonia. Across all three diagnoses, 30-day mortality was significantly greater at CAHs than non-CAHs. However, the absolute differences were relatively small (1.8% in Joynt, Orav, et al.), with the authors concluding that the CAHs serve the vital purpose of providing access to care for rural and underserved communities. However, quality enhancements are needed.[42,43]

Similarly, in 2006, Lichtman et al.[44] found that the 30-day risk-stratified mortality rate was significantly higher for ischemic stroke patients at CAHs. However, the 30-day risk-stratified readmission rate was lower at CAHs vs. non-CAHs. Low-volume non-CAHs had similar 30-day risk-stratified mortality rates to CAHs, pointing to low patient volumes, reduced CAH resources, and patient characteristics not accounted for in this study, possibly affecting the findings.

Theme 2: Access to Hospital Care - Effects of Closures and Openings on Vulnerable Rural Populations

As theorized by the VPCM,[1] resource availability differences influence health outcomes. Accordingly, the second theme derived from the data comprises the differences in health status between areas with full access to hospital and emergency care and those without access to needed services. According to Johnston and colleagues,[38] variances in hospital beds per 1,000 people in the hospital service area were associated with significant differences in mortality rates. Access to care factors accounted for 89% of the probability of preventable hospitalizations and 32% of mortality differences between urban and rural residents.

The closure of hospitals and emergency departments disproportionately affects low-income and minority populations. Vulnerable populations, particularly impoverished and African American communities, were 32% more likely to face increased drive times of more than 30 minutes than more affluent communities.[25] Communities with medium or high proportions of patients without insurance experienced 69% and 55% higher chances of experiencing changes in drive time increases. Rural communities were at a higher risk of experiencing these increased drive times than urban areas. Emergency department closures affected only 11% of the population from 1996 to 2005, but affected communities were more likely to be rural.[23] Additionally, decreased access to hospital care increased the vulnerability of rural populations (with extant income and education deficiencies) to medical and social disparities[38] compared to urban populations and further decreased access to other needed care, especially physician services.[36]

In non-rural areas, vulnerable populations may also suffer from the loss of hospital and emergency services. Romero et al.[31] conducted a qualitative study that asked participants how the closure of St. Vincent's Catholic Medical in Lower Manhattan (an urban inner-city vulnerable community) affected patients, community, and health care providers. The researchers learned that the closure had a magnified effect on vulnerable patients, particularly those unable to travel to the nearest hospital facility. Countouris et al.[32] found that older adults in a Pittsburgh suburb experienced feelings of abandonment, fear, frustration, and isolation, encountered transportation challenges, and lacked knowledge and literacy about obtaining health care after their nearby community hospital closure.

Human Capital and Vulnerable Populations

Human capital and other SDOH associated with vulnerability also appear to factor into these adverse outcomes. For instance, Yamashita and Kunkel[24] found a significant relationship between distance and heart disease mortality did not hold after controlling for rurality, poverty, African American status, uninsured rates, and lack of access to a private vehicle. Similarly, Rhudy and associates[27] found that certain SDOH associated with rural disparities (age, education, income, and insurance status) had a more significant impact on acute coronary syndrome-related mortality than the distance from the interventional cardiac care facility.

Relative Risk Associated with Time-Sensitive Events

The VPCM theorists suggest that resource availability affects relative risk in terms of exposure to risk factors and health behaviors, and these factors ultimately influence health status and outcomes.[1] Travel times (i.e., timely accessibility) to hospital and emergency care may be a surrogate for the relative risk associated with inadequate care utilization for treatment of time-sensitive conditions.

Researchers are becoming increasingly interested in the effects of travel time adjustments on geographic access to care and, in some instances, health outcomes.[24,25,27,33-35] Burkey et al.'s optimization models[35] indicated that up to one-third of Tennessee, Virginia, and Carolina (North and South) hospitals could close (to reduce potential service redundancy) without adversely affecting travel times. However, travel times were expected to increase dramatically beyond the one-third closure threshold. McCarthy's team[34] found through their isochrone examination of hospital closures nationwide (2010 – 2019) that most affected residents did not lose services within a 60-minute drive (note that isochrone studies map areas accessible from points within a certain time threshold). The study did not account for the hospitals lost since 2019 or the loss of specific services (e.g., obstetrics) at the remaining hospitals.

Other research confirmed that rural communities are at high risk of experiencing increased travel times[25] due to hospital closures. Undue travel times (greater than 30 minutes) increased 180-day, 1-year, and 3-year mortality rates by up to eight percentage points.[23] Moreover, travel times exceeding 30 minutes translated into significant long-term adverse effects on acute myocardial infarction patients who consequently received treatment at nearby high-occupancy bystander (the next closest) emergency departments.[22]

Busingye et al.[33] found that the communities furthest away (greater than 90 minutes) from cardiac and stroke units had higher mortality risks than those within the shorter travel distances. While Rhudy et al.[27] found no significant increases in acute coronary syndrome-related mortality for drive times over 60 minutes after adjusting for age, it is important to note that their analysis did not include patients who died before reaching an interventional cardiac facility, only those who experienced in-hospital mortality.

Missing the Benefits of Expanded Access

Of interest, recent hospital openings often did not benefit vulnerable populations.[22,26,33] For instance, a concerted effort to expand trauma center access in New Mexico successfully achieved a 20.8% increase in access to trauma care from 2007 to 2017.[26] However, most of the improved access occurred in suburban communities. Access improvements were less likely to reach rural communities and American Indian reservations. Additionally, Busingye et al.[33] found that while Middle Tennessee geographic access to specialized cardiac and stroke care within 30 minutes increased from 1999 to 2010, rural areas and those in socioeconomically disadvantaged neighborhoods were less likely to see improved access to care and more likely to have no access to stroke care within 90 minutes travel. Conversely, cardiac patients exposed to decreased travel times of less than 30 minutes resultant from emergency department openings (more likely in urban and suburban areas[33]) were more likely to receive timely percutaneous coronary intervention and better 30-day mortality rates.[22]

Health Outcomes

Declining resources and subsequent increases in relative risk potentially worsen health outcomes, according to the VPCM.[1] While closures result in increased volume at remaining facilities that may improve outcomes (by increasing providers' experience in treating certain conditions[44]), there may also be adverse effects due to changes in volume and patient mix. For instance, drive time increases of 30-plus minutes among high occupancy bystander emergency departments accounted for a significant increase in one-year mortality rates and 30-day readmission rates for patients with acute myocardial infarction.[22] Also, Crandall et al.[28] noted that upon the closure of the Los Angeles' Martin Luther King, Jr. trauma center (which served vulnerable inner-city patients), admissions increased in three of four nearby trauma centers. Payer mix shifted significantly in these facilities, and while overall mortality did not increase, a significant number of deaths attributable to gunshot wounds did. Additionally, Romero et al.[31]

found that patient participants were negatively affected by long waits and overcrowding at bystander hospitals and emergency departments when nearby hospitals closed.

Discussion

Impact of Hospital Closures on Vulnerable Rural Populations' Health Disparities

Our purpose in conducting this integrative literature review was to synthesize the existing research about the closures of rural hospitals and emergency departments. We found that much of the literature addressed the quality of care delivered in these facilities and the closures' effects on vulnerable patients and communities. Accordingly, we discuss the implications for access to care, SDOH, health disparities, and policy with a vulnerability focus.

Vulnerable populations are those social groups with elevated susceptibility to harm, neglect, or poor health outcomes,[1,45] a definition fitting many modern rural populations. Kilbourne and colleagues[46] incorporate a similar definition of vulnerable groups in their health services research framework, emphasizing the resultant gaps in health status or health care quality. Accordingly, the current hospital closures trend and subsequent shifts in access to care (confirmed in these articles) threaten vulnerable rural peoples who experience higher levels of chronic disease and premature death,[47] lower socioeconomic status, and poor access to other essential health services such as primary care.[36,48]

Rural residents have higher mortality rates than their urban counterparts, particularly in the Southeastern United States.[49,50] However, Gong et al.[50] concluded from their state-level analysis that if rural residents had a similar socioeconomic status and the same access to health care that urban populations do, the rural residents would have lived longer. Consequently, the decreases in care access (confirmed by several study authors[25,34] in this review) may ultimately exacerbate health inequities and poor outcomes[22,23] in vulnerable rural communities.[51,52] Hospital closures may trigger a downward spiral of detrimental effects related to SDOH, as counties lose an average of 300 jobs and see a decline of $1,400 (in 2018 dollars) in per capita income when their only hospital closes.[16] Considering the role that SDOH play in health outcomes,[24,27] further socioeconomic degradation in response to hospital closures is likely to advance health disparities.

As noted above, the closure of hospitals and emergency departments disproportionately affects low-income and minority populations.[23,25] For example, over six years (2012 to 2018), the median distance to emergency services increased by 20.9 miles and to drug and alcohol addiction services by 39.1 miles for rural residents living in closed hospital service areas.[9] Additionally, decreased access to care increases the vulnerability of rural populations to medical and social disparities (compared with urban populations) associated with lower incomes and lower educational attainment[38] and leads to personal and community senses of loss and hopelessness.[32,53]

Rural hospital closures have lesser-known consequences. Decreased competition among remaining hospitals means lower quality of care and higher prices.[54] Hence, hospital closures may result in growing health disparities for rural patients (compared with urban patients) through this indirect but significant pathway. However, if patients steer toward hospitals with sufficient volumes, the quality of care may improve for specific procedures,[44] so long as patient volumes and drive times are not excessive.[22]

Part of a More Extensive Network

Rural hospitals are part of a more extensive care network; thus, their status affects others in the health care system. For instance, patient stabilization at CAHs contributed to reduced mortality and LOS at Level 1 trauma center[37] while potentially reducing unnecessary transfers to higher levels of care and associated costs. Bed-to-population ratios (whose declines influence the broader system's ratios) affect patient outcomes in those with complex chronic illnesses,[38] while rural hospitals affect system-wide competition, quality, and costs.[54] Notably, hospital closures (rural *and* urban) may affect patient experiences and outcomes at bystander hospitals.[22,31]

Policy

To correct health inequities, we must understand the underlying causes through research and address them, just as the VPCM theorists depicted in their model.[1] Accordingly, we recommend addressing four policy domains to reduce rural health disparities: SDOH, quality assurance, innovative health care delivery systems, and hospital funding.

SDOH

The socioeconomic status of patients and communities, often disparate in rural and vulnerable communities, influences health.[47] The 2019 U.S. poverty rate was 15.3% in rural areas, compared to 11.9% in urban areas of the country.[55] Similarly, in 2019, 13.6% of the nation's rural residents had not completed high school compared with 11.7% of urban dwellers. These differences contribute to health inequities and disparities. According to the Healthy People 2030 initiative,[56] policymakers should take action to improve the upstream elements (apart from health care delivery) that indirectly impact health by enhancing housing, transportation, education, work environments, air quality, nutritional food accessibility, and physical activity opportunities. These enhancements are requisite if we are to reduce disparities in vulnerable rural communities.

Quality Assurance

Researchers who found that CAHs fell short of non-CAHs in several studies point to needed quality improvement programs to better serve the patients in rural and underserved communities.[42-44] These may be enacted at the federal, state, and local levels. Furthermore, state hospital associations[48] and the Bipartisan Policy Center Rural Health Task Force[51] propose alternative delivery models (including telehealth) to bolster quality in these communities.

Innovative Health Care Delivery Systems

Alternative delivery models have the potential to improve care quality and better meet the needs of 21st-century vulnerable rural populations. Telehealth holds promise for bridging access gaps by bringing patients and providers closer together through technology.[57] Provider visits are a cornerstone of telehealth. Still, the technology also links patients to needed monitoring for chronic health conditions to improve patient safety and quality of life while reducing hospitalizations.[58] Telehealth strategies may also bring providers closer, opening the door for expert consultations. However, all telehealth requires connectivity, and policymakers must ensure that broadband internet services are available and affordable.[57,58]

Another promising delivery innovation is the *hospital at home* model.[59] Though not a new concept (Johns Hopkins trademarked a home hospital program in 2002), some health systems are revisiting this option for delivering acute hospital care for appropriate patients, especially in the age of telehealth.[60] Not all patient conditions are suitable for home hospital care. Still, the model has succeeded with patients requiring pneumonia, dehydration, heart failure, and COPD exacerbation treatments. One challenge in making this program viable in the U.S. is financing. Medicare does not pay for acute fee-for-service patient care outside traditional hospital settings.[60] However, the COVID-19 pandemic is changing this scenario, as the hospital at home scheme has started to change what Medicare qualifies as allowable locations for acute treatment delivery.[59,60]

Intended to reduce the need for hospital and emergency care, integrated health systems that deliver patient-centered primary, behavioral, dental, substance use disorder, and, sometimes, urgent care are more than a half-century old but gaining traction.[61] Most often found in rural communities, HRSA’s Health Center Program centers care for more than triple the number of patients now than in 2000. These community health centers may be federally qualified health centers (FQHCs) if they receive federal funding, but the essential requirements are community and patient governance, health care services at reduced rates in underserved communities, and meeting clinical quality measures.[61,62]

Hospital Funding

Rural hospitals close for multiple reasons, but the primary reason is underfunding.[9,16,53,54,63,64] Financial shortfalls result from numerous factors, including low-income populations,[11] a more significant number of individuals who are uninsured or lack employer-based insurance coverage,[65] lower patient volumes,[54,64] aging populations,[11] outdated payment and delivery systems,[11] and health technologies, which are expensive and reduce the need for lucrative inpatient services.[16] Furthermore, some community hospitals suffer from a bypass effect, occurring when patients (presumably with more resources) leave the community to seek care at hospitals outside of their communities.[16] These factors culminate in hospitals' inability to survive, and the closures ultimately reduce both potential and realized access to care[66] if not followed by measures to mitigate the losses.[48,63]

Future Research

Many studies in this integrative review do not employ causal inference designs. Most were observational (see Table 1.1) and did not examine the impact of confounding factors, such as SDOH, health behaviors, space, and time. Consequently, future research should explore causal relationships between hospital closures and poor health outcomes through difference-in-difference or modern group matching methods.[67]

Conclusion

Rural hospitals provide vital access to care in rural and underserved communities. Nevertheless, hospital closures are more likely to affect rural communities with pre-existing disparate health outcomes. As hospitals close, travel times increase cumulatively, reduce access to care, and, in turn, increase the risks associated with time-sensitive health events. Ultimately, the loss of rural hospitals may also increase mortality and morbidity in vulnerable communities and the overall health system through interrelated effects on bystander hospitals, availability of health care providers, socioeconomic status, and community wellbeing. Consequently, policymakers should work to improve SDOH, ensure the quality of care at remaining hospitals, promote alternative health care delivery systems, and enhance funding for care delivery. Future research should better establish the causal relationships behind declining access to care and health disparities.

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Appendix

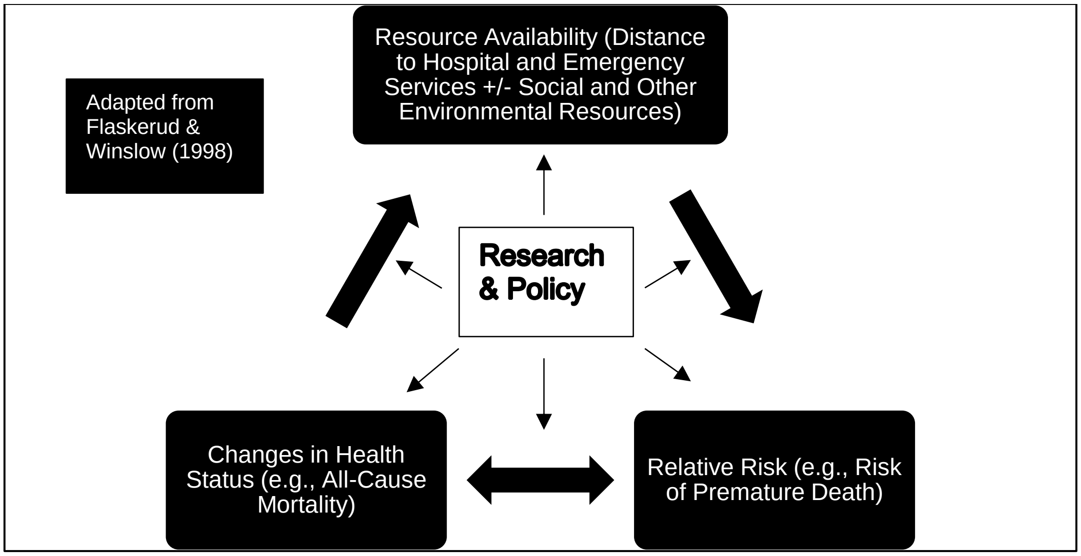

Figure 1.1. *The VPCM, adapted for hospital and emergency department closures study*

Table 1.1. *Summary of studies*

Author/Year	Focus	Geographic Area	Study Design/ Sample	Quality Score: Rigor/Relevance (High, Med., or Low)
Comparisons of Care Provided				
Gadzinkski et al. (2013)	Differences in utilization and outcome measures between CAHs and non-CAHs for patients undergoing the eight most performed CAH surgical procedures between CAHs and non-CAHs	The U.S.	Retrospective cohort study (2005 to 2009) *n*=1282 CAHs and 3612 non-CAHs, representing 6,587,713 surgical admissions	Low/High
Ibrahim et al. (2016)	Differences in surgical outcomes and costs for patients treated in CAHs vs. non-CAHs	The U.S.	Cross-sectional retrospective review N=1,631,904 MCR beneficiary admissions; CAHs *n*=828, non-CAHs *n*=3676	Low/High
Ibrahim et al. (2018)	Differences in mortality, serious complications, re-operation, and readmission for patients undergoing emergency colectomies performed at CAHs and non-CAHs between 2009 and 2012?	The U.S.	Cross-sectional retrospective correlational study *n*=219,170 patients who underwent urgent or emergent colectomies.	Low/High

Table 1.1 Continued

Author/Year	Focus	Geographic Area	Study Design/ Sample	Quality Score: Rigor/Relevance (High, Med., or Low)
Johnston et al. (2019)	Rural, micropolitan, and metropolitan access to primary care, specialists, and hospital beds	The U.S.	Retrospective time-series design, using CMS fee-for-service data *n*=66,585,996 weighted patient-years in the final sample. 9.6% rural, 17.6% micropolitan, 72.8% metropolitan. This represented 11,581 unique beneficiaries.	Low/High
Joynt et al. (2011)	Comparison of the quality of care at CAHs vs. non-CAHs for three common diagnoses (AMI, CHF, & pneumonia). Identify what contributes to differences in the quality of care between the two types of hospitals.	The U.S.	Retrospective observational study using Hospital Quality Alliance data (2008 to 2009) *n*=4738 hospitals (1268 CAH; 3470 non-CAH) and 2,351,701 index admissions for AMI, CHF, & pneumonia	Low/High

Table 1.1 Continued

Author/Year	Focus	Geographic Area	Study Design/ Sample	Quality Score: Rigor/Relevance (High, Med., or Low)
Joynt et al. (2013)	Comparison of 30-day mortality for AMI, CHF, and pneumonia in CAHs vs. non-CAHs and rural CAHs vs. rural non-CAHs (from 2002 – 2010). Identification of the resources that are associated w/ improvement.	The U.S.	Retrospective observational study using data from MCR FFS patients CAH hospitals (*n*=860 in 2002 and 1264 in 2010). Non-CAH (*n*=3108 in 2002 and 3255 in 2010). AMI: *n*=1,902,586 admissions; CHF: *n*=4, 488,269 admissions; pneumonia: *n*=3,891,074	Low/High
Lichtman et al. (2012)	Differences in 30-day mortality and 30-day readmission rates (both risk-standardized for ischemic stroke patients) at CAHs vs. non-CHAs in 2006	The U.S.	Retrospective review of MCR data (2006) *n*=4546 hospitals (1165 CAHs and 3381 non-CAHs) and 310,381 ischemic stroke discharges (10,267 from CAHs; 300,144 from non-CAHs)	Low/High

Table 1.1 Continued

Author/Year	Focus	Geographic Area	Study Design/ Sample	Quality Score: Rigor/Relevance (High, Med., or Low)
Natafgi et al. (2017)	Surgical patient safety outcomes in CAHs in comparison to comparably sized PPS rural hospitals in a four-state analysis	Colorado, North Carolina, Vermont, and Wisconsin (< 8% of CAHs in the U.S.)	Retrospective review of HC-UPSID and AHA annual survey data *n*=35,674 discharges (14,296 from 100 CAHs and 21,378 from 36 small PPS hospitals)	Low/High
Windorski et al. (2019)	Differences in ICU LOS, ventilator requirements and duration, hospital LOS, and mortality for trauma patients treated initially in a CAH ED vs. those initially transferred to a level 1 trauma center	The U.S.	Retrospective correlational study using chart review data (2009-2014) *n*=1478 patients; 73.3% transferred from CAH, 26.7% transported directly to level 1 trauma center	Low/High
Analyses of Hospital Closures and Openings				
Anderson et al. (2019)	How the expansion of trauma care centers in N.M. has translated into improved access to trauma care services at the population level and the characteristics of those with access to care	New Mexico	Retrospective cross-sectional analysis using spatial data at the census block level, 2007 - 2017. *n*=2,082,669 general population	High/Low

Table 1.1 Continued

Author/Year	**Focus**	**Geographic Area**	**Study Design/ Sample**	**Quality Score: Rigor/Relevance (High, Med., or Low)**
Burkey et al. (2017)	How hospital closures based upon optimization models differ from actual closures (2001 – 2015); whether short-term optimization models are stable over time; how recommended closures affect service equity/equality; and whether recommended closures disproportionately impact rural communities	North Carolina, South Carolina, Virginia, and Tennessee	GIS-informed optimization modeling design using AHA and Census Bureau Data *N*=4 states	High/High
Busingye et al. (2011)	The changes in spatial and temporal disparities in access to emergency cardiac and stroke care that occurred in Middle Tennessee from 1999 to 2010	Middle Tennessee	Retrospective network analysis and two-way comparison design *n*= 30 counties, 250 census tracts, and 1.2 million people	High/High
Countouris et al. (2014)	The impact of a community hospital closure on older adults in a suburb of Pittsburgh	Pittsburgh, PA	Qualitative focus group study (2010 – 2012) using a community-engaged research process. *n*=37 participants	High/Low

Table 1.1 Continued

Author/Year	Focus	Geographic Area	Study Design/ Sample	Quality Score: Rigor/Relevance (High, Med., or Low)
Crandall et al. (2016)	The effect of the closure of L.A.'s MLK trauma center on the distribution of admissions to nearby trauma centers and the impact of the closure on mortality rates in these centers and within L.A. County	Los Angeles, CA	Retrospective observational study involving non-public patient-level data from the state of California, 1999-2009 *N*= 37,131 trauma patients	Low/Low
Germack et al. (2019)	The relationship between rural hospital closures and the supply of physicians following a closure	The U.S.	Retrospective design, assessing rural U.S. hospitals that experienced at least one closure, 1997 – 2016 *n* = 1541 rural counties over 20 years; equated to 30,820 county-years	Low/High
He et al. (2017)	The effect of time to definitive care on patient outcomes after the closure of trauma centers	Uncertain	Chart review; pre- and post-event design, 2008 – 2009 and 2011 - 2013 *n*=27,843 patients	Low (not enough information – conference abstract)/Low
Hsia & Shen (2011)	The populations most affected by the rising rate of hospital trauma center closures (2001-2007)	The U.S.	Retrospective correlational design *n*=31,475 zip codes covering 283 million people	Low/High

Table 1.1 Continued

Author/Year	Focus	Geographic Area	Study Design/ Sample	Quality Score: Rigor/Relevance (High, Med., or Low)
Hsia & Shen (2019)	Patient outcomes (in AMI patients) at bystander hospitals (high and non-high occupancy) when a nearby E.D. opens or closes	The U.S.	Retrospective time-series probability and fixed effects design *n*=1,143,745 patients across 3720 hospitals (1209 of which were high occupancy)	High/High
Joynt et al. (2015)	Characteristics of hospitals that closed between 2003 and 2011, the effect of closures on mortality and readmission rates, and whether outcomes varied by the acuity of medical condition or rurality	The U.S.	Retrospective correlational design, using MCR data, 2003 - 2011 *n*=32,485,906 MCR beneficiaries, 195 hospital closures, and 2847 hospital service areas (184 w/ closures).	High/High
Liu et al. (2014)	How California E.D. closures (from 1999-2010) affected inpatient mortality rates at nearby hospitals	California	Retrospective analysis, using C.A. Office of Statewide Health Planning and Development's Hospital Annual Utilization data from 1999-2010 *n*=16,246,892 admissions to CA hospitals via ED	High/High

Table 1.1 Continued

Author/Year	**Focus**	**Geographic Area**	**Study Design/ Sample**	**Quality Score: Rigor/Relevance (High, Med., or Low)**
McCarthy et al. (2021)	The impact of rural hospital closures (2010 – 2019) on the proportion of the population that can reach a hospital or E.D. by road w/in 15, 30, 45, & 60 minutes	The U.S.	Retrospective GIS-informed isochrone design, using U.S. Census Bureau population data (2010) and Provider of Services (hospital location) CMS data (2010 – 2019) *n*=9 Census Bureau divisions, 48 contiguous states, and the populations therein	High/High
Rhudy et al. (2016)	Effects of delayed interventional cardiology access and social factors associated w/ excess ACS, NSTEMI, or STEMI mortality	Maine	Retrospective population-based secondary analysis of census and CMS claims data overlaid on a GIS-derived base map for 2013 *n*=3126 ACS cases meeting inclusion criteria (2247 NSTEMI; 879 STEMI).	Low/High

Table 1.1 Continued

Author/Year	**Focus**	**Geographic Area**	**Study Design/ Sample**	**Quality Score: Rigor/Relevance (High, Med., or Low)**
Romero, Kwan, Swearingen, et al. (2012)	The impact of the 2010 closure of St. Vincent's Catholic Medical in Lower Manhattan on patients, community, and health care providers	New York, NY	Community-based participatory qualitative approach, using key informants and focus groups *n*=16 key informants and six focus groups (44 group participants)	High/Low
Romero, Kwan, Nestler, et al. 2012.	The impact of the 2010 closure of St. Vincent's Catholic Medical in Lower Manhattan on patients, community, and health care providers	New York, NY	Descriptive survey study with both closed and open-ended questions *n*=1438 respondents (local service providers & residents)	Low/Low
Shen & Hsia (2012)	Effects of increased drive times to the nearest E.D. on mortality rates, the health profile of the patients, and long-lasting outcomes of patients experiencing AMI	The U.S.	Retrospective observational difference-in-differences design, using American Hospital Association and MedPAR data, 1996 - 2005 *n*= 1.49 million patient-year observations	High/High

Table 1.1 Continued

Author/Year	**Focus**	**Geographic Area**	**Study Design/ Sample**	**Quality Score: Rigor/Relevance (High, Med., or Low)**
Yamashita & Kunkel (2010)	The relationship between age-adjusted heart disease mortality and distance to a hospital, adjusted for social factors such as poverty, education, and insurance coverage	Ohio	Retrospective spatial analysis, using U.S. Census Bureau and Ohio Department of Health data for the year 2000 *n*=88 Ohio Counties (representing > 11 million residents in 2000)	High/High

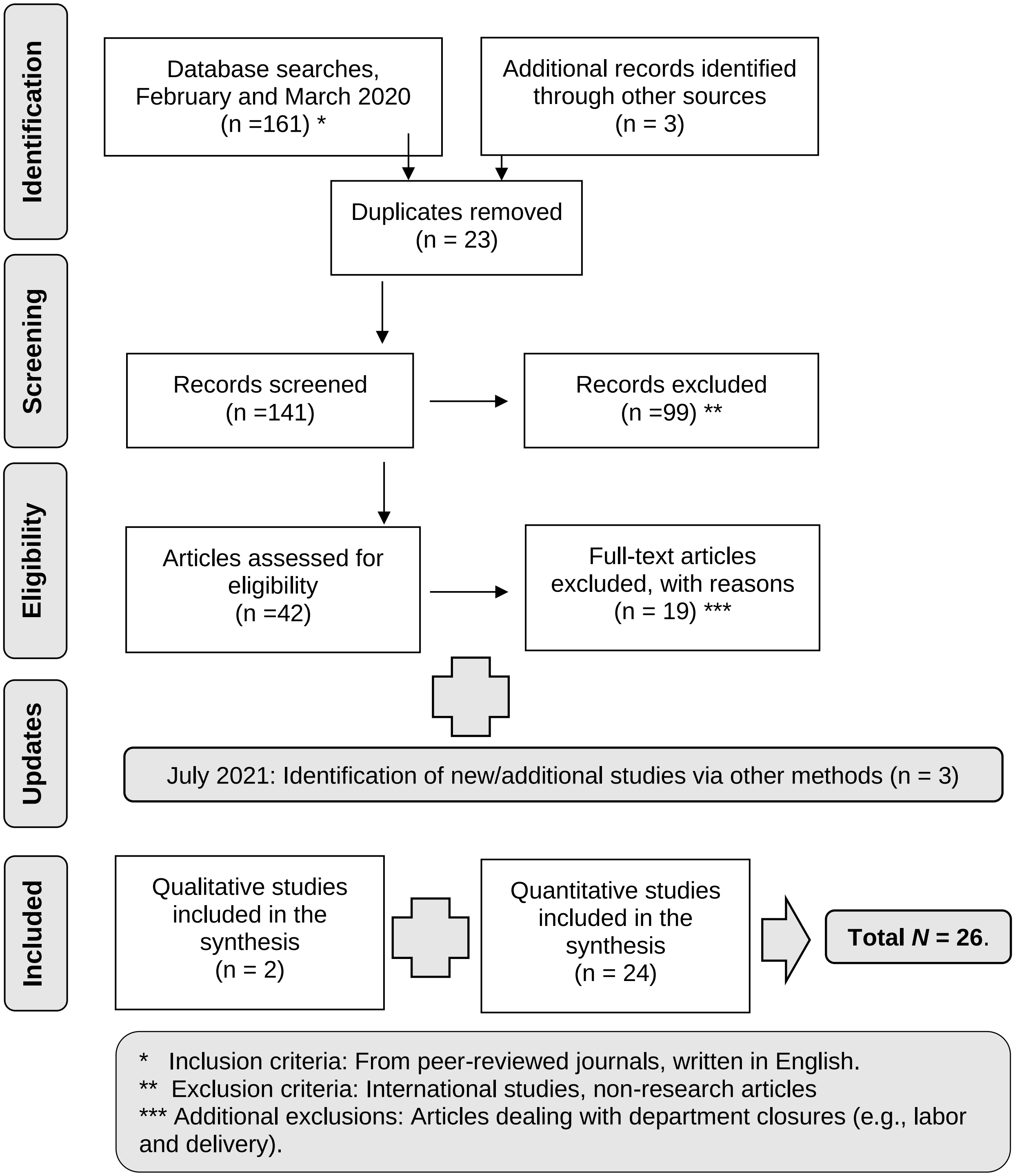

Figure 1.2. *Search strategy: Adapted from Moher et al.*[68] *and Page et al.*[69]

Chapter 2: Using Geographic Information Systems (GIS) in Health Disparities Research: Access to Care Considerations

This chapter, written by Tracey Stansberry, Liem Tran, and Carole Myers, has been submitted to *Nursing Research* and is under review.

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Abstract

Background: In disparities research, geographic information systems (GIS) allow nurse researchers to incorporate the spatial constructs of *potential* access to care and associated aspatial attributes (i.e., facilitators or barriers to *realized* access); however, how researchers account for access to care may affect study results.

Objective: This methods article aims to inform nurse scientists about the benefits of GIS-based research methods and access to care constructs, metrics, distance calculations within GIS platforms, and implications for modeling results.

Methods: Researchers may calculate distances and travel times (proxies for potential access to care) within GIS platforms using Euclidean distances or road networks. These calculations require researchers to select the most appropriate area units (e.g., counties or census tracts) for their dataset and research question.

Discussion: GIS offers many opportunities for nurse scientists to integrate spatial and aspatial data in their research, especially in their investigations of health disparities and other health-related phenomena. We provide an exemplar of access to care determinations in a spatial science study examining Tennessee's disparate rural health outcomes (considering growing distances to hospital and emergency room care as many hospitals in the state's vulnerable communities close). The differing approaches to distance and travel time calculations impact the modeling results of this and other GIS-informed studies, which inform policymakers as they work to reduce health disparities and improve the well-being of patients and communities.

Keywords: GIS, access to care, nursing research, health disparities, rural hospitals

Opportunities to be healthy can differ based on where you live.

——Victoria Niederhauser, *Torchbearer*

Health disparities are the preventable differences in the hardships from disease, injury, violence, or opportunities to optimize one's health (Centers for Disease Control and Prevention, 2017). The concept of health disparities does not incorporate all health inequalities. Some differences in outcomes are attributable to contrasting natural or biological traits (such as age or gender) or freely chosen health-threatening practices (such as football) (Whitehead, 1992). Another is the temporary advantage of selecting healthy practices, assuming everyone will have similar opportunities soon. However, the concept of health equity calls for eliminating unjust and unfair practices that lead to preventable disparities so that everyone can reach their total health capacity (Fawcett, 2019). Preventable disparities result from myriad factors, which include structural and systematic inequities and contrasting levels of health's social and environmental determinants (Adler et al., 2016; Tudor, 2022). Nurses, along with other health services researchers, funders, and policymakers, have an ethical and professional obligation to understand the factors contributing to these disparities and implement policies to reduce them (Adler et al., 2016; Cross et al., 2021; Fawcett & Russell, 2001).

Stakeholders and researchers delineate disparities according to group-defining characteristics such as race and ethnicity, gender identity, disability, socioeconomic status, and spoken language (CDC, 2017; Tudor, 2022). Furthermore, researchers increasingly recognize geographic differences in health outcomes. These geographic differences allow us to understand better the populations affected by health disparities. Moreover, we can now analyze the effects of spatial boundaries and attributes (e.g., distance to care), along with other attributes (such as median household income and health insurance status), on health-related outcomes (Ozdenerol, 2016). Accordingly, many disparities researchers and policymakers use geographic information systems (GIS) to focus on underserved populations and optimal utilization of services.

GIS and Nursing Research

Computerized GIS (first developed by Roger Tomlinson in 1963) provide robust platforms for tracking, analyzing, modeling, and depicting these effects (Esri, n.d.). The primary advantages of GIS involve data visualizations that reveal trends not easily recognized in more conventional databases (Ozdenerol, 2016). Tomlinson developed GIS to manage Canada's national land-use management program (Esri, n.d.). Still, researchers and managers in many other fields (e.g., criminal justice, urban planning, and health care to name a few) have embraced its use for understanding and solving real-world problems. Not surprisingly, geographers were the pioneers of GIS-informed health-related research (Khan & Bhardwaj, 1994), but nurse scientists and other health services researchers benefit from incorporating GIS technologies into their investigations (Moss & Schell, 2004; Rababah et al., 2014).

For nurse scientists, GIS platforms connect spatial boundaries to nursing's meta-paradigmatic concepts of health, person, caring, and environment (Moss & Schell, 2004; Smith, 2018) and offer insights into myriad health-related phenomena. Moss and Schell (2004) encouraged nurses to engage in more GIS-based research in the early 2000s. Since then, the methodology has gained traction in nursing (Lind et al., 2020; Rababah et al., 2014), albeit slowly, having found only ten GIS-informed nursing research articles since 2014. As nurses join multidisciplinary research teams and GIS software gains new robust capabilities, the profession's participation in GIS-related research is expected to continue to increase.

An in-depth, step-by-step tutorial of all potential GIS methodologies is beyond the scope of this article. Consequently, this article provides an overview of a spatial approach to nursing research (particularly health disparities and health services research) and primary considerations for assessing access to care, a common construct in disparities research (Khan & Bhardwaj, 1994). We also provide an exemplar of access to care determinations in a spatial science approach to examining Tennessee's disparate rural health outcomes (when distances to hospital and emergency room care are increasing significantly as many hospitals in the state's vulnerable communities close). The various methods for determining access (i.e., distance calculations) have implications for modeling results and subsequent takeaways for policymakers.

Method

Initiating a GIS-informed research project resembles the planning process for other nursing research studies. The procedure begins with recognizing a research problem, a phenomenon of concern to patients, communities, or fellow nurses (Polit & Beck, 2017), followed by a detailed literature assessment and identification of knowledge gaps (Kearney, 2017; Tappen, 2022). Nurse scientists are well-advised to identify a theoretical framework that will help explain their phenomenon of interest and assist in formulating a research question and set of testable hypotheses (Polit & Beck, 2017; Tappen, 2022). However, the theory need not be GIS-specific, only consistent with the research problem and question.

Careful study planning and design (Polit & Beck, 2017) while preferably collaborating with other researchers (Grady, 2017) are necessary. Given the unique nature of GIS computations, we highly recommend recruiting a well-experienced geographer to join one's research team. GIS-based nursing research may not directly involve human or animal subjects. Still, some institutions require review board approval before beginning (Ozdenerol, 2016).

Identifying variables, both predictors and outcomes, for GIS-related research is where the research pathway diverges somewhat from other forms of quantitative research. Understandably, access to care has been the primary focus of many GIS-informed studies, such as Yin's (2018) study of urban and rural inequalities in spatial access to prenatal care in Georgia and McCarthy et al.'s (2021) isochrone study of access to hospital care. However, there are essential things to consider when including access to care as a study variable.

Important Considerations about Care Access

Researchers have defined access to care in various ways (Aday & Andersen, 1974; MacKinney et al., 2014; Penchansky & Thomas, 1981). However, Khan & Bhardwaj (1994), building on the work of previous scholars, proposed an access to care framework that stands out for its applicability to GIS-informed nursing research studies. These geographers distinguish between *potential* and *realized* access to care, emphasizing the role that spatial proximity and social and environmental (i.e., aspatial) resources play in facilitating (or preventing) utilization of services. Potential access primarily concerns the availability and geographic (spatial) proximity of patients and communities to needed services, while realized access incorporates the concepts of accessibility and utilization. For example, people may live nearby a needed health care service. Still, if they do not have the means of paying for the service or entering the facility, services are inaccessible, and access is ultimately not realized. Thus, *un*realized access may result in persistent disparities despite proximity (i.e., potential access) to needed health care facilities and services (Khan & Bhardwaj, 1994; Ozdenerol, 2016).

Suppose nurses do not include access to care in disparities research. In that case, they are missing critical determinants impacting nurses' care of patients and patients' quality of life and overall health. For example, when patients and communities lose access to quality healthcare services, nurses (and other healthcare providers) may not have the entire cadre of resources to deliver high-quality care. Moreover, patients and communities experience anxiety over where to turn for care (Murry et al., 2021). When timely access is critical to the successful treatment of emergency conditions, the proximity of services and the wherewithal to access those services may mean the difference between life and death (Advani et al., 2017).

Data Determinations

Determining whether access to care is the outcome variable of interest or a predictor of health disparities is salient. Given the theoretical differences between potential and realized access to care, disparities studies may benefit from employing access to care as a predictor of health outcomes/disparities (i.e., the products of realized access). Proximity represented by Euclidean distances is one option as an explanatory distance (i.e., spatial) variable in health-related GIS studies. However, travel time data based on road networks may be preferred

(Sander et al., 2010), though travel times between points of interest may require complex calculations within GIS software and significant processing memory and data use credits (Esri, 2019).

Aspatial predictors vary. Researchers commonly employ demographic, socioeconomic, and health behavior metrics (among others), noting their moderating effects on realized access (Khan & Bhardwaj, 1994; Krieger et al., 2003). Researchers may locate data for GIS-based research in large datasets, many of which are publicly accessible (Bolstad, 2019). For instance, some addresses of health care facilities are available in open mapping sources. At the same time, aspatial attributes (e.g., socioeconomic measures) of geographic areas are available from the U.S. Census Bureau, the CDC, and other online databases.

Still, other GIS spatial and aspatial data may require the researcher to input data based upon direct observation and tracking (Bolstad, 2019; Donia, 2019). For example, through a process of field digitization, researchers may accurately collect and track specific site data (e.g., contaminated wells or disease outbreaks) via receivers that utilize global navigation satellite systems (commonly known as GPS) (Bolstad, 2019). Other data may result from previous research that scientists incorporate into attribute tables. An exemplar of access to care use in a spatial analysis of factors contributing to one state’s health disparities in the wake of multiple hospital closures follows.

Exemplar – Tennessee’s Hospital Closures

Tennessee’s hospitals are closing at a per capita rate higher than any other state (Cecil G. Sheps Center for Health Services Research, 2021). Most of these closures have occurred in the state’s rural communities, where health disparities prevail (Murry et al., 2021; Rural Health Information Hub, 2021). Most quantitative studies surrounding hospital closures in Tennessee and elsewhere have examined their impact on distance and travel times to essential care (as outcome variables) (Burkey et al., 2017; McCarthy et al., 2021). However, anecdotal reports (Kent & Walton, 2018; Stansberry, 2019) and qualitative studies (Letheren, 2021; Murry et al.,

2021) point to additional profound repercussions on Tennessee's local economies, community development, and health outcomes negatively affecting rural health disparities.

GIS provides a robust platform for diving deeper into the data surrounding evolving distances to hospital and emergency care. This exemplar provides an overview of a GIS-based nursing research study examining which aspatial and spatial variables, including potential access to care, significantly predict Tennessee's disparate rural health outcomes. Moreover, the exemplar focuses on the potential access to care calculations we employed in our more comprehensive study ascertaining these health outcomes effects. The University of Tennessee Human Research Protection Program determined that this study did not require an institutional review board (IRB) review since it did not involve human subjects as defined by federal regulations.

The Vulnerable Populations Conceptual Model (VPCM) by Flaskerud and Winslow (1998) provided an appropriate framework for investigating the effects of declining access to health care resources on relative risk and health outcomes. According to the theorists, a drop in human capital and environmental resources increases the relative risk associated with decreased health care utilization. Furthermore, resource declines lead to worse health outcomes (e.g., mortality and morbidity). Consequently, our research question is, "Considering Tennessee's hospital closures since 2010, what is the relationship between the state's disparate rural mortality rates and decreased access to hospital and emergency care (plus other environmental resource and human capital covariates)?"

Accordingly, we designed a GIS-informed retrospective ecological correlational study (using cross-sectional time-series data for Tennessee's 95 counties from 2010 to 2019). We selected our predictors (independent variables and covariates) according to the theoretical framework for this study, the VPCM (Flaskerud & Winslow, 1998). The selected variables also align with Andersen's behavioral model of health services use (Andersen, 1995). We focused on two dependent variables: county-level all-cause and time-sensitive mortality rates, which we obtained from the CDC's Wide-ranging Online Data for Epidemiologic Research (WONDER) website (CDC, 2021).

We calculated annual average distances and travel times to hospitals, our principal independent variable (reflecting potential access to care). We used *vector* data representations (as opposed to *raster* data) in the GIS software based on the counties' and census tracts' polygon shapes and discrete hospital point locations (Li et al., 2016). It is worth noting that vector data models represent spatial data using coordinates for shape-defining points and attributes, while raster data models use a column and row grid to define space (Bolstad, 2019). We used publicly available data (much from the American Community Survey datasets) to select county-level measures of human capital, including socioeconomic measures (e.g., median household income and uninsured status) and demographic indicators (e.g., median age and ethnicity). We also gathered primary care provider data from the Health Resources and Services Administration (U.S. Department of Health and Human Services, 2021) and measures of county rurality (derived from Purdue University's Index of Relative Rurality as presented to the Tennessee Advisory Commission on Intergovernmental Relations) (Roehrich-Patrick & Moreo, 2016). Counties with an index value over 0.316 were considered predominantly rural for purposes of this study, based on the delineation of predominantly rural Tennessee within the report (though we acknowledge the *threshold trap* presented to Tennessee lawmakers). The threshold trap is an issue with grouping entities into categories rather than along a continuum. This practice may erroneously infer that each unit within a given category is similar (Roehrich-Patrick & Moreo, 2016).

Access to Care Calculations

Accounting for potential access to care was a multi-tiered process. We began by setting up map layers with Tennessee's counties and census tracts in ArcGIS (v.2.9.2) and importing Tennessee's baseline (2010) hospital point locations for general acute care and critical access hospitals from the U.S. Department of Homeland Security (2021). We then cross-referenced the locations with the Tennessee Department of Health's Hospital Summary Reports and Joint Annual Reports (Tennessee Department of Health, 2021) to ensure we accounted for the state's general acute care hospitals and emergency departments for each year of our study. We accounted for hospital locations on January 1 of the year following any status changes. For instance, we accounted for a July 2016 hospital closure on January 1, 2017, location data. We defined a hospital closure as the cessation of inpatient and ER services. If an ER remained in operation, the hospital remained "open" for analysis since the facility would still potentially impact patient mortality by treating patients for emergent (and possibly urgent) conditions.

Determining a Starting Point

Next, to act as starting points for calculating county-level distances and travel times to hospitals or emergency services, we found the county and census tract *centroids* (the center of an area or polygon) by running the *Calculate Geometry* tool in ArcGIS Pro. We based the census tract centroid calculations on the U.S. Census Bureau's 2010 shapefiles (U.S. Department of Commerce, 2021b). County centroids were population-weighted and varied slightly from year to year, depending on Census Bureau population estimates from the American Community Survey.

An important consideration about centroid use is whether the point lies in a road-accessible location. If the centroid lay in a sparsely populated area without nearby roadways, the actual distances and modeled distances may vary, sometimes significantly. Still, precedence for weighting the population at the centroid exists (Anderson et al., 2019; Burkey et al., 2017; Ye & Kim, 2016). While this practice may introduce aggregation errors to a study, it is an acceptable approach because patient-level disaggregated data are often not available (Ye & Kim, 2016).

Euclidean Distances

After determining the census tract centroids in ArcGIS Pro, we ran the *Generate Near Table* geoprocessing tool to determine the straight-line (Euclidean) distances. This method involved calculating the geodesic distances from each census tract centroid to the nearest hospital for each year. We then found the mean census tract distance within each county (using the ArcGIS Pro *Summarize Within* tool) and added these annual county-level values to our map layer attribute table.

Road Network-based Travel Times

We also ran the ArcGIS Pro *Find Nearby Locations* tool to determine road network-based travel times in minutes from the centroids to the nearest hospital or emergency facility at the county and census tract levels. We included a parameter basing these calculations on the roadway nearest the centroid. The initial calculations were straightforward and involved determining the travel time from the county centroid to the nearest facility in minutes. Alternatively, the census tract-based calculations were more involved and time-consuming than county centroid calculations due to 1,497 Tennessee census tracts from the 2010 decennial census (U.S. Department of Commerce, 2021a). Calculating these values for all ten study-period years also consumed numerous geoprocessing credits with Esri. Note that some ArcGIS Pro tools consume credits, which unlock additional geoprocessing capacity; Esri, the software company that developed and maintains ArcGIS Pro, furnishes these credits to academic institutions and other subscribers for a fee. Like the Euclidean distance mean calculations noted above, we calculated the average census tract travel times within each county (using the ArcGIS Pro *Summarize Within* tool). We then added these values to our map layer attribute table.

Calculation Comparison

Figure 2.1 contains a series of bar graphs (compiled in SPSS v.27) representing the significant differences in access to care between the state’s rural and non-rural areas using our three access to care representations. However, the bar graphs also illustrate varying degrees of difference between rural and non-rural counties, depending on our study's three methods for calculating access to Tennessee hospitals and emergency care facilities (2010 -2019).

Table 2.1 highlights the comparative access to care calculations for an eight-county subset of Tennessee's 95 counties in 2010. Strikingly, the two travel time calculation methods produce different results that vary in degree from one county to the next. For example, when shifting from the county centroid road network-based travel times to the county-level mean census tract centroid-based travel times, Anderson County's travel times vary by 3.49 minutes (a 37% increase) while Carroll County's travel times vary by 8.83 minutes (a nearly 206% increase).

Also noteworthy are the differences these varying calculations generate in the correlational analyses. In calculating bivariate correlations (in SPSS v.27) between the two travel time classifications of access to care and the dependent variables (all-cause and time-sensitive mortality) for each county during the study timeframe, we noted different significance levels (see Table 2.2). The bivariate correlations for the county-level mean census tract-based travel times were significant at an alpha level of < 0.001, but the correlations for the county centroid-based travel times were either not significant or significant at an alpha level of < 0.05. These differences illustrate the impact of access to care representations at the bivariate modeling level. However, effects may also be observed at the multivariate modeling level.

We present the three separate access to care regression coefficients from multivariate negative binomial generalized linear mixed-effects regression models of their effects on all-cause and time-sensitive mortality rates (run in R-Studio 2021.09.0) in Table 2.3. The model included the fixed effects of county-level access to care, median age, median household income, the percentage of uninsured adults under age 65, rurality, and ethnicity (percentage Hispanic or Latino) and accounted for the variations in mortality rates with respect to time (year) and geographic division (East, Middle, and West Tennessee) via a random intercept for each of these two factors. The three representations of access to care affected mortality rates somewhat. While the *p*-value differences are negligible for the all-cause mortality models, they vary more in the time-sensitive mortality models (with *p*-values ranging from .053783 to

.179272). Note that the negative coefficients indicate the likely presence of an unaccounted factor that absorbed the bivariate effects of access to care on mortality rates. Still, this example illustrates the impact of selected access to care metrics at the multivariate level.

Discussion

GIS and its associated software packages offer wide-ranging statistical and spatial modeling capabilities and excellent data visualization potential. However, researchers may benefit from shifting access to care from the outcome variable of interest in disparities research to a predictor of health outcomes. In either case (access to care as a predictor or outcome variable), the methods used to calculate the values affect the spatial distance representation and the final analyses, as illustrated in our exemplar. Simple Euclidean (i.e., straight line) distance may be a statistically significant predictor of outcomes, but accounting for terrain and traffic effects on access to care, particularly in emergencies, is in keeping with prior research about preferred distance measurements. For example, Sander et al. (2010) compared Euclidean, road-network, and raster-based cost-weighted distances. They preferred road-network distances (absent compelling theoretical reasons to use the other two distance representations). In any regard, transparency about which method researchers used in calculating spatial distance is paramount.

On the other hand, using ArcGIS to calculate road network-based travel times can be time-consuming and expensive, as we experienced in our study. Other means of calculating these travel times exist. For instance, Huber and Rust (2016) proposed using the *osrmtime* command in the Open Source Routing Machine (OSMR) and OpenStreetMap (platform-independent free downloadable mapping software packages) for road-network calculations due to the system’s streamlined use of a PC’s computational capacity. Other advantages of this system include users’ ability to make unlimited requests independent of internet and online providers and the ability to replicate results easily. Other researchers have utilized Google Maps in determining road network travel times. However, online mapping services (such as Google) use real-time data and make frequent licensing agreement changes, which makes replicating results somewhat difficult (Huber & Rust, 2016). For example, temporary detours and traffic congestion may alter the expected or average travel times.

A limitation to our exemplar study's use of road network-based travel times as a surrogate for access to care is its disregard for the impact of air ambulance networks. The U.S. Government Accountability Office (2019) reported that between 2012 and 2017, the nation saw a 23% increase in the areas served by air ambulance helicopter bases, mainly in the West and South. However, the 2019 report notes that air ambulances transport relatively few patients. Thus, while our use of road network-based travel times remains relevant, this caveat may account for unexpected variability in study coefficients.

GIS offers additional advantages to nurse researchers engaged in disparities research. For instance, GIS' capacity to move beyond distance and travel time measurements as an outcome of changing access to understand and account for spatial dependency (Sarrias, 2020) is a strength of this methodology. We do not describe the complete results of our broader multivariate mixed-effects spatial models here. However, our study illustrates how one can extend the spatial aspects of access to care to ascertain the downstream effects on disparate mortality rates (while controlling for time and spatial dependency).

Furthermore, GIS affords researchers varying degrees of granularity (Li et al., 2016), depending upon the spatial units employed in their studies. For example, geographic units based on zip codes offer finer levels of granularity than county-based units. The smaller scale associated with census tract centroid use (as opposed to county centroids) likely accounts for the varying levels of significance we noted in our bivariate analyses. Ultimately, the optimal level of granularity hinges upon the research question and the availability of specific data.

Another compelling advantage of GIS for nursing research is the wisdom gained from integrating multidisciplinary perspectives and skills into nursing research teams (Rababah et al., 2014) and the consequent capacity to inform health policymakers. In the 21st Century, GIS also allows research teams to share their findings with online communities, build upon the knowledge of other scientists, and collaborate with scientists from around the world (Esri, 2019).

Conclusion

Nurses have an ethical responsibility to address health disparities and inequities. Evidence indicates that these disparities often vary according to aspatial attributes within geographic environments that account for access to care. However, in addition to distinguishing between potential and realized access to care, understanding the impact of various methods for calculating distance and travel times is crucial. Assessing one method's statistical and theoretical significance over another may strengthen the resultant inferential statistics and conclusions derived from spatial modeling of access to care's effects on health outcomes and disparities. However, researchers must be transparent about the method employed in their final models.

This manuscript adds to the current body of nursing research methods by emphasizing the benefits of GIS methods in health disparities research. Our exemplar demonstrates how GIS aids nurse scientists in understanding Tennessee's rural health disparities, considering the state's declining access to hospital and emergency care from 2010 to 2019. Furthermore, our exemplar tables and figure depict the various access to care representations and their effects on descriptive, bivariate, and multivariate analyses. Nurse scientists may refashion the GIS method we employed for numerous health disparities studies, especially when access to care is of theoretical and practical importance in answering disparities-related research questions. In the end, GIS-based nursing research informs stakeholders, legislators, and health policymakers in their quest to improve the health and well-being of patients and communities.

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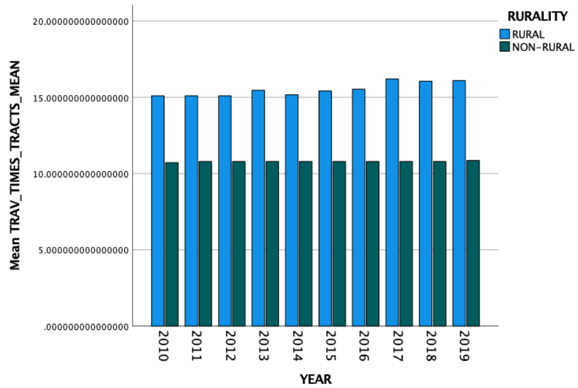
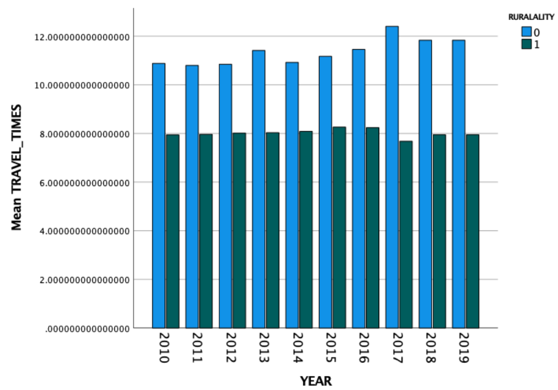
Appendix

Average county-level census tract centroids to the nearest facility travel times in minutes



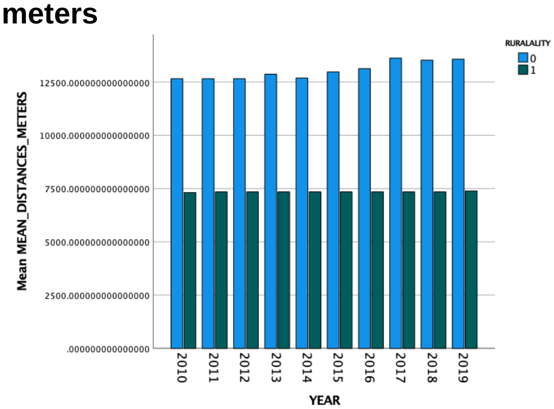
p < 0.001.

Mean county centroid to the nearest facility travel time in minutes



p < 0.001.

Average county-level census tract centroids to the nearest facility Euclidean distances in meters



p < 0.001.

Figure 2.1 *Annual Tennessee rural and non-rural access to hospital and emergency care, 2010 -2019*

Table 2.1. *Comparison of access to care metrics in a subset of Tennessee counties, 2010*

County name	Euclidean distances: County-level mean distance from census tract centroids to the nearest hospital (in meters)	Travel times: Road network-based travel times from county centroids to the nearest hospital (in minutes)	Travel times: County-level mean road network-based travel times from census tract centroids to the nearest hospital (in minutes)
Anderson	9,007.39	9.36	12.85
Carroll	10,804.82	4.29	13.12
Fentress	9,786.25	11.35	10.96
Haywood	8,904.84	6.04	9.92
Morgan	20,411.35	22.70	25.59
Pickett	18,307.14	28.28	26.80
Polk	15,060.43	34.02	17.83
Weakley	11,436.70	9.94	13.38

Table 2.2. *Comparison of bivariate correlations using different representations of travel times*

Outcome variable (*n* = 950)	**Travel times: Road network-based travel times from county centroids to the nearest hospital (in minutes)**	**Travel times: County-level mean road network-based travel times from census tract centroids to nearest hospital (in minutes)**
All-cause mortality	$p = 0.091$ Pearson correlation = 0.055	$p < 0.001$** Pearson correlation = 0.122
Time-sensitive mortality	$p = 0.028$* Pearson correlation = 0.071	$p < 0.001$** Pearson correlation = 0.142

Note. ** Correlation is significant at the 0.001 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 2.3. *Multivariate coefficient estimates: Comparison of three separate access to care metrics' effects on all-cause and time-sensitive mortality for Tennessee counties, 2010 - 2019*

Outcome variable (*N* = 950)	**Euclidean distances: County-level mean distance from census tract centroids to the nearest hospital (in meters)**	**Travel times: Road network-based travel times from county centroids to the nearest hospital (in minutes)**	**Travel times: County-level mean road network-based travel times from census tract centroids to nearest hospital (in minutes)**
All-cause mortality	β = -2.187e-06 *t*-value: -4.036 *p*-value: .000059	β = -1.852e-03 *t*-value: -4.969 *p*-value: < .00001	β = -2.869e-03 *t*-value: -5.676 *p*-value: < .00001
Time-sensitive mortality	β = -1.419e-06 *t*-value: -1.344 *p*-value: .179272	β = -1.308e-03 *t*-value: -1.794 *p*-value: .073133	β = -1.915e-03 *t*-value: -1.931 *p*-value: .053783

Note. β = coefficient estimate. *p*-values calculated using an online calculator by Stangroom (2022) and 943 degrees of freedom.

Chapter 3: A GIS-Informed Mixed-effects Modeling Approach to Understanding Tennessee Hospital Closures' Effects on County-Level Mortality Rates, 2010 – 2019

This manuscript, written by Tracey Stansberry, Carole Myers, Liem Tran, Patricia Roberson, and Sangwoo Ahn, will be submitted to *PLOS ONE*.

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Abstract

Background: Tennessee, a state with poor health rankings and disparate mortality rates between rural and non-rural communities, has lost more hospitals per capita than any other state since 2010. The growing distance and travel times to hospital and emergency care, along with the loss of other related health services, puts the state's rural residents at risk for worsening health and economic disparities.

Purpose: Based upon the Vulnerable Populations Conceptual Model, our study sought to understand the relationship between the state's disparate rural mortality rates and the growing distance and travel times to hospital and emergency care plus other environmental and human capital resources from 2010 to 2019.

Methods: We conducted a deductive GIS-informed retrospective ecological correlational study using annual cross-sectional secondary data from publicly available relevant datasets from 2010 to 2019. After descriptive and initial correlational testing, we employed aspatial and spatial negative binomial generalized linear mixed-effects models (GLMMs).

Results: The bivariate tests confirmed statistically significant correlations between our IV (access to care), each covariate (median age, median household income, uninsured status, ethnicity, and rurality), and all-cause and time-sensitive mortality rates (2010 to 2019). At the multivariate level, the fixed effects of county-level median household income, median age, and rurality were the most significant predictors ($p < .001$) of all-cause and time-sensitive mortality rates after accounting for the variations in mortality rates with respect to time and the state's geographic division (East, Middle, and West) via the random intercept components for these two factors. After applying the random intercept components, we found reduced statistical significance for the fixed effects of access to care, ethnicity, and uninsured status.

Implications: In our analyses, socioeconomic and demographic factors eclipsed the effects of Tennessee’s growing distance and travel times to hospital and emergency care. However, we assert that rural communities cannot achieve the economic gains necessary for reduced mortality without health investments to break the downward poverty-poor health spiral. With sustainable investments in rural community health, Tennessee’s policymakers can spawn a “virtuous cycle” of health and wealth.

Keywords: Rural hospital closures, health disparities, rural economies, Tennessee, rural health investment

Health disparities are an ever-present upshot of rural life. In the United States, rural residents have a life expectancy that is three years shorter than those residing in large metropolitan communities (Singh et al., 2017). Despite decreases in the overall mortality rate (deaths per 100,000) between 1999 and 2019, the age-adjusted mortality rate for 25- to 64-year-old rural residents increased by 12.1%, while the gap between rural and large metropolitan mortality rates tripled (Cross et al., 2021). The South is particularly at risk (Hoffman & Holmes, 2017), and Tennessee, ranked 44th out of 50 states regarding health outcomes and clinical care in 2020 (United Health Foundation, 2021), is no exception. Consequently, the state's health disparities effects on vulnerable rural communities are profound. For instance, in Scott County, Tennessee (an economically distressed rural community), life expectancy in 2018 was three years below the state average and five years below the national average (Robert Wood Johnson Foundation, 2022).

Despite ongoing health disparities, access to needed rural health-related resources is declining (Miller, 2020). Namely, Tennessee's hospital closures lead the nation on a per capita basis. Since 2010, the U.S. has lost 138 rural hospitals; during this time, Tennessee has lost 16 rural facilities and several other metropolitan ones (Cecil G. Sheps Center for Health Services Research, 2021). Before 2005, U.S. hospital openings outpaced closures by 116 facilities, and closures often reduced redundancy (American Hospital Association Resource Center, 2014). However, since 2010, hospital losses have accelerated and begun to affect areas without other sources of care, as illustrated by growing distances to the nearest source of care. For example, between 2012 and 2018, in the U.S.'s 62 areas that lost hospitals with emergency department services, the median distance to care increased by 20.9 miles (to a median straight-line distance of 24.1 miles), according to the U.S. Government Accountability Office (2020).

Entangled with hospital closures are the effects on other health services. Germack et al. (2019) found that when rural hospitals close, physicians leave, a dip in service availability that often persists for six years or longer. These physicians practice in various areas, including primary and specialty care. While this may be a “chicken or the egg” question (as significant physician departures before hospital closures lead to hospital instability and decreased admissions), both avenues result in downward spiraling effects on health care service availability. In Tennessee, the lack of primary care physicians and hospitals go hand-in-hand; counties with no hospital had the highest population-to-primary care physician and population-to-mental health provider ratios in 2016 (Pelligran, 2019). This lack of primary and hospital services likely results in delayed prevention, detection, and treatment of health conditions and decreased access to other needed health care services (U.S. Department of Health and Human Services, 2022b). This lack of health care access likely accounts for approximately 20% of Tennessee’s poor health ranking status (United Health Foundation, 2021, 2022).

Beyond concerns about declining access to care lie the hospital closures’ effects on the economic health of rural communities and social determinants of health (SDOH). When rural hospitals close, significant employment sources from the hospital, associated support businesses, and the broader community disappear (Murry et al., 2021). According to a 2006 study by Holmes et al. (2006), when rural communities lost their only hospital, per capita incomes dropped by four percent, and unemployment rates increased by 1.6 percentage points on average, both significant amounts. These findings are consistent with results from the U.S. Government Accountability Office’s (2020) examination of the socioeconomic characteristics of those living in service areas with and without hospital closures between 2013 and 2017. The report indicates a 1.2 percentage point unemployment difference and more than a $5000 median family income difference between the two service area categories. There was also an exaggerated difference in the percentage of uninsured residents living in closed and non-closed hospital service areas (12.7% and 8.9%, respectively). The significant correlations between the SDOH and health disparities (Singh et al., 2017) make this potential negative impact of hospital closures on the health of rural residents even more concerning.

Theoretical Framework

Given the multiple vulnerabilities of rural communities, the Vulnerable Populations Conceptual Model (VPCM), a middle-range nursing theory by Flaskerud and Winslow (1998), framed our study, which assessed the effects of declining access to hospital and emergency services in Tennessee on health outcomes. The VPCM, developed to identify vulnerable populations and formulate community-based interventions, ties together the concepts of resource availability, relative risk, and health status in an iterative circle. The model is used to explore the relationships between the factors leading to vulnerability and the ultimate impact of these factors on health outcomes and disparities.

Purpose and Hypotheses

Arising from the VPCM, our study sought to answer the following: considering Tennessee's hospital closures since 2010, what is the relationship between the state's disparate rural mortality rates and the growing distance or travel time to hospital and emergency care plus other environmental and human capital resources? Accordingly, we hypothesized the following:

1. Distance or travel times to hospital and emergency care will account for significant variance in county-level all-cause and time-sensitive event mortality rates.
2. Social and environmental factors will significantly influence the impact of travel times or distance to care on all-cause and time-sensitive event mortality rates.
3. Tennesseans living in counties with the highest travel times to hospital and emergency care will have an increased relative risk of death due to time-sensitive events.

Methods

To test our hypotheses, we conducted a deductive GIS-informed retrospective ecological correlational study using annual cross-sectional secondary data from publicly available relevant datasets from January 1, 2010, to December 31, 2019. We selected this date range because the bulk of Tennessee's hospital closures have occurred since 2010, and covariate data were readily available through 2019. Though additional Tennessee hospitals closed after 2019, we limited our analyses to these ten years because the COVID-19 pandemic delayed data releases and skewed mortality rates for 2020 and beyond. Though GIS-based research is relatively new to nursing science, this method is well-established for disparities and access to care studies (Khan & Bhardwaj, 1994) and becoming more commonplace among nurse researchers (Moss & Schell, 2004; Rababah et al., 2014).

We defined hospitals as facilities furnishing general acute care or those defined as critical access hospitals (Centers for Medicare and Medicaid Services, 2021). We considered hospitals as “closed” if they ceased to furnish inpatient and emergency services; if the emergency department remained in operation, the hospital remained “open” for purposes of determining access to care since these services are expected to impact mortality rates. However, if hospitals converted to behavioral health or long-term care facilities, we classified them as closed for our analyses. We classified Tennessee’s rural counties using Purdue University’s 2010 Index of Relative Rurality (Roehrich-Patrick & Moreo, 2016). We considered counties with an index value greater than 0.316 predominantly rural for this study. Still, we appreciate the *threshold trap* the index’s developers presented in their report to Tennessee lawmakers.

Data Sources

We first downloaded Tennessee’s annual county-level crude all-cause mortality rates (one of two outcome variables) from the CDC’s Wide-ranging Online Data for Epidemiologic Research (WONDER) website (CDC, 2021). Next, we compiled a list of time-sensitive ICD-10 codes (representing deaths from conditions requiring immediate medical attention, such as sepsis, cardiac and pulmonary events, cerebrovascular events, hemorrhage, and injuries). We then downloaded the annual crude mortality rates associated with these codes. Rather than age-adjusted mortality rates, we employed crude rates per 100,000 population because the

CDC advises against using the age-adjusted rates as direct measures of mortality risk and, instead, using the data as relative indices only (CDC, 2022).

We also obtained annual data from the U.S. Census Bureau's American Community Survey (ACS), 2010 – 2019 (U.S. Department of Commerce, 2021a, 2021b) and selected measures of human capital, including socioeconomic measures (e.g., median household income and uninsured status) and demographic indicators (e.g., total population, median age, and ethnicity). We selected vector-based spatial data and employed the WGS 1984 geographic and NAD 1983 StatePlane Tennessee FIPS 4100 projection coordinate systems for spatial reference (Bolstad, 2019) to determine hospital and emergency department locations. We imported suitable hospital location and state shapefile data from the U.S. Census Bureau (2021c), the U.S. Department of Homeland Security (2021), and the Tennessee Department of Health (2021). We determined the county's geographic division (East, Middle, and West Tennessee) per Tenn. Code §§ 4-1-202 through 4-1-204 (Grand Divisions and State Capital, 2020). Last, we derived primary care provider data from the Health Resources & Services Administration's Area Health Resources files (SAS tables) (U.S. Department of Health and Human Services, 2021a) and calculated annual population-to-primary care provider ratios for each county.

Data Quality

As the U.S. Census Bureau's ACS provided the bulk of our covariate data, we reviewed its quality in-depth. The ACS provides research data for numerous health-related researchers and policymakers (Citro & Kalton, 2007). With its focus on community characteristics, resident demographics, housing information, and other social determinants of health (SDOH), researchers now consider it the nation's premier high-resolution population-related geographic data (Spielman et al., 2014). Designed to replace the decennial census long-form survey, the Census Bureau mandates a response (U.S. Department of Commerce, 2022) and currently mails the survey monthly to 250,000 U.S. households (Citro & Kalton, 2007). The Bureau creates one-, three-, and five-year projections of resident populations and associated characteristics, which it continually updates to reflect new data. To more accurately estimate populations, the Bureau adds a finite population correction to reflect the variance estimations (especially for smaller areas) to its three- and five-year estimates (Torrieri, 2014). Once the population is estimated (based upon the above), the data are projected with a margin of error (MOE) to reflect a 90% confidence level (U.S. Department of Commerce, 2020). ACS data standard errors (estimate variability due to sampling) are calculated by dividing the MOE by a constant of 1.645, the critical value for a confidence interval (CI) of 90%. Still, the survey is not flawless. Importantly, we found the ACS's construct, content, and external validity, along with its assumptions and reliability (Tappen, 2022), satisfactory for our study.

Ethical Considerations

The University of Tennessee Human Research Development Program reviewed this study and determined that it did not involve human subjects as defined by federal regulations. Therefore, it did not require a review by the university's institutional review board (IRB). We obtained no patient data, only population-based data.

Sample

Our sample, representative of our geographical area of concern, comprised Tennessee's 95 counties. Given our use of annual cross-sectional data for 2010 to 2019, our final sample represented 950 county years for analysis. This approach was appropriate for handling a sample with time-series data but required the addition of a *time/year* variable (Grace-Martin, 2022). We justified our sample size based upon its representation of the entire Tennessee population for the ten-year study period (i.e., we collected all data available for the population of interest) (Lakens, 2022). Still, we recognize the possible error introduced by the ACS 5-year estimates, which are based upon county-level population subsets (Spielman et al., 2014).

Data Preparation

We carefully reviewed each dataset for completeness and aberrant values to prepare our data for analysis. We then compiled them in a long-form Excel (v.16.60) spreadsheet containing annual county-level data from 2010 to 2019 (Grace-Martin, 2022). The only dataset containing missing values was the one with the time-sensitive mortality rates (from the CDC WONDER data). The CDC did not populate these values due to the small death count (less than 20) in several counties with small populations and instead marked them as *unreliable* (Centers for Disease Control and Prevention, 2022). In total, 18 values (or 1.89% of the total 950) were considered unreliable; we imputed the missing values by averaging the two nearest reliable values in the time series for each specific county with missing values.

We previously reported our process for calculating the annual average Euclidean distance and travel times to hospitals and emergency facilities (2010 to 2019) using ArcGIS Pro (v.2.9.2) in Stansberry et al. (2022). The distance and travel times to Tennessee's hospital and emergency facilities represent the spatial component of *potential* access to care (our principal predictor), as described by Khan and Bhardwaj (1994). Accordingly, our covariate data represent each geographic unit's aspatial (or social) attributes. We imported our finalized Excel long-form spreadsheet of combined data into SPSS (v.27) and R-Studio (2021.09.0) for analysis.

Analyses

We conducted a series of tests at the univariate, bivariate, and multivariate levels (Bannon, 2013). These included analyzing the descriptive statistics for our sample, the correlations between the predictors and outcome variables, and the effects of access to care on mortality rates after controlling for a series of covariates. We also assessed for evidence of multicollinearity. We employed generalized linear mixed-effects models (GLMMs) for our multivariate analysis. Due to the presence of correlated outcome measurements for each of Tennessee's counties (annual county-level mortality rates), the GLMMs included the fixed effects of the predictors (IV and CVs). They also accounted for the variations in the dependent variables with respect to time and geographic division (East, Middle, and West Tennessee) via a random intercept component for each of those two factors (Bolker et al., 2009). Since mortality rates are count data, we converted our mortality rates to integers and began our multivariate testing process with Poisson GLMMs (Bono et al., 2021).

Results

See Table 3.1 for our descriptive statistics and the results of the analysis of variance (ANOVA) testing for Tennessee's rural (n = 80) and non-rural (n = 15) counties. From 2010 to 2019, we found statistically significant (p < .001) between-group differences (rural vs. non-rural) for all county-level attributes. Tennessee's rural counties had, on average, higher median age, lower median household income, higher percentages of uninsured residents, higher percentages of residents identifying as white, and lower percentages of residents identifying as Hispanic or Latino. Regarding access to care, rural residents, on average, had less access to primary care providers and traveled further to hospital and emergency care facilities (for all three access to care measures). Rural counties consistently experienced higher mortality rates per 100,000 (for all causes and time-sensitive conditions) each year, 2010 - 2019 (depicted in Figure 3.1).

See Table 3.2 for the results of our bivariate analyses. These results revealed the county centroid-based travel times exhibited less significant correlations with mortality rates (all-cause p = .090 and time-sensitive p = .028) than the two county-level mean census tract-based metrics of distance (p < .001) and travel time (p < .001) to the nearest source of hospital or emergency care. Furthermore, most covariates correlated significantly with mortality rates across the study area. Median age, median household income, rurality, and ethnicity correlated significantly with all-cause and time-sensitive mortality rates (p < .001). However, the percentage of residents under the age of 65 lacking health insurance was significant in relation to time-sensitive mortality rates (p = .001) but not all-cause mortality rates (p = .777).

For our multivariate models, we confirmed that no collinearity between the models' continuous predictors existed; correlations were < .70 (though several predictors correlated at levels between 0.30 and 0.50), tolerances were > 0.2, variance inflation factors (VIF) were < 2, and variance proportions were within acceptable limits. The mortality data violated the Poisson distribution assumption (the variance was greater than the mean for all-cause and time-sensitive mortality rates: 50,753.063 > 1195.26 and 7301.097 > 305.63, respectively), leading us to run a series of negative binomial regression models. These models handle the overdispersion by including quadratic mean-variance relationships (Yirga et al., 2020). Each negative binomial model set included aspatial fixed-effects, aspatial mixed-effects, and spatial mixed-effects models using the 'spaMM' package (Rousset & Ferdy, 2014). These models assessed the effects of access to care (the county mean census tract centroid-based Euclidean distances, the census tract centroid-based travel times, and the county-centroid-based travel times) on county-level all-cause and time-sensitive mortality rates. We employed the Laplace approximation parameter estimation method for the mixed-effects models with a log-link function. Using a contiguity neighborhood weight matrix, we tested for spatial autocorrelation of each model's residuals through Monte-Carlo simulations of Moran's *I*. We assessed the model fit through Akaike information criterion (AIC) value and likelihood value comparisons within each model group.

The measures of spatial dependency were weakly significant. However, the six aspatial mixed-effects models performed better (with lower AIC and higher likelihood values) than the spatial mixed-effects models. In the aspatial mixed-effects models (see Table 3.3), the fixed effects of county-level median household income, median age, and rurality were the most significant predictors ($p < .001$) of all-cause and time-sensitive mortality rates after accounting for the variations in mortality rates with respect to time and geographic division via the random intercept components for these two factors. Alternatively, after applying the random intercept components, the fixed effects of the access to care measures, ethnicity, and uninsured status were either less significant (at an α of .05) than the other predictors or not statistically significant. Furthermore, access to care and uninsured status variables exhibited negative coefficient estimates, a flip from the bivariate correlations.

Discussion

This study's purpose was to ascertain which factors impact disparate mortality rates in Tennessee, considering the state's hospital closure crisis since 2010 and using the VPCM to frame our selection of study variables and guide our hypotheses. We expected that a lack of human and environmental resources would negatively impact relative risk. Furthermore, we expected areas with fewer resources would suffer significantly worse health outcomes.

We found that Tennessee's rural counties were significantly older and poorer, had fewer health-related resources, and had higher mortality rates than their non-rural counterparts from 2010 to 2019 ($p < .001$; see Figure 3.1 and Table 3.2). Consequently, all six mixed-effects models revealed that median age, socioeconomic status, and rurality significantly impacted county-level mortality rates ($p < .001$; see Table 3.3). These results align with the literature and recent data (Gong et al., 2019; Murry et al., 2021; Tennessee Department of Health, 2019; United Health Foundation, 2022; Yamashita & Kunkel, 2010). We also found that from 2010 to 2019, all but three of the fifty-seven counties with the highest mean all-cause mortality rates (by natural breaks classification) were rural (see Figure 3.2). Similarly, all thirty-one counties with the highest mean time-sensitive mortality rates were rural (see Figure 3.2).

Logically, communities with higher median ages experience greater crude mortality rates. However, we found that Tennessee's rural counties also experience significantly different age-adjusted all-cause (mean 974.36 rural vs. 846.28 non-rural counties; $p < .001$) and time-sensitive (mean 253.84 rural vs. 186.90 non-rural counties; $p < .001$) mortality rates. Nevertheless, rural communities have far fewer resources to care for their aging populations than non-rural communities. Suburban and urban communities are more likely to have tertiary hospitals with more employees and beds (Freeman et al., 2015) and more primary care providers, specialists, and other health care providers (Ricketts, 2005). This pattern points to inequitable health resource allocation, with higher-need rural patients unable to access these facilities and services. In other words, the communities with the greater age-related health requirements have fewer necessary resources than the younger, healthier communities.

According to the U.S. Department of Agriculture (2022), Tennessee's rural communities, on average, have lower socioeconomic status, a conclusion confirmed by our study's findings. Besides median age, median household income had the most significant impact on mortality rates in our bivariate and multivariate analyses (see Tables 3.2 and 3.3). Furthermore, in the multivariate analyses, we found that the correlations between spatial access to care and mortality rates diminished when we factored in the effects of median household income. These results align with those of Yamashita and Kunkel (2010). They also found the significant bivariate correlation between Ohio counties' distance to hospital care and heart disease mortality vanished when accounting for socioeconomic and other social factors, such as employment and education levels. Furthermore, Gong and associates (2019) found that higher rural mortality rates at the state level are most closely linked to socioeconomic deprivation (though low physician supply and lack of health insurance also played a role). Similarly, Busingye et al. (2011) concluded from their study of access to stroke and cardiac care in Middle Tennessee that travel times correlated with socioeconomic status, translating into differential mortality risks at the neighborhood level.

Rurality is linked with myriad issues affecting health outcomes, as evidenced by our results and others. The significant differences in mean all-cause and time-sensitive mortality rates between rural and non-rural communities indicate an increased relative risk of dying (not just from emergent conditions) in rural communities, where access to hospital and emergency services is declining. However, our results point to factors other than geographic isolation accounting for these disparate mortality rates. In addition to socioeconomic disparities, rural communities also have higher rates of chronic disease, lower levels of educational attainment, higher rates of smoking, lower rates of employment, poorer health literacy, and health workforce shortages (Kusmin, 2015; Moy et al., 2017; U.S. Department of Health and Human Services, 2022a, 2022b). All of these disparities may negatively impact health outcomes and mortality rates. Gong et al. (2019) concluded that the singular phenomenon of rurality did not appear to be directly related to increased mortality. However, they found that the phenomena associated with rurality (such as poverty and low educational attainment) correlated with higher rural mortality rates (versus those in non-rural areas).

The reverse effects for the access to care variables at the multivariate level, though still significant for all-cause mortality rates (see Table 3.3), are counterintuitive. These counterintuitive results may be due to the statistical phenomenon called *Simpson's paradox* (or *suppression effect*) (Arah, 2008). Simply stated, in non-experimental data analyses, specific combinations of covariates may reveal reverse directionality because of how the variance explained is parsed across the included covariates. It is plausible that this phenomenon also impacted the county-level uninsured percentages in our time-sensitive mortality models.

A related possibility is that the access to care parameters (i.e., travel times and distance) absorbed the impact of omitted covariates in our multivariate models. However, we chose covariates according to the constructs of the VPCM. Furthermore, these predictors are similar to those Yamashita and Kunkel (2010) employed in their GIS-based study of Ohio county-level distance to care and heart disease mortality and Gong et al. (2019) used in their study of urban versus rural mortality rates. We ran another model series to assess the effects of including population-to-primary-care-provider ratios. However, this addition added little to the models' significance and did not change the coefficient reversals. Still, it is impossible to account for all confounding factors, a restriction Zhang (2014a) called the Achilles heel of observational data and studies. Also, one must take precautions not to overfit models with excessive covariates, as findings may become difficult to interpret due to noise variables being introduced purely by chance (Zhang, 2014b).

Still, other issues may be responsible for the above counterintuitive results. While we had 950 observations in our long-form dataset, our sample represented only 95 counties, a relatively low number based upon projected access to care effects of around .20 (according to the United Health Foundation's (2022) County Health Rankings Model*)*. This sample size issue may have led to a Type II error, i.e., an actual positive significant effect that was not detected due to an underpowered study (Tappen, 2022). Furthermore, county-level data aggregates may not have adequately represented access to care for patients residing further from the county or census tract centroids (which we used in our access to care calculations). Also, while beneficial for comparative descriptive statistics, our dichotomizing of the Index of Relative Rurality may have aggregated widely varying characteristics into two categories (rural vs. non-rural). In other words, the regression models would benefit from a continuous value representation of rurality (Roehrich-Patrick & Moreo, 2016). Suppose our rural/non-rural categorization parsed out the predictive effects disproportionately across the two factors (since our models represented 80 rural but only 15 non-rural counties). In that case, continuous index values in our GLMMs might deliver different results. Furthermore, data issues (such as ACS margins of error or possible response bias) or the following additional limitations may have affected our multivariate results.

Limitations

Our study is limited in several added ways. First, we did not capture air and ground ambulances' effects on time-sensitive outcomes. Still, the U.S. Government Accountability Office (2019) reports that helicopters transport a relatively small portion of patients. Furthermore, Chaudhary et al. (2019) reported that when rural hospitals and emergency facilities close, ground ambulance transport times increased by 46% (15.7 minutes) from the previous year, primarily attributable to increased incident-to-hospital distances. Therefore, our spatial access to care measures likely account for a significant portion of patient access to emergency care services.

Second, our study includes the percentage of uninsured individuals less than 65 years old rather than percentages based on all ages. This omission is due to the lack of total population uninsured percentages prior to 2012. However, the U.S. Census Bureau Small Area Health Insurance Estimates (SAHIE) provided county-level uninsured percentages for ages below 65 and were available for the entire study period. Given that most individuals over 65 have Medicare Part A, which covers hospitalization, we felt our reliance on the SAHIE data was appropriate. Furthermore, our bivariate analysis indicated that uninsured status correlated with our outcome variables at a slightly lower significance level with $p = .001$ for time-sensitive mortality and not significantly ($p = .777$) for all-cause mortality. However, given the theoretical and policy importance of health insurance resources in facilitating the realized impact of access to care (Khan & Bhardwaj, 1994; U.S. Department of Health and Human Services, 2022b), we kept this predictor in our multivariate analyses.

Third, annual mortality data are not purely independent observations as one would typically assume for linear regression models (LeSage & Pace, 2009). However, our GLMMs accounted for the variations in the outcome variables (mortality rates) with respect to time and the state's geographic division (East, Middle, and West) via a random intercept component for each of those factors. This process overcomes the violated independent observations assumption when spatial contexts exist (LeSage & Pace, 2009).

Fourth, our sample size of 95 counties was relatively small. We overcame a portion of this limitation by including cross-sectional data for multiple years in long form (Grace-Martin, 2022), which increased our number of observations for analysis to 950. Still, expanding our sample to the counties of surrounding states or improving our sample's granularity through census tract level analyses may enhance our findings. Also, our study did not account for the effects of nearby out-of-state hospitals and emergency departments on border counties. Patients may receive treatment at out-of-state hospitals for emergencies (Dorsey, 2021), and Tennessee is now an emergency medical services (EMS) compact licensure state (meaning the state's EMS personnel may practice in other states that recognize compact licensure) (Prentiss, 2017). Therefore, future mortality research may benefit from including these out-of-state facilities.

Last, we based our study on observational population-based data, which cannot overcome the selection bias controlled for in randomized control group experimental designs. Given the nature of our research problem and available data, a randomized control study was impractical and possibly unethical. However, future research may overcome some of this bias and establish causality through a difference-in-difference or modern matching method design (Zubizaretta, 2022).

Strengths

While limitations may curb the applicability of our research findings, our study exhibited several strengths. First, we moved beyond the explanatory distance realm of *potential* access to care (i.e., availability) (Khan & Bhardwaj, 1994) and assessed the associated health outcomes after assessing spatial dependency. We also included and accounted for multiple aspatial (i.e., social) attributes associated with our spatial elements (Tennessee counties). Future research may benefit from assessing additional attributes that impact relative risk for adverse health outcomes (e.g., smoking rates, access to transportation, and broadband coverage). Still, we included theoretically derived elements aligned with the VPCM (Flaskerud & Winslow, 1998) and Khan and Bhardwaj's (1994) Access to Care Framework.

The relatively small amount of missing data from our datasets also strengthened our study. Less than 2% of time-sensitive mortality rates required imputation, and all other datasets were complete. In addition, our use of publicly available datasets with acceptable levels of quality and precedence for use in health services research supports our findings.

Policy Implications and Recommendations

Our study draws attention to the complex web surrounding the causes of Tennessee's rural hospital closures and their effects on mortality rates. However, many of these complexities point to an overarching issue, money. Rural hospitals are starving for funding and economic stability, as are the surrounding communities. Our review of the literature and study findings revealed that rural hospital *and* rural-resident survival hinge on financial well-being. In other words, a solid health-wealth connection exists (Singh et al., 2017). A deep dive into rural economic development is beyond the scope of this article. Therefore, our recommendations focus on the economic gains that result from improving the health of communities. This approach is similar to the Thrive Rural Framework for rural economic prosperity, which emphasizes shifting the "underlying structures and conditions that disadvantage rural people and places" (Aspen Institute, 2022, p. 3) and ensuring that rural people "have what they need to participate and thrive" (p.3).

Health as an Economic Engine

As Mirvis and Bloom (2008) succinctly explained, health as human capital and investment act as economic engines, setting a nation or community up for a "virtuous cycle" (p. 94) of improved health that yields economic gains, which, in turn, further improves health (and so forth). The mechanisms by which these economic advancements occur vary. However, drivers include productivity gains, outside economic investments when investors recognize a healthy workforce, cost savings from preventive health measures, educational attainment from decreased school absenteeism, and extended longevity that increases the number of years in the workforce (Adler et al., 2016; Mirvis & Bloom, 2008; Mirvis et al., 2008).

Unfortunately, many rural communities are in the reverse cycle of poor health and poverty. For example, counties with persistent poverty consistently outpaced other areas of the U.S. in COVID-19 case rates beginning in September 2020 (Dobis et al., 2021). Moreover, in 2016, the U.S. incurred $2.6 trillion in economic productivity costs from chronic disease (Waters & Graf, 2018), which is most prevalent in rural communities (Moy et al., 2017).

In Tennessee, poor health and decreased economic activity go hand in hand. A report from the Boyd Center for Business and Economic Research (Murray et al., 2020) revealed that in 2018, increased poor health in the past 30 days aligned with declines in mean annual income and labor force participation for 45- to 64-year-old persons. Furthermore, the report indicates that between 2013 and 2018, population heart health and employment growth aligned closely, as did primary care to population ratios (low in rural and economically distressed counties) and total employment. That is to say, unhealthy communities cannot participate freely in our economic system and, consequently, exert a drag on national, state, and local economies (Murray et al., 2020). Consequently, policymakers must focus not only on traditional rural economic development actions (such as industrial recruitment) but actively work to improve the health of these communities. Here, we offer several mechanisms that may launch a "virtuous cycle" of health and wealth in rural communities by addressing Tennessee's rural health and economic structure and processes.

Rural Hospitals

The federal government made one of its most substantial investments in health care with the passage of the Hill-Burton Act of 1946, a bipartisan piece of legislation that resulted in the construction of over 4,200 hospitals and long-term care facilities and nearly $13 billion in federal, state, and local investment through 1975 (Cellucci et al., 2019). While some maintain that this government investment offset private investments to the tune of a 70% crowd-out effect (the offset reductions in non-government investment) (Chung et al., 2016), the legislation undoubtedly resulted in billions of dollars that improved health care access and the economies of poor and underserved communities across the nation. We maintain that while the 21st-century rural hospital model deserves redesign (Mason, 2017), rural hospital investment is still a worthwhile endeavor, particularly considering economic benefits within the communities (Holmes et al., 2006; U.S. Government Accountability Office, 2020). This process begins by aligning their service offerings with the community's needs, addressing quality issues to maximize health dividends and returns on investment, and restructuring reimbursement to line up with present-day expenditures.

Expanded Primary Care Access

The benefits of primary and preventive care cannot be understated. Nations that invest heavily in these essential services generally see better health outcomes at reduced costs than those that do not (World Health Organization, 2020). Li (2021) asserted that more than 80% of routine illnesses and chronic conditions can be treated adequately by family health care providers and primary care teams, reducing costs and reliance on secondary care settings.

MacKinney et al. (2014) reported that U.S. Primary care Health Professional Shortage Areas (65.49% of which we find in rural communities (U.S. Department of Health and Human Services, 2022a)) have higher percentages of patients with fair to poor health status and chronic health conditions. This situation points to the health ramifications of primary care shortfalls and inequitable resource allocation, which may worsen when rural hospitals close. This detrimental effect is due to the associated departure of physicians in the wake of a closure (Germack et al., 2019) and the loss of the emergency room, which serves as a primary care source for some rural residents (Letheren, 2021).

Shifting the U.S.'s reliance on specialty and secondary care (what Shi and Singh (2019) refer to as *specialty maldistribution*) to comprehensive primary care is no easy feat. It requires committed policymaking. Consequently, we recommend several policy measures to improve primary care availability and accessibility in rural communities. First, expanded recruitment and retention investments are needed to incentivize entry into primary care and long-term service in rural and underserved communities (Bodenheimer & Pham, 2010; Rural Health Information Hub, 2021b). To accomplish this goal, in part, all states and territories should allow all providers of primary care services to practice to the fullest extent of their education and credentialing (Kueakomoldej et al., 2022; National Academies of Sciences, Engineering, and Medicine, 2021).

Advanced Practice Registered Nurses (APRNs). APRNs are a group of registered nurses with either master's or doctorate degrees who deliver care within multiple settings.

However, most are likely to practice in primary care and are more likely to practice in rural communities than other health care providers (National Academies of Sciences, Engineering, and Medicine, 2021). Enacting full practice authority (FPA) for this group of health professionals will boost the supply of primary care providers (Kueakomoldej et al., 2022) and consequent health outcomes. FPA for APRNs may also confer substantial economic growth through various added mechanisms. For example, Myers et al. (2020) found in their economic impact study that granting FPA to Tennessee's APRNs would likely add nearly 7,700 jobs and $1 billion to the state and local economies from 2017 to 2025. However, Tennessee and ten other states continue to restrict one or more aspects of APRN practice (American Association of Nurse Practitioners, 2022).

The APRN workforce also tends to be more resilient when hospital resources decline. While Germack et al. (2019) found that the supply of physicians declines before and after rural hospital closures, this same group of authors found no such departure of nurse practitioners or certified registered nurse anesthetists (2021). Given APRNs' plasticity in the marketplace, policymakers should endeavor to ensure APRNs' unencumbered practice.

Health Centers. In addition to growing the primary care workforce through provider incentives and FPA for APRNs, policymakers at the federal and local levels should expand the presence of Community Health Centers, Rural Health Centers, and Federally Qualified Health Centers. These health centers (which vary in definition, reimbursement structure, and quality reporting) receive taxpayer dollars to provide care in underserved communities. Consequently, they are more likely to exist in rural communities (National Association of Community Health Centers, 2007; Rural Health Information Hub, 2021a). With health centers growing in number, the Health Resources and Services Administration (2021) estimated that more than a quarter-million full-time Health Center Program staff served almost 29 million patients at Health Centers across the U.S. in 2020 and were instrumental in the early COVID-19 vaccination rollout. During the nationwide shutdown, they also provided over 28.5 million virtual visits to ensure continuity of care. In 2020, 97% of these centers provided mental health services, while 77% provided care for those suffering from substance use disorders.

In addition to enhancing health through direct coordinated patient care, health centers also yield substantial cost savings and economic returns in underserved communities. For instance, the National Association of Community Health Centers (2020) reported that the nation's health centers generated $63.4 billion in economic activity and 455,000 jobs in 2019. That same year in Tennessee, health centers generated nearly $660 million in economic activity and 4,352 full-time equivalent jobs. Given rural and underserved communities health and economic payoffs, policymakers must ensure their continued growth through sustainable investments.

Emergency Care: Free-standing ERs

In addition to primary care, patients must have access to emergency services in times of need. While accessible, high-quality, comprehensive primary care reduces the need for secondary and tertiary hospital services, the closure of hospitals and emergency departments nationwide has resulted in emergency department overcrowding (Shi & Singh, 2019). The growing dearth of these services in rural communities has also led to considerable community anxiety surrounding the logical offshoot, increased mortality and morbidity (Letheren, 2021; Murry et al., 2021). While ground and air ambulance personnel may bridge some gaps, they cannot fully replace emergency departments' highly specialized 24-hour care (Chaudhary et al., 2019; Shi & Singh, 2019). The need persists, even when these facilities limit their care to stabilization before transferring patients to higher levels of care (Windorski et al., 2019).

Therefore, policymakers should take steps to ensure the balanced and fair presence of more free-standing emergency facilities. In Tennessee, 17 counties had no emergency department as of April 2019 (Pelligran, 2019; Tennessee Department of Health, 2021). A recent measure by the U.S. Congress will allow some CAHs and other small rural hospitals with fewer than 50 beds to convert to Rural Emergency Hospital status beginning January 2023 (U.S.

Department of Health and Human Services, 2021b). While this new hospital classification is a step in the right direction for ensuring emergency services in communities with struggling hospitals, it does little to help those currently without hospital and emergency services. Therefore, we recommend that states work with communities to ensure their ability to build and maintain free-standing emergency facilities should they be unable to access these services within a reasonable time frame.

Internet Connectivity Investments

Policymakers should ensure greater access to high-speed, affordable broadband services. Researchers and the federal government now consider access to these internet services a super-determinant of health (Bauerly et al., 2019; Federal Communications Commission, 2022b), as it facilitates other SDOH, such as employment and education. Broadband also paves the way for essential health messaging, electronic monitoring of patient health status, and care delivery. Furthermore, this connectivity may improve deficient levels of rural health literacy and make it simpler for rural communities to access and understand health messaging and navigate the health system (Temple, 2022). The recent pandemic also highlighted the importance of affordable, reliable internet services in maintaining employment, child and adult education, and health care access (Federal Communications Commission, 2022a; Peters, 2020). Assume rural communities are to improve their economic, physical, and mental well-being. In that case, policymakers must continue filling the gaps in rural electronic communications through funding for expanded networks and laws facilitating novel approaches to providing services in short-supply locales (Bauerly et al., 2019; Myers, 2019).

Barriers to Implementation

Barriers to the implementation of these recommendations exist. Competing political interests (Longest, 2016) impact the allocation of finite resources (to fund rural hospital support, high-speed internet expansion, and rural health care provider incentives). In the case of full practice authority for Tennessee APRNs, these competing interests have also stalled legislative action to remove professional practice restrictions that some stakeholders believe will benefit one professional group over another (Myers et al., 2022). Furthermore, community buy-in and sustained local involvement in creating and operating health centers (U.S. Department of Health and Human Services, 2010) may be problematic if community leaders are unaware of the resources available to facilitate these processes. To overcome these potential barriers, nurses must continue to advocate for evidence-based policies to reduce disparities and improve the well-being of vulnerable rural Tennesseans.

Future Research

This study demonstrated the interconnectedness of human and environmental capital by assessing their combined impact (focusing on distance and travel times to hospital and emergency care) on Tennessee's mortality rates from 2010 to 2019. However, future research should build upon this work and incorporate the combined effects of additional rural hospital closures during the COVID-19 pandemic, when rural communities grappled with declining resources and heavy disease burdens. Also, future studies should assess the effects of additional possible confounding factors, such as air ambulance utilization, chronic disease burden, and additional resources such as education and literacy rates. Future research should consider the granularity of the spatial data and the level at which data are aggregated for analyses (e.g., census tract, census block, or zip code levels). Furthermore, researchers should consider expanding the sample size (to include additional states), using a non-dichotomized Index of Relative Rurality, or employing different statistical models to assess their impact on the adjusted correlations. Moreover, causal inference study designs (such as difference-in-difference studies) may also be warranted.

Conclusion

Despite the U.S.'s unprecedented wealth, disparities between urban and rural health outcomes continue to grow. Tennessee, with its low health rankings, is no exception. Unfortunately, access to rural health care services and economic parity continue to decline across the state, catching many communities in a downward spiral of poor health and starving economies. This study confirmed that significant differences existed between Tennessee's rural and urban county-level mortality rates, human capital, and environmental resources, all while the state is losing more hospitals per capita than any other state (2010 – 2019). Our bivariate analyses confirmed that distance and travel times to the nearest hospital and emergency care source correlate significantly with county-level mortality rates. However, county-level median age, household income, and rurality were the most significant predictors of all-cause and time-sensitive mortality rates in our multivariate aspatial and spatial GLMMs. Researchers should undertake future studies that employ causal inference designs and assess the effects of hospital closures since 2019 and other covariates.

We agree that good health fuels the economic engine that holds the potential to reverse Tennessee's downward spiral of rural poverty and poor health. Consequently, we set forth several rural health policy recommendations. These include sustaining rural hospitals, expanding primary care availability through APRN full practice authority and additional health centers, expanding emergency care options, and ongoing expansion of affordable, reliable high-speed internet technologies in rural communities. With sustainable long-term investments in the health of rural communities and patients, Tennessee's legislators and policymakers can instead spawn a "virtuous cycle" of rural health and wealth across the state.

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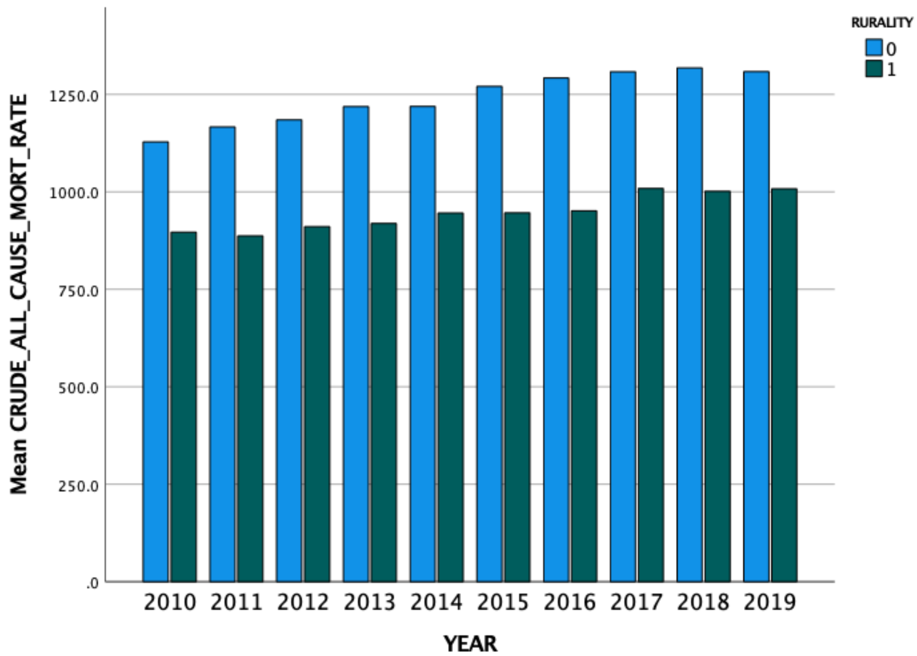
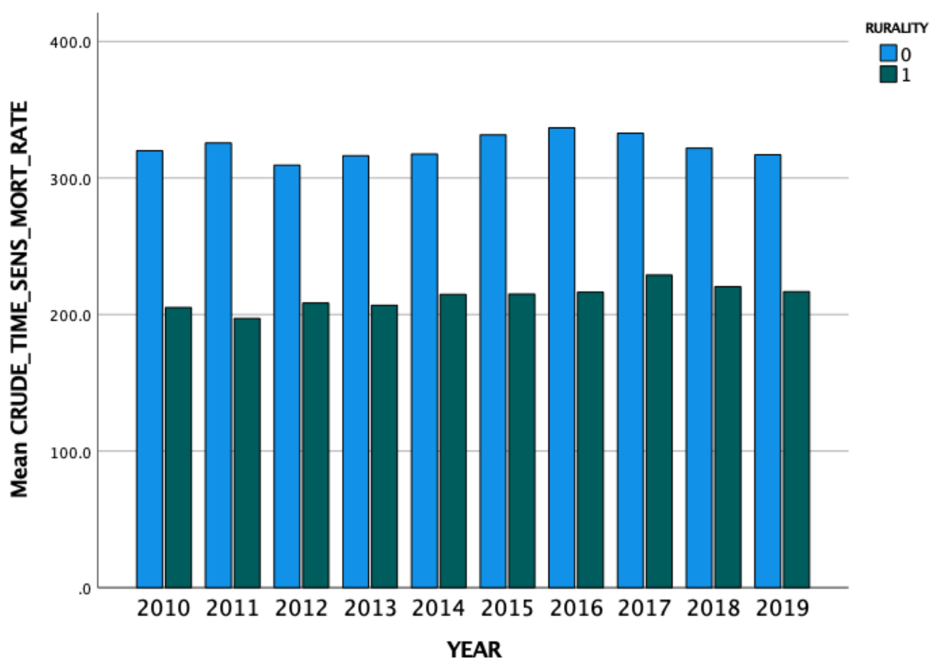
Appendix

Table 3.1. *County-level attributes for Tennessee based on rurality, 2010 – 2019 (95 counties)*

County-level Attributes	Rural (*n* = 80 counties)		Non-rural (*n* = 15 counties)	
	Mean*	SD	Mean*	SD
Median Age	41.84	2.82	38.11	3.71
Total Population	31,560.62	21,661.22	262,990.96	237,271.10
Median household income	39,365.77	7,370.45	51,280.16	13,913.45
Uninsured percentage (age <65 years)	14.58	2.84	13.05	3.18
Population to primary care provider ratio	1116.54	750.26	494.09	195.91
Ethnicity: Percentage Hispanic/Latino	2.76	2.04	5.26	2.72
Race: Percentage identifying as white	92.46	9.35	82.34	15.29
Census tract-based Euclidean distance (meters)	9,223.37	6,097.42	7,347.45	1,892.50
Census tract-based mean travel time (minutes)	15.52	6.50	10.79	2.40
County centroid-based travel time (minutes)	11.36	8.77	8.01	3.36
All-cause mortality (per 100,000)	1,241.61	191.41	947.60	231.31
Time-sensitive mortality (per 100,000)	322.93	79.30	213.02	50.44

Note. * Per ANOVA testing, the between-group differences (rural vs. non-rural counties) for all county-level means were significant at a level of $p < .001$, $N = 950$ (95 counties x 10 years).

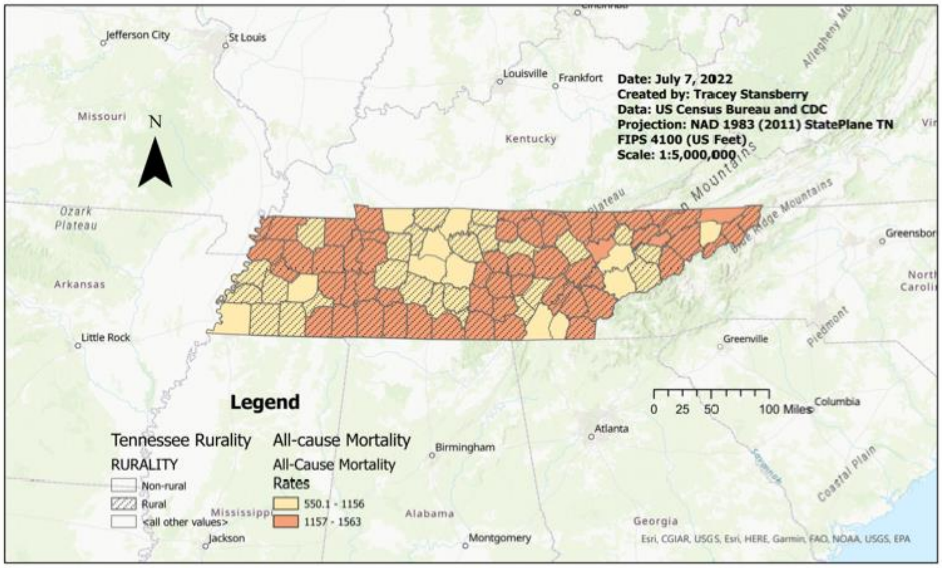




Note. Blue = rural counties; gray = non-rural counties.

Figure 3.1. *Tennessee's all-cause (top) and time-sensitive (bottom) mortality rates by rurality and year, 2010 - 2019*

County-Level All-Cause Mortality by Rurality,
Tennessee,
2010 - 2019,
Natural Breaks (2)



County-Level Time-Sensitive Mortality by Rurality,
Tennessee,
2010 - 2019,
Natural Breaks (2)

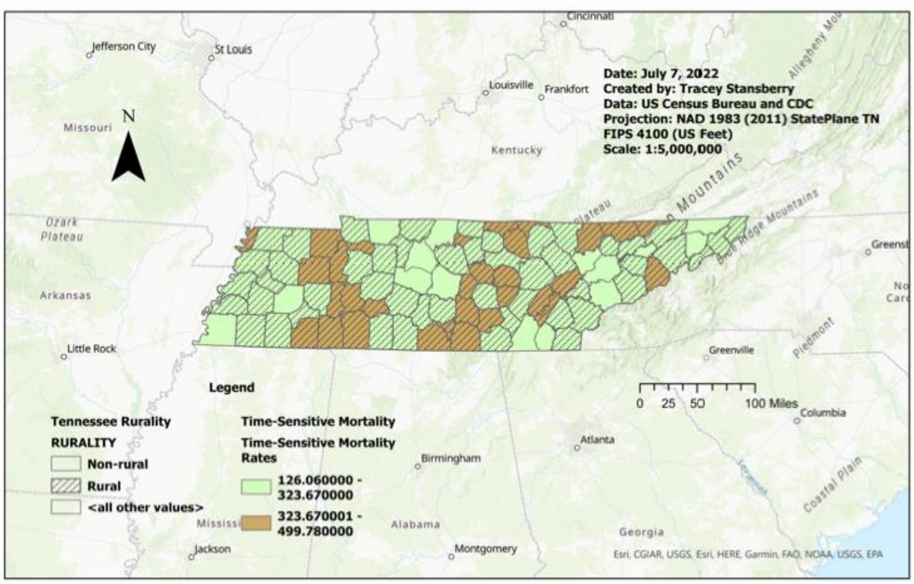


Figure 3.2. *County-level mortality by rurality, Tennessee, 2010 – 2019*

Table 3.2. *Bivariate correlations between factors and mortality rates, Tennessee counties, 2010 – 2019*

County-Level Metric	All-cause mortality		Time-sensitive mortality	
	Pearson's Correlation	*p*-value (2-tailed)	Pearson's Correlation	*p*-value (2-tailed)
Median age	.721	< .001**	.520	< .001**
Median household income	-.584	< .001**	-.539	< .001**
Uninsured percentage (age <65 years)	.009	.777	.104	.001*
Ethnicity: Hispanic/Latino percentage	-.404	< .001**	-.425	<.001**
Census tract-based mean Euclidean distance	.132	< .001**	.162	<.001**
Census tract-based mean travel time	.122	< .001**	.142	<.001**
County centroid-based travel time	.055	.090	.071	.028∞
Rurality (rural vs. non-rural)	.469	<.001**	.476	<.001**

Note. Findings based on 95 counties over ten years (N = 950). ∞ Correlation is significant at a 0.05 level. * Correlation is significant at a 0.01 level. ** Correlation is significant at a 0.001 level.

Table 3.3. *Coefficients and t-values for the six aspatial negative binomial GLMMs, Tennessee counties, 2010 – 2019, N = 950 (n = 95 counties x 10 years)*

	All-cause mortality models			Time-sensitive mortality models		
Predictor	Census tract-based mean Euclidean distance	Census tract-based mean travel time	County centroid-based travel time	Census tract-based mean Euclidean distance	Census tract-based mean travel time	County centroid-based travel time
Access to care metric	**β: -2.187e-06 t-value: -4.036**	**β: -2.869e-03 t-value: -5.6766**	**β: -1.852e-03 t-value: -4.969**	β: -1.419e-06 t-value: -1.344	β: -1.915e-03 t-value: -1.931	β: -1.308e-03 t-value: -1.794
Median age	**β: 3.114e-02 t-value: 25.172**	**β: 3.129e-02 t-value: 25.5276**	**β: 3.142e-02 t-value: 25.528**	**β: 2.956e-02 t-value: 12.830**	**β: 2.973e-02 t-value: 12.925**	**β: 2.981e-02 t-value: 12.956**
Median household income	**β: -1.210e-05 t-value: -23.884**	**β: -1.202e-05 t-value: -23.9156**	**β: -1.192e-05 t-value: -23.621**	**β: -1.431e-05 t-value: -16.134**	**β: -1.429e-05 t-value: -16.125**	**β: -1.423e-05 t-value: -16.073**
Uninsured % (<65 years old)	**β: -8.522e-03 t-value: -3.429**	β: -7.791e-03 t-value: -3.1456**	β: -7.524e-03 t-value: -3.029**	**β: -1.055e-02 t-value: -3.620**	**β: -1.044e-02 t-value: -3.568**	**β: -1.027e-02 t-value: -3.533**
Ethnicity: Hispanic or Latino %	β: 2.687e-03 t-value: 1.450	β: 1.727e-03 t-value: 0.9311	β: 2.228e-03 t-value: 1.203	β: -7.422e-03 t-value: -2.344**	β: -7.886e-03 t-value: -2.476**	β: -7.631e-03 t-value: -2.410**
Rurality (rural vs. non-rural)	**β: -6.126e-02 t-value: -5.477**	**β: -6.018e-02 t-value: -5.5262**	**β: -5.435e-02 t-value: -5.022**	**β: -1.361e-01 t-value: -6.241**	**β: -1.358e-01 t-value: -6.343**	**β: -1.319e-01 t-value: -6.229**

Note. Statistically significant t-values (2-tailed; $p < .001$) are displayed in bold and based on 943 degrees of freedom (Stangroom, 2022). ** Statistically significant t-values (2-tailed) at a level of $p < .05$.

Conclusion

This dissertation consists of three manuscripts (preceded by an introductory chapter), exploring Tennessee's disparate rural mortality rates in the wake of the state's hospital closures from 2010 to 2019. These closures, the highest per capita in the nation, have occurred disproportionately in the state's rural communities, yet little is known about the impact on the health outcomes or rural health disparities. This work extends the knowledge of the effects of hospital and emergency department closures on Tennessee's county-level mortality rates while accounting for time, space, and other social and environmental resources.

The introductory chapter offers insight into the history of hospital closures in the U.S. and Tennessee and the scientific domain of spatial inquiry for nursing research. The Vulnerable Populations Conceptual Model (VPCM), the foundational mid-range nursing theory that framed this study, is covered in-depth, along with the geographically based Access to Care Framework. This introduction also covers this study's research question and purpose to understand the relationship between the state's disparate rural mortality rates and declining access to hospital and emergency care, adjusting for other environmental and human capital resources. The introduction also provides brief orientational definitions of health equity (this study's overarching concept) and rural hospitals.

The first manuscript is an integrative literature review that summarizes and compares studies (published since 2010) exploring U.S. hospital closures and their effects on vulnerable rural populations. Prior research has focused mainly on the nation's hospital and emergency department closure effects on access to care and the quality of care delivered in the facilities. If these facilities provide adequate or high-quality care, their closures put communities at risk of worsening health disparities. Furthermore, several studies and reports revealed these closures' community-level economic and emotional effects. Yet, scant research investigating Tennessee's hospital closure effects on disparate rural mortality rates exists. The focus on access to care found in much of the literature provides the foundation for our study. Rather than focusing on access as an outcome, our study focuses on access as a predictor of health outcomes.

The second manuscript is a methods article that presents the advantages of spatial science for nursing health disparities research and provides an exemplar of how access to care determinations impact study results. Geographic information systems (GIS) methods and associated data processing platforms allow researchers to integrate spatial data (e.g., access to care metrics) and associated aspatial (i.e., social) attributes into statistical analyses and modeling. The manuscript contains an exemplar, which spells out this study's three methods for determining access to care and how the various calculations for distance and travel times yield varying results in the final models. Spatial science methods are gradually gaining traction within nursing science, albeit slowly. Ultimately, these methods allow nursing health services and disparities researchers to inform policy by assessing the impact of myriad spatial and aspatial factors on patient and community health and well-being.

The third chapter, a comprehensive results and implications manuscript, covers this study. Namely, this study was a GIS-informed retrospective ecological correlational study that assessed the relationship between Tennessee's disparate rural mortality rates and the growing distance and travel times to hospital and emergency care plus other environmental and human capital resources over ten years, 2010 to 2019. This study used publicly available data and employed descriptive and correlational testing, followed by aspatial and spatial analyses using negative binomial generalized linear mixed-effects models (GLMMs). The study confirmed significant correlations between county-level mortality (all-cause and time-sensitive mortality rates) and access to care (distance and travel times), median age, median household income, uninsured status, ethnicity, and rurality (at the bivariate level). In the GLMM, the fixed effects of county-level median household income, median age, and rurality were the most significant predictors ($p < .001$) of all-cause and time-sensitive mortality rates after accounting for the variations in mortality rates with respect to time and the state's geographic division (East, Middle, and West) via the random intercept components for these two factors. After applying the random intercept components, we found reduced statistical significance for the fixed effects of access to care, ethnicity, and uninsured status. Still, the study confirmed our research hypotheses. Specifically, distance or travel times to hospital and emergency care accounted for significant variance in county-level all-cause and time-sensitive event mortality rates (in our bivariate analysis). Social and environmental factors (median age, median household income, and rurality) significantly influenced the effects of travel times and distance to care on mortality rates. Rural Tennesseans (with longer distances and travel times to hospital and emergency care) had an increased relative risk of death (as demonstrated by significantly higher mortality rates in rural counties compared to non-rural counties).

Implications for Policy

This study found the effects of access to care diminished somewhat when accounting for other social and environmental factors. Specifically, after median age, median household income and rurality were the most significant contributing factors to Tennessee's disparate rural mortality rates, pointing to previously documented health-wealth connections exemplified by cycles of poverty and poor health. However, scholars have recognized that good health improves wealth and socioeconomic standing. Accordingly, policymakers must break the downward spiral of Tennessee's rural poverty and poor health by supporting rural health through a series of policy measures. These actions include sustaining rural hospitals, expanding primary care availability through APRN full practice authority and additional health centers, expanding rural emergency care options, and ongoing expansion of affordable, reliable high-speed internet technologies in rural communities. With these long-term investments in the health of rural communities and patients, Tennessee's legislators and policymakers can kick start the rural economic engine and give rise to a "virtuous cycle" of rural health and wealth across the state.

Implications for Future Research

This study demonstrated the interconnectedness effects of human and environmental capital on social and physical well-being. However, future research should build upon this study by incorporating the impact of additional rural hospital closures during the COVID-19 pandemic, when rural communities grappled with declining resources and heavy disease burdens. This extra focus could illuminate issues surrounding declining surge capacity that resulted from Tennessee’s rural hospital closures. Future studies should also account for the effects of additional resources (e.g., air ambulance utilization, chronic disease burden, educational attainment, and literacy rates), incorporate the non-dichotomized Index of Relative Rurality, and expand to include nearby out-of-state hospitals in access to care calculations. Causal inference designs (such as difference-in-difference designs), larger sample size (to include surrounding states), and increased spatial granularity are also warranted.

Vita

Tracey T. Stansberry, MSN, APRN, AOCN, is an Advanced Practice Nurse with over 18 years of experience providing care in the rural sector. Stansberry earned her BSBA in 1989 and MSN in 2001, both from the University of Tennessee Knoxville. In 2003, she worked with leaders in Scott County, Tennessee, to open the community's first cancer treatment center. She acted as its Director of Clinical Services with Dr. Dirk Davidson until January 2019, when she began the PhD program in Nursing at UTK. Having experienced the 21st Century's decline in access to rural health services first-hand, Stansberry focused her doctoral studies on Rural Health Policy and Health Services Research. Stansberry currently serves on the Community Advisory Board at Big South Fork Medical Center, the Scott County Department of Health's Advisory Board, the Tennessee Nurses Association District 2 Board, Mountain Peoples' Health Council (FQHC) Board, and the Tennessee Health Care Campaign Board of Directors. Stansberry is a member of the American Nurses Association, American Association of Nurse Practitioners, the Oncology Nursing Society, Phi Kappa Phi, Academy Health, and Sigma Theta Tau International Honor Society of Nursing.