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Geographic patterns of end-stage renal disease and kidney transplants in the Midwestern United States

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ABSTRACT

This research analyzes geographic patterns of ESRD incidence and kidney transplantation at county level in an area that covers 11 states in the Midwestern US from 2004 to 2011. We investigate whether variations in ESRD incidence exist among white, black, and Native American population groups, and the degree to which disparities existed with respect to access to kidney transplantation, and with respect to rural and urban counties. Spatial clusters of ESRD incidence rates are detected using global Moran's I and local Getis-Ord G_i^* statistic. Spatial accessibility to transplant centers is evaluated using the enhanced two-step floating catchment area method where dissimilarities due to varying travel times and ESRD incidence rates result in differences in spatial access among the groups. Results show that while similar age-adjusted ESRD incidence rates hold for white and black population groups in urban counties, the kidney transplant rate is 73% lower among black patients than for whites in the study area. A lack of transplant centers in locations that correspond to strongly clustered age-adjusted ESRD incidence rates in southern Missouri and central South Dakota, contribute to lower spatial access indices in these counties. The results of the analyses capture varying patterns of ESRD incidence rates and kidney transplants in this Midwestern region and highlight spatial disparities for certain population groups.

1. Introduction

At the end of 2012, 449,342 patients in the United States were undergoing treatment for end-stage renal disease (ESRD) (U.S. Renal Data System, 2014). ESRD is defined by irreversible chronic kidney disease requiring renal replacement therapy with dialysis treatments (hemodialysis or peritoneal dialysis) or a kidney transplant. A kidney transplant improves survival and quality of life among ESRD patients (Mathur, Ashby, Sands, & Wolfe, 2010). Not all patients with ESRD are candidates for a kidney transplant due to concomitant medical or surgical conditions that may increase risks of transplant complications (Kasiske et al., 2001). Among all patients listed for a transplant, only a quarter will receive a transplant, and about 15% will die while waiting for a transplant due to organ shortages. Based on statistics relating to primary diagnosis from the United States Renal Data System (USRDS)[1], hypertension and diabetes are the two leading causes for increasing numbers of individuals with ESRD. When patients are diagnosed with ESRD, they start receiving dialysis treatments including hemodialysis and peritoneal dialysis (U.S. Renal Data System, 2014). Previous research on geographic variations in ESRD occurrence and acquisition of kidney transplants have investigated continental patterns (e.g., Ashby et al., 2007) as well as spatial variability in ESRD incidence *vs*. transplant rates for certain individual state-based cases, for example, ESRD in South Carolina (Fan et al., 2007) and California (Soret, McCleary, Wiafe, Rivers, & Montgomery, 2001). For this study, we investigate geographic patterns of rates of ESRD incidence and kidney transplants at the county level for two regions in the United Network for Organ Sharing (UNOS). The area covers eleven states in the US Midwest and West including North Dakota, South Dakota, Minnesota, Wisconsin and Illinois (UNOS Region 7), and Wyoming, Colorado, Nebraska, Kansas, Iowa and Missouri

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[1] www.usrds.org.

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(UNOS Region 8) with a total incidence of 105,338 ESRD patients representing approximately 12.49% of the US ESRD population during the years 2004–2011. Nine organ donation service areas (DSAs) handle the allocation of organs for transplantation purposes in this region. As part of this study, we examine the geographic pattern of ESRD incidence across the region for different population groups, with a particular focus on white, black, and Native American population groups. We also study the degree to which the pattern of spatial access to kidney transplants corresponds to the spatial distribution of ESRD incidence for these different groups in this study area. Through this research, we seek to reveal where disparities may exist with regard to obtaining treatment based on spatial accessibility to transplant centers and rurality of counties. In a region that may be thought of as being rather homogeneous with respect to population, our work reveals that the burden of this illness does vary between groups and varies geographically. Such disparities could be a significant factor for morbidity and mortality among impacted ESRD patients. This work is an area-based study that investigates both ESRD incidence and transplantation for different racial groups and geographic locations that may help to provide insights for policy makers to balance opportunities for kidney transplantation for ESRD patients.

2. Background

Previous research has shown that in the United States, there is a disparity between the distribution of white, black, Asian, and Native American ESRD patients, and the numbers of kidney transplants that correspond for each group (Arce, Goldstein, Mitani, Lenihan, & Winkelmayer, 2013; Eggers, 1995; Kasiske et al., 1991; Sanfilippo et al., 1992). Research by Mathur et al. (2010) shows that before 2009 there was generally a high incidence of ESRD among black population and Native Americans, and a lower incidence among whites, Asians and others. According to the 2014 Annual Report from National Institutes of Health, the ESRD incidence among black patients is 2.96 times greater than that among whites in 2012 (U.S. Renal Data System, 2014). However, those higher ESRD incidence groups may have lower kidney transplant rates in certain locations due to various factors (Hall, Choi, Xu, O'Hare, & Chertow, 2011) including socioeconomic status (Rodriguez, Hotchkiss, & O'Hare, 2013) and high prevalence of a certain blood type (Vranic, Ma, & Keith, 2014). Lower income, less educational attainment, or lower rate of employment is linked to a lower ability for attaining costly renal care (i.e., long term dialysis and transplants) and thus higher rates in ESRD incidence (Rodriguez et al., 2013). Previous studies have also found that black population, as a group with a higher density of ESRD patients but lower organ supply as well as renal care delivery, receive fewer kidney transplants, even in highly populated areas such as Chicago, Atlanta, and Los Angeles (Mathur et al., 2010; Rodriguez et al., 2013). In addition to inequalities in socioeconomic status between different population groups (Sequist et al., 2004) and while all patients with ESRD In the United States are eligible to receive Medicare coverage for both dialysis and kidney transplantation regardless of their age, studies from Flores (2006) found that health literacy among minority groups, for example, lower proficiency in English, may also be a significant barrier for ESRD patients to be afforded high quality health care.

Previous research on spatial patterns of kidney transplants has considered different geographic scales (Cass, Cunningham, Wang, & Hoy, 2001; Valderrábano, Gómez-Campderá, & Jones, 1998). A study at the state level for the US during 1996–2005 showed an imbalance between rates of transplants and ESRD incidence (Ashby et al., 2007), where only 20 out of 50 states had lower ESRD rates and higher transplant rates (mainly in the north and northeast of the country) compared with other states. In an investigation of ESRD patterns in South Carolina from 1990 to 1999, Fan et al. (2007) explored ESRD and related risk factors (e.g., physician density and rate of hypertension) by county in South Carolina and found a higher ESRD incidence rate among rural African Americans than other residents. To examine spatial variations between ESRD populations and kidney transplant distributions in California, spatial clusters of illness and treatment were computed and mapped at ZIP code level to identify populations at risk in California (Soret et al., 2001). Researchers found that among three clusters of high transplant rates in San Diego, San Jose, and Lake Tahoe, only the cluster in San Diego corresponded with a high ESRD rate. Determining the regional variability of ESRD incidence rates between racial groups affords an opportunity to identify high-risk locations within a small area. These place-specific results where unequal access to kidney transplantation is observed are especially useful for decision-making by local renal services and can lead to changes in policies and increases in transplant rates among the disadvantaged (Fan et al., 2007). Using GIS, populations and locations can be identified and mapped according to their different levels of spatial access to kidney transplant center locations. Spatial access refers to geographic barriers often between healthcare consumers and providers (Joseph & Phillips, 1984) and impedance in patients' travel to health care services while also considering the availability of facilities (Guagliardo, 2004; Luo & Qi, 2009; Wang & Luo, 2005). To identify potential demand area for cancer care facilities, spatial accessibility to the facilities was quantified at national level (Shi, Alford-Teaster, Onega, & Wang, 2012). More recently, an investigation of possible spatial barriers to in vitro fertilization (IVF) treatment services for the state of Iowa, applied a modified gravity model and self-organizing map techniques to determine quantitative scores for spatial accessibility and identify potentially underserved areas (Gharani, Stewart, & Ryan, 2015). One model that has become popular for quantifying spatial accessibility is the two-step floating catchment area (2SFCA) that calculates physician-population ratio within a catchment area in terms of each facility and sums up the ratio within a catchment size of each population enumeration (Luo & Wang, 2003). The basic form of this model does not consider variable catchment sizes, however, and has been extended as the enhanced two-step floating catchment model (E2SFCA), variable two-step floating catchment model (V2SFCA) and variable-width floating catchment model (VFCA) (Dony, Delmelle, & Delmelle, 2015; Luo & Qi, 2009; Luo & Whippo, 2012).

Another factor that has been studied for its contribution to an inequality between kidney transplant rates and ESRD incidence for different racial and ethnic groups is the possible disparity between urban and rural patients (Axelrod et al., 2008; Fan et al., 2007; Rodriguez et al., 2007). Patients living in rural areas typically have longer travel distances to kidney transplant centers and may experience a longer waiting time and have fewer available kidney specialty services (such as nephrologists) (Axelrod et al., 2008; Rodriguez et al., 2013; Vranic et al., 2014). In addition, lower socioeconomic status as well as racial composition of neighborhoods among rural residents are also associated with lower accessibility to kidney transplants especially since ESRD is a very costly condition and requires expensive dialysis facilities (Rodriguez et al., 2013). Studies have shown that black patients living in rural areas (particularly in the US South) are less likely to receive transplants compared to whites (O'Hare, Johansen, & Rodriguez, 2006).

3. Methods

3.1. Data sources

The incidence counts of ESRD from 2004 to 2011 for each county