Clinical Commentary Review

Rural Health Disparities in Allergy, Asthma, and Immunologic Diseases: The Current State and Future Direction for Clinical Care and Research

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Rural health disparities are well documented and continue to jeopardize the long-term health and wellness for the millions of individuals who live in rural America. The disparities observed between urban and rural residents encompass numerous morbidity and mortality measures for several chronic diseases and have been referred to as the "rural mortality penalty." Although the unmet health needs of rural communities are widely acknowledged, little is known about rural health disparities in allergies, asthma, and immunologic diseases. Furthermore, the intersection between rural health disparities and social determinants of health has not been fully explored. To achieve a more complete understanding of the factors that perpetuate rural health disparities, greater research efforts followed by improved practice and policy are needed that account for the complex social context within rural communities rather than a general comparison between urban and rural environments or focusing on biomedical factors. Moreover, research efforts must prioritize community inclusion throughout rural areas through meaningful engagement of stakeholders in both clinical care and research. In this review, we examine the scope of health disparities in the rural United States and the impact of social determinants of health. We then detail the current state of rural health disparities in the field of allergy, asthma, and immunology. To close, we offer future considerations to address knowledge gaps and unmet needs for both clinical care and research in addressing rural health disparities. **(J Allergy Clin Immunol Pract 2024;12:334-44)**

Key words: *Rural; Health disparities; Social determinants of health; Allergy; Asthma; Allergic rhinitis; Food; Atopic dermatitis; Immunology*

BACKGROUND

Rural communities face distinctive health challenges due to a complex interplay of cultural, social, economic, and geographic factors that are compounded by disparities in age, income, health status, health care access, and community capacity (eg, availability of community resources).[1] The unmet health care needs of rural communities are noted as priorities by multiple national agencies and organizations including the US Department of Health and Human Services, the National Institutes of Health, and the National Quality Forum.[2-4] In addition, the National Center for Advancing Translational Sciences and the Asthma and Allergy Foundation of America have designated individuals residing in rural areas as a vulnerable population.[5,6] Despite allergies and asthma being among the most common chronic diseases in the United States,[7,8] the literature on rural health disparities for these diseases is scant and sporadic. Several recent reports have focused on health disparities in allergies and asthma[6,9-11] but did not fully address rural health disparities. Thereby, the American Academy of Allergy, Asthma & Immunology's (AAAAI's) intent on featuring rural health disparities in allergies, asthma, and immunologic diseases as discussed in this review article is timely. In this review, we provide a framework for the scope of health disparities in the rural population and address important considerations for social determinants of health (SDHs) as a potential pathway through which SDHs impact the rural population leading to rural disparities.[12] We then examine the current state of rural health disparities pertaining to allergies, asthma, and immunologic diseases. In closing, we discuss future directions for clinical care and research in rural populations with a focus on allergy, asthma, and immunology.

HOW IS RURAL DEFINED?

The term "rural" encompasses diverse meanings, including agricultural landscapes, small towns, geographic isolation, and low population density.[13] The US government has no standard definition for rural, but federal agencies apply various definitions that differ in terms of minimum population thresholds to distinguish rural from urban areas.[14] The main classification systems used by federal agencies, policy analysts, and researchers to define rural areas include the following: (1) the US Census

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Abbreviations used
AAAAI- American Academy of Allergy, Asthma & Immunology
AD- atopic dermatitis
AI- artificial intelligence
CRS- chronic rhinosinusitis
ED- emergency department
FA- food allergy
NAM- National Academies of Medicine
PIDD- primary immunodeficiency disorder
SDH- social determinant of health
SES- socioeconomic status

Bureau's urban and rural definitions, (2) the Office of Management and Budget's Metropolitan and Micropolitan Statistical Area standards, (3) the Federal Office of Rural Policy rural-urban commuting areas, which has been frequently used in research, and (4) the National Center for Health Statistics Urban-Rural Classification System, which uses data from the Office of Management and Budget and the Census Bureau (Table I). The common aspect across all definitions is that rural is the area left over after urban areas are quantified. Depending on the definition chosen, about 15% to 20% of the US population lives in rural or nonmetropolitan areas, although about 85% of the total US land area may be classified as rural (Figure 1).[1,20]

RURAL HEALTH DISPARITIES

Rural health disparities have drawn significant attention in public health research and policy since the release of 2 landmark national reports from the Centers for Disease Control and Prevention and the National Advisory Committee on Rural Health and Human Services.[21,22] Both reports highlighted significant disparities in life expectancy and mortality for the 5 leading causes of death (heart disease, cancer, unintentional injury, chronic lower respiratory disease, and stroke) in the United States between rural and nonrural residents.[21,22] With regard to overall mortality and life expectancy, the National Advisory Committee on Rural Health and Human Services reported that from 2005 to 2009, the mortality rate in rural (nonmetro) counties was 13% higher than in metro counties, and metro and nonmetro life expectancies were 2 years apart (78.8 years and 76.8 years, respectively).[22] Furthermore, rural-urban disparities in mortality and life expectancy have widened over time[22] as the age-adjusted death rate in 1999 was 7% higher in rural areas than in urban areas; by 2019, the rate was 20% higher in rural areas than in urban areas. Understanding the factors contributing to these disturbing trends in the rural-urban mortality gap is critical for reducing place-based health disparities.

SOCIAL DETERMINANTS OF HEALTH

The literature has firmly established how variation in social context is often as or more impactful on health than variation in biological factors alone, and these social factors are more associated with health inequities.[23-37] These are known as SDHs: health effects from the "conditions in which people are born, grow, live, work and age."[38] These conditions include community context, economic stability, education access and quality, health care access and quality, and neighborhood and built environment[39] as well as the structural forces that cause differences in these social factors that lead to worse health outcomes for certain individuals and groups. A 2017 report from the National Academies of Medicine (NAM), *Communities in Action: Pathways to Health Equity,* conceptualizes the pathways of SDHs to include differential access to health care resources, differential health knowledge, and differential literacy and behavior.[40] We propose the framework depicted in Figure 2 to understand rural health disparities that can be applied to a broad range of allergic, asthma, and immunologic diseases.[6,42,43]

On the basis of this framework, a high-risk population for greater disease burden and poorer outcomes can be defined as those with greater health needs but limited capacity defined by socioeconomic status (SES), a key element of SDHs, because conceptually, SES defines one's ability to access desired resources (human, materialistic, and social).[41] Therefore, the 2017 NAM white paper recommended delivering high-value care *in the personal and social context* via innovative technology and science as the vital direction for US health and health care.[44] This recommendation is consistent with those by the National Advisory Committee on Rural Health and Human Services: "enhance the departmental assessment, evaluation, and lessons learned from all of its Community Health Worker projects in a manner that makes the findings easily accessible by the public," thereby highlighting the importance of a patient's social context for delivering health care.

RURAL CONTEXT FOR SDHS

Population and aging trends

As of 2022, the population in rural (nonmetro) counties was approximately 50 million individuals.[45] The gap in annual population growth between metropolitan and rural areas was relatively large during most of the 2010s, as metro areas grew by 8.8% during that decade, with rural areas averaging negative or near-zero growth. The differences in metro and rural population growth rates began closing after 2016 as birth rates steeply declined nationwide.[46] This trend continued, and in fact, population gains in rural areas exceeded those in metropolitan areas for the first time in 50 years between 2020 and 2021.

The overall US population has aged over the last 2 decades as the baby boomer generation entered their 60s and 70s. This aging trend has escalated in rural areas because of out-migration of young adults and in-migration of older adults to rural retirement destinations. In 2021, individuals aged 65 years and older comprised more than 20% of the rural population for the first time in US Census history. It will be important to study the impact of changes in population and aging trends in rural communities on health outcomes, including the role of migrant workers. Migrant workers account for about 15% of the agricultural workforce and likely amplify health disparities in rural communities. The migratory culture of this population group increases isolation, which results in difficulties to develop relationships with health care providers, to maintain treatment regimens, and to follow health records.[47,48]

Income and education trends

The poverty rate has been consistently higher in rural than urban areas from 1979 to 2021. The rural poverty rate was 15.4% in 2021 as compared with 12.3% in urban areas. Median income was $73,557 in urban areas in 2021 in contrast to $52,023 in rural areas that same year.[49]

Although the educational attainment of individuals residing in rural areas has increased significantly over time, it has not approximated that in urban areas, especially in college and postgraduate education. From 2000 to 2019, the proportion of the rural population aged 25 years and older who had completed

TABLE I. Overall description of and difference in commonly used rural definitions for policy and research

Taxonomy	Overall description and definition of urban (rest: rural)	% of rural residents (US)
Rural and urban by Census Bureau[13,15,16]	• *Urban areas* primarily based on housing unit density measured at the census block level • At least 2000 housing units or at least 5000 people (national average of 2.6 people per occupied housing unit)—change from the previous minimum of 2500 people that had been in place since the 1910 Census • No longer distinguish between urbanized areas (≥50,000) and urban clusters (<50,000) in 2020 Census	20% in 2020 (vs 19% in 2010, 21% in 2000)
Metropolitan and nonmetropolitan by the OMB[13,17]	• *Counties designated as metropolitan* (containing a core urban area of 50,000 or more population) • Metropolitan areas as central counties with 1 or more urbanized area (cities with a population of ≥50,000) and outlying counties that are economically tied to the core, which was measured by commuting to work	15% in 2010 (vs 17% in 2000)
RUCA by the US Department of Agriculture Economic Research Service[18]	• *Definitions of urban (vs rural) may vary* depending on which aspects of rurality are most relevant to the topic at hand and then select an appropriate definition • Classify US Census tracts using measures of population density, urbanization, and daily commuting • Primary codes (1-10): delineate metropolitan, micropolitan, small town, and rural commuting areas on the basis of size and direction of the primary (largest) commuting flows • Secondary codes: based on secondary commuting flows, providing flexibility in combining levels to meet varying definitional needs and preferences (1.1, 2.1, 4.1, 5.1, 7.1, 7.2, 8.1, 8.2, 10.1, 10.2, 10.3) • RUCA-ZIP code areas by transferring RUCA values from the census tracts that comprise them • Planned 2020 RUCA code information release date is uncertain (as of June 24, 2023)	16% in 2010 (vs 20% in 2000) when RUCA primary codes 4-10 are used as rural
The National Center for Health Statistics Urban-Rural Classification Scheme[19]	• *Six levels of urban-rural classification in 2 categories* (4 metropolitan county and 2 nonmetropolitan county designations based on the OMB standards for metropolitan and micropolitan statistical areas) • Four metropolitan county designations (large central, large fringe, medium, small) • Two nonmetropolitan county designations (micropolitan, noncore)	20% in 2021

OMB, Office of Management and Budget; *RUCA*, rural-urban commuting area.

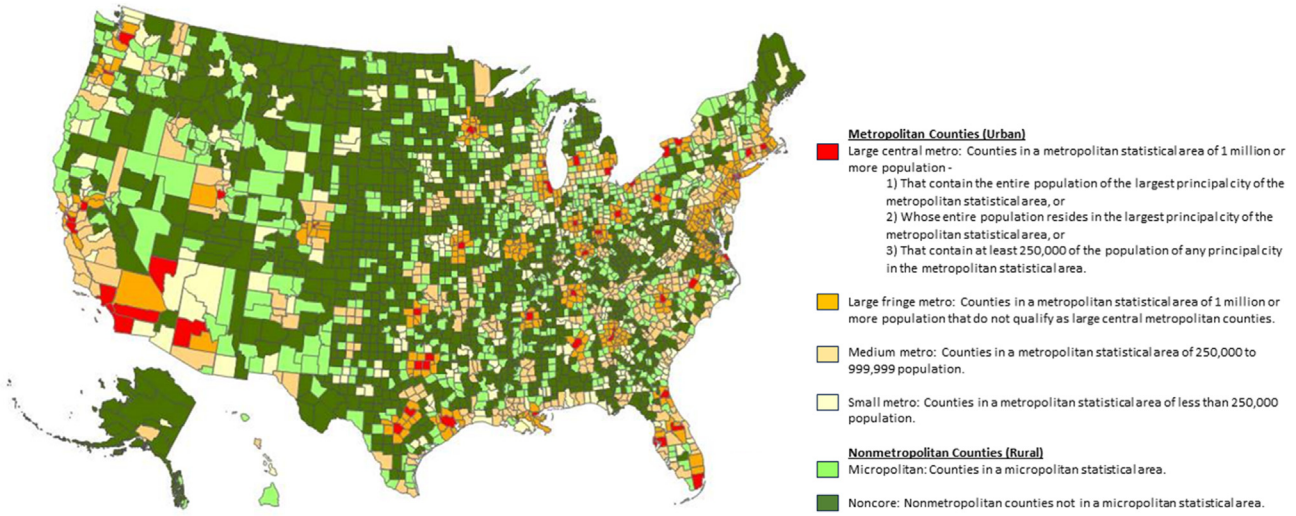

FIGURE 1. Urban-rural classification scheme for counties by the National Center for Health Statistics.

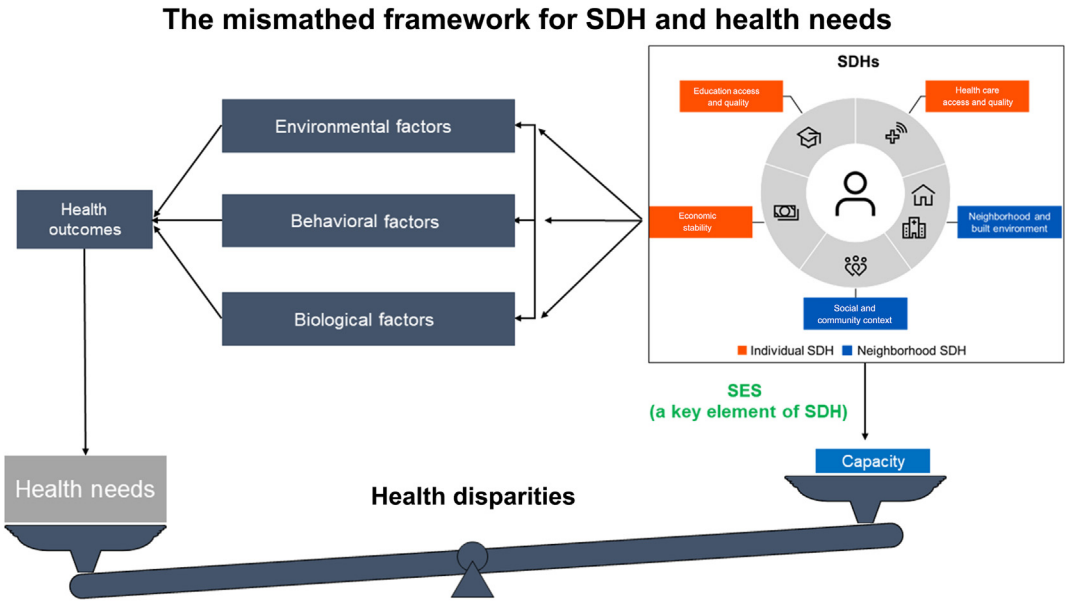

FIGURE 2. Proposed framework for SDHs in relation to health disparities.[39,41,42]

a bachelor's degree or higher increased from 15% to 21%. Over the same time frame in urban areas, the proportion with a bachelor's degree or higher increased from 26% in 2000 to 35% in 2019.[50]

Access to health care trends

The rural population lacks health insurance at higher rates than those living in urban areas. As of 2017, about 12.3% of individuals in completely rural counties lacked health insurance compared with 11.3% for mostly rural counties and 10.1% for mostly urban counties.[51] Even though most rural residents have health insurance, rural areas have a paucity of health care professionals who provide primary care, dental, and mental health services. Rural areas comprise most of all Health Resources and Services Administration—designated health professional shortage areas, constituting more than 60% of all primary care and dental health professional shortage areas and almost 60% of all mental health health professional shortage areas.[1] Furthermore, because specialists and subspecialists generally cluster in urban areas with larger populations to support their practice, rurally located specialists are lacking, resulting in a greater reliance on primary care providers to function as specialists due to necessity in these underserved settings. However, not only are primary care providers already resource-constrained with delayed appointment availability reported through the United States, they also do not possess the required training necessary to manage all specialty care needs locally.[52]

Moreover, access to adequate health care continues to be increasingly challenging in rural areas due to closures of numerous health care facilities.[1] Since 2010, a total of 152 rural hospitals have either completely closed or have been converted to

outpatient-only facilities,[53] which has resulted in substantial increases in distance (20-40 miles) to receive health care services and out-migration of providers.[54] The financial viability of the remaining facilities remains an ongoing concern.[1]

In terms of allergy/immunology, specialty care access may continue to worsen, as the allergy and immunology workforce in the United States is anticipated to be short by 500 allergist/immunologists by 2025.[55] At present, little is known about the availability, geographic distribution, and access to allergy/immunology specialists in the United States,[56] and it is worth studying the burden and outcome of allergic and immunologic diseases in relation to access to allergist/immunologists in the United States, especially rural communities. Our group is currently planning this epidemiological work.

RURAL HEALTH DISPARITIES IN ALLERGIC, ASTHMA, AND IMMUNOLOGIC DISEASES

Allergic rhinitis

Allergic rhinitis is a common condition in the United States, with a prevalence of physician-confirmed diagnosis of 14% among adults and 13% among children.[57,58] Studies exploring the rates of allergic rhinitis in urban versus rural areas of the United States are sparse. A meta-analysis of cohort studies including Europe, Asia, Canada, and the United States found no difference in the relative risk of allergic rhinitis between urban and rural areas.[59] Although the direct and indirect costs of allergic rhinitis are known to be significant,[60] the disproportionate impact of these costs due to gaps in access to specialty care also remains unknown. Moreover, the specific impact of differential access to allergen immunotherapy between rural and urban patients is unknown and needs further studies.

Asthma

Previously it was thought that asthma prevalence was lower in rural versus urban areas.[61] Yet, recent research has demonstrated little to no difference in prevalence by rurality.[62-67] Although there is some evidence that people living on farms have lower rates of allergies and asthma, a relatively small proportion of rural residents in the United States live on farms.[68] In addition, as shown in the recent Environmental Influences on Child Health Outcomes study, asthma incidence is highly contextual. There were no consistent risk or protective factors identified for asthma incidence and outcome across populations with different age, sex, race or ethnicity, family history of asthma, SDHs, neighborhood, and urban/rural setting due to interactions and confounding among these factors, and there was no consistent pattern for lower incidence of asthma among children residing in largely rural states such as those in the Midwest region (rather interaction among geographic factors, age, and family history of asthma).[69] Specifically, the Environmental Influences on Child Health Outcomes study showed that asthma incidence was determined by interactions (eg, widely recognized interaction between sex and age in asthma incidence was further modified by a family history of asthma)[70] and reported neighborhood environment (eg, poverty level) significantly affected asthma risk, although they did not examine the effect of living in rural versus urban settings.[69] This observation can be further confounded by different asthma phenotypes as shown in the recent report from the Tasmanian Longitudinal Health Study, a population-based cohort study of longitudinal asthma phenotypes from childhood to middle-age adults.[71] A longitudinal study based on all individuals without previously diagnosed asthma aged 0 to 79 years living in Ontario, Canada, on April 1, 1996, and monitored for 11 years found that the lifetime asthma risk was higher in individuals living in urban areas compared with those living in rural settings (34.5% vs 30.1%) or low-income neighborhoods (35.0% in the lowest-income quintile vs 32.2% in the highest).[72] At any rate, the influence of geographic factors on asthma incidence observed in the Environmental Influences on Child Health Outcomes study appears to be modified by multiple factors (contextual), which is probably a more realistic observation instead of identifying a single dominant risk factor. Overall comparison of asthma incidence or prevalence between urban and rural settings may not be meaningful and informative, because it depends on which groups in urban versus rural settings are compared given the significant within-group variability. As such, national surveillance data show that asthma prevalence in rural versus urban settings highly depends on each state.[67]

Similarly, asthma outcomes do not consistently differ between rural and urban areas. For example, self-reported asthma attacks and emergency department (ED)/urgent care center use among children are significantly higher in urban versus rural areas, with no differences among adults.[67] A study of 2000-2014 Medical Expenditure Panel Survey data found that children living in poor urban areas of the United States had higher rates of asthma-related ED visits and hospitalizations as well as lower odds of asthma controller medicine use than children living in other areas.[73] A study limited to children receiving Medicaid insurance similarly found higher rates of asthma-related ED visits and hospitalizations in urban areas.[74] However, other studies have shown higher[64] or similar[62,65,75] morbidity among rural versus urban children/youth. Asthma mortality rates among adults are highest in rural areas, with no differences among children.[67,76]

The relationship between asthma status, outcomes, or care quality and rurality is highly contextual depending on demographic, clinical, SDH, community, and regional factors. This poses challenges for reproducibility of study results on the association of rurality with asthma outcomes under the traditional causal framework but invites a socioecological framework (eg, the Dahlgren and Whitehead model)[27] to understanding and studying rural disparities in asthma outcomes and developing strategies addressing such disparities. The effort for a broader understanding of asthma in the social and rural context will lead us to more real-world perspectives in addressing rural disparities in asthma care by delivering high-value asthma care in the more personal and social context of patients via innovative science and technology as suggested by NAM.[44] In this context, modern technologies and innovative SDH measures may greatly enhance our ability to address unmet needs of rural populations with asthma.

Apart from telehealth technology, a few existing and emerging technologies will be specifically relevant to addressing rural disparities in asthma and beyond. Because of the unavailability of accurate individual-level SDH measures, health care organizations have to rely on either inaccurate aggregate-level SDH measures or systematically biased, unstandardized, and frequently unavailable patient-reported SDH measures in electronic health records. Digital tools or care strategies that exclude SDHs, or are based on these problematic SDH data, will further exacerbate health disparities. This represents a major national challenge in addressing SDHs and health disparities. The HOUSES Index and Cloud Platform directly addresses this national challenge. The HOUSES index has been shown to be associated with asthma prevalence in

both adults and children[77,78] and predicts asthma outcomes.[79,80] The HOUSES Index is a validated, objective, standardized, and patient contact–free individual-level SDH measure based on publicly available individual housing data (assessment data of the County Assessor's Office) and is available for the entire 50 states. Now, the Mayo Clinic HOUSES Program provides the HOUSES Index to any participant in the US health ecosystem through the HOUSES Cloud Platform in a real-time, Health Insurance Portability and Accountability Act (HIPAA)-compliant, and automated manner through an Application Program Interface. One of the major innovative features of the HOUSES Index and Platform is its ability to enable a geospatial analysis that guides health care organizations' community engagement and outreach as it precisely identifies a hotspot for a high-risk asthma population with an underresourced background. This technology will be extremely useful for a population management approach in the rural community setting that is geographically vast, making outreach programs difficult if one does not know where their target populations are located. Such approaches have been demonstrated in our previous work.[81,82] For example, with this technological support, community health workers can effectively and efficiently outreach target populations in their community setting.

Another emerging technology is Asthma-Guidance and Prediction System, an artificial intelligence (AI)-powered clinical decision support system with a remote patient monitoring device.[83] The AI-powered Asthma-Guidance and Prediction System enhances asthma care by automatically gathering and providing the most relevant information for asthma management to clinicians, which improves asthma outcomes while greatly reducing clinician's burden for asthma care (eg, reducing review time for electronic health records from 9 minutes to 2 minutes) and potentially health care costs.[84] Now, the Asthma-Guidance and Prediction System is equipped with a remote patient monitoring device that enables remote asthma management (ie, managing asthma in "the clinic without walls"), which will greatly improve health care access for asthma care in rural populations while effectively and efficiently managing asthma and reducing clinicians' burden. This new technology-driven tool for asthma care is scheduled to be tested through a randomized controlled trial. These technologies will be relevant to asthma as well as other allergic disorders. Additional AI-driven technologies with potential applicability to managing asthma and other allergic disorders have been discussed in a recent review article published in the *Journal of Allergy and Clinical Immunology,* and we refer readers to this review article.[85]

Atopic dermatitis

Studies addressing disparities among patients with atopic dermatitis (AD) with regard to rural populations are significantly lacking.[9] In the United States, AD affects approximately 7% to 10% of adults and 13% of children.[86] When analyzing health care resource use by US Census regions, the Midwest demonstrated the poorest access for AD ambulatory care and the highest rate of ED visits for AD flares compared with the Northeast, South, and West regions.[87] Because the Midwest has a vast majority of rural counties compared with other regions, these findings imply that rural health disparities for AD may exist. Moreover, higher utilization of urgent care or ED for AD is correlated with lower household income and educational level, which are both issues more commonly present in rural versus urban settings.[88] The paucity of data and studies of AD and disparity between rural and urban populations reinforces the need for further studies that can better define what interventions would be most effective in decreasing any disparity that exists between these populations.

Food allergy

In the United States, the prevalence of food allergy (FA) is highest and increasing among Black Americans, followed by Hispanic, Asian, and White Americans.[89] A national, cross-sectional survey demonstrated that childhood FA is higher in urban (9.8%) versus rural areas (6.2%) after adjustments for race/ethnicity and other factors.[90] However, a large study examining private insurance claims showed a greater increase in FA diagnoses in rural than in urban areas.[91] Rural patients with FA often face food insecurity, lost productivity, and high costs for medical, special diets (if available), and transportation expenses, all resulting in poor quality-of-life scores due to FA-related anxiety.[92]

Most generalists do not feel adequately prepared to manage FAs.[93] Consequently, avoidance advice based on indiscriminate testing by nonallergist providers leads to increased future FA risk.[94] Furthermore, poor access to expert allergy care results in more frequent ED visits and hospitalizations for patients with FA.[95] Opportunities to improve rural FA patient care include partnerships with primary care clinicians (eg, Project ECHO [Extension for Community Healthcare Outcomes], which uses videoconferencing technology to share specialist knowledge with providers in remote communities),[96] support of patient advocacy groups, addressing food insecurity, reviewing epinephrine autoinjector use, and supplying FA action plans with culturally sensitive FA education.[9] Another critical factor is inclusion of special populations including rural populations in clinical trials and improving school preparedness.[97] Finally, emerging evidence suggests that technologies such as mobile applications may offer benefits for patients with FA through allergen identification, recipes, and education.[98-100]

Other allergic and immunologic diseases

Drug allergy. Review of the literature yields no studies specifically evaluating the impact of drug allergies on rural populations in the United States as compared with urban areas. Thus, it is unclear whether there are any specific differences in rates of identified drug allergies between these populations. Certainly, the impact of a medication allergy on pursuing optimal medical therapy is well recognized, particularly with regard to cancer care and infectious disease management. Perhaps most well studied is the impact of penicillin allergy as the most commonly identified drug allergy in medical records. Penicillin allergy is estimated to have a prevalence of 6% to 25%,[101,102] and yet more than 95% of these individuals can safely receive penicillin after appropriate evaluation.[103] Broad-spectrum antibiotics often used as an alternate in "penicillin-allergic" patients are associated with higher cost of care, increased antibiotic resistance, and suboptimal antibiotic therapy.[104] Barriers to penicillin allergy delabeling include system-based barriers such as access to specialty care,[105] with fewer than 5000 practicing allergists in the United States[106] and most acute care hospitals lacking access to allergy/immunology specialists and penicillin diagnostic testing.[107] Use of multidisciplinary teams is helping to bridge these gaps[108] along with expanding use of telehealth,[56] which may prove instrumental in addressing the impact of drug allergy on health care outcomes and cost, particularly in the rural setting.

Chronic rhinosinusitis. The heterogeneity of chronic rhinosinusitis (CRS) with diagnostic criteria requiring the need to

assess patient-reported symptoms along with objective evidence of sinus mucosal inflammation has made large-scale epidemiological studies logistically challenging.[109,110] CRS affects approximately 15% of the US population based on the National Health Interview Survey, though strict application of diagnostic criteria yielded a much lower prevalence of 2% in a 2000 study in Olmsted County, Minn.[110] Given these limitations in accurately measuring the prevalence of CRS nationally, identification of differences in rural versus urban areas is essentially nonexistent. Further studies would be valuable, noting that CRS is associated with high health care utilization.

Access to specialists with expertise in caring for these patients is imperative in their outcomes, and yet there are significant recognized disparities in distribution of allergist/immunologists and otolaryngologists between rural and urban parts of the United States.[55,111-113] Studies have shown that biologics, aspirin desensitization, and surgical intervention improve clinical outcomes,[114] all of which are managed through access to this specialty care. Expert consensus from both allergy/immunology and otolaryngology groups have concluded that there is limited evidence for antibiotics in the treatment of CRS[115-117] and yet, assessment of antibiotic prescribing practices for upper respiratory tract infections among primary care providers found high rates of unnecessary antibiotic utilization (42.2%) with increased association of care delivered in the rural care setting.[118] Further study of the impact of disproportionate access to specialty care for management of CRS would be beneficial in informing future strategies to address these suspected gaps.

Primary immunodeficiency disorders. Diagnosis of primary immunodeficiency disorders (PIDDs) may be challenging and rare, with PIDD prevalence estimates ranging from 1:200,000 to 1:400,000 people.[119] In the United States, the prevalence rate of PIDDs was twice as high among White Americans as among black and Hispanic Americans,[120] and the possible lower prevalence in the latter groups could be due to genetic differences, lack of specialty care, and several aspects of SDHs.[121] Although health disparities in the clinical care of PIDDs are known,[122] the prevalence and risk factors of PIDD in rural versus urban populations are unknown.

Timely diagnosis and treatment is essential to mitigate morbidity and mortality related to PIDDs. Access to hematopoietic cell transfusion, potentially curative therapy, is likely limited in the rural population. Other interventions for health disparities in PIDDs may include updated epidemiologic studies including rural populations and more robust strategies to diversify the bone marrow donor pool to increase the likelihood of HLA-matching for patients with PIDD.[9]

KNOWLEDGE GAPS AND RESEARCH NEEDS

After careful review of the literature on rural health disparities, major knowledge gaps in 4 key areas emerged: (1) the lack of epidemiological data on the burden of each allergic disorder and its outcomes in rural communities, (2) understanding of such epidemiological profiles of rural populations in the socioecological model given the unique population, economic, cultural, and geographical context, (3) availability, geographic distribution, and access to allergy/immunology specialists in the United States and its impact on health outcomes, and (4) the importance of rural community engagement and research partnerships between academic institutions in urban settings and rural hospitals.

1. The lack of epidemiological data on the burden of each allergic disorder and its outcomes in rural communities

The incidence, prevalence, and risk factors of allergic and immunologic conditions in rural populations are largely unknown with the exception of asthma. Even so, further investigation of asthma that accounts for the social and rural context is needed to better personalize care in rural individuals. Without delineating the epidemiology of allergic and immunologic conditions in the rural United States, it would be difficult to (1) ascertain the degree of health care disparities that exist, (2) gauge the outcomes of the current health care infrastructure, and (3) formulate needed interventions. Thus, comprehensive efforts to address these knowledge gaps on local, regional, and national levels are essential to adequately address rural health care needs for these conditions. Most importantly, community engagement will be vital for these research efforts to be successful and sustainable.[123]

2. Understanding of epidemiological profiles of rural populations in the socioecological model

Rural communities have distinctive cultural, social, economic, and geographic factors that are compounded by disparities in age, income, health status, and health care access as well as their interplays of these factors at multiple different levels. On the basis of the socioecological framework depicted in Figure 2, we propose to define a high-risk population for greater disease burden and poorer outcomes as those with greater health needs but limited capacity defined by SES, a key element of SDHs.[33] The 2017 NAM white paper recommended delivering high-value care *in the patient's personal and social context* via innovative technology and science as the vital direction for US health and health care.[44] However, at present, understanding the epidemiological profiles of rural populations in each allergic disorder in the socioecological context beyond biomedical mechanisms and factors is significantly limited. This limited understanding hampers our ability to deliver specialty care in each patient's personal context. This is true for engaging rural populations in clinical and translational research as highlighted in the recent special population workgroup report.[124] For this challenge, as SDHs account for rural disparities in health care, assessing and addressing SDHs in rural settings using a suitable patient-level SDH measure needs to be considered. For example, an innovative new individual-level SDH measure called the HOUSES Index (individual housing-based SES measure) is available by using a patient's address and publically available property data in the United States, enabling large-scale, population-based studies as well as patient-level interventional studies. The HOUSES Index addresses the current challenges many health care organizations face (eg, biased, unstandardized, and frequently unavailable self-reported SDH measure in electronic health records[125] and the limitation of inaccurate area-level SDH measures[126,127]) and has been shown to predict the need of SDH support and 40+ health outcomes including asthma in adults and children.[77-79,128] The HOUSES Index can be used for enhancing asthma care in rural settings[81,82,129] and for targeting and engaging rural populations in clinical and translational research.[124] Addressing SDHs of patients is critical to deliver care or engage rural populations in research, and it is also crucially important to identify and engage the stakeholders in planning and executing clinical care and research. A planned, detailed, and inclusive approach to community engagement cannot be overemphasized.

3. **Availability, geographic distribution, and access to allergy/immunology specialists in the United States and its impact on health outcomes**

As discussed previously, a key theme of each allergic disorder is the lack of literature and knowledge on the nature of access to allergy/immunology specialty care and its outcome. Readily available allergy/immunology specialty care is critical to access novel interventions and medications such as biologics, immunomodulators, and digital therapeutics. Differential access to these treatment modalities in rural communities is unknown. Thereby, it is crucially important to identify areas with low allergy/immunology provider density with high health risk for allergic disorders and high-density areas with underresourced populations. As shown in Project ECHO for geographic distribution of endocrinologists for diabetic care, similar work needs to be conducted for allergist/immunologists.[130] This information will provide important guidance to the AAAAI and scientific and health care communities as to the locations of populations with the greatest unmet needs and their epidemiological profiles. In turn, these epidemiological profiles will help determine the needs of these populations including rural populations. For example, health care interventions (eg, digital technologies or other strategies) can be contextualized in the geographic density of allergist/immunologists and SDH factors of populations (as described above). In this context, digital technologies will be increasingly important to address the needs of rural populations. For example, machine learning or AI can enable computational phenotyping approaches for better studying asthma in rural populations[131] and scalable AI-powered asthma care or telehealth approaches.[56,84] Bayesian modeling can be used to identify local risk factors for disparities in asthma outcomes.[75] Numerous other technologies that may also expand the care of allergic and immunologic conditions include remote patient monitoring, mobile applications, digital inhalers, electronic diaries, and wearable devices.[56,75,84,100,131-133] Not only may these technologies extend and enhance provider-patient relationships, but they may also promote provider wellness and reduce risks of burnout.[132] In addition to technologies to extend allergy/immunology specialty care, other health professionals such as primary care providers, physician extenders, respiratory therapists, and pharmacists may receive additional training for allergy skin testing, spirometry, and management of asthma, food allergies, drug allergies, and other allergic conditions.[96,134-137] However, as widely recognized, many technological approaches depend on broadband coverage in rural communities. The official broadband definition is 25 Mbps download and 3 Mbps upload, or 25/3. Unfortunately, a digital divide has been present for years as 17.3% of Americans in rural areas lack coverage from fixed terrestrial 25/3 Mbps broadband, as compared with only 1.2% of Americans in urban areas. This discrepancy significantly worsens with higher internet speeds, with 44.4% of rural Americans lacking coverage for 250/25 Mbps broadband, as compared with only 5% of those in urban areas. A lack of broadband infrastructure limits Wi-Fi speeds, and new mobile internet technologies such as 5G and satellite are unlikely to meet broadband speeds. Moreover, rural properties tend to be more dispersed than densely populated urban areas, resulting in greater distances from nodes and cell towers. Therefore, data must travel further to reach its destination, resulting in increased latency and slower speeds for the end user.[138] The multitude of broadband access issues highlights the importance of SDHs and requires innovative strategies engaging stakeholders in private and public sectors.

4. **Rural community engagement and research partnerships between academic institutions in urban settings and rural hospitals**

As noted in each of the knowledge gaps for rural health disparities, community engagement and research will be essential for progress to be achieved. Guiding principles for community engagement should embody empowerment, fairness, justice, participation, and self-determination. Community engagement may take many forms, and partners may include individuals, community organizations, health care providers, clinics/hospitals/health systems, and government agencies. To realize successful collaboration with a community, all parties involved must strive to understand the point of view of all other partners. This approach allows partners to better understand and address the underpinnings of health issues. In doing so, time-limited projects may evolve into long-term partnerships that advance from the traditional focus on a singular health issue to address a broad spectrum of economic, environmental, political, and social factors that affect health.[139] Numerous studies have investigated various community engagement strategies. In most studies, effective, collaborative partnerships were developed by using community personnel and liaisons as well as local organizations, which included faith-based organizations and/or local health-related facilities.[123] Furthermore, community engagement through academic/university partnerships has proven to be successful in several areas. Specifically, the recent American Heart Association request for application ("Health Equity Research Network [HERN] on Improving Access to Care and other Health Inequities in Rural America") is a great example. This request for applications promotes research partnerships between academic institutions and rural hospitals including federally qualified critical access hospitals in rural communities. This type of request for applications from private and public sectors should be encouraged and promoted. These types of partnerships will greatly help to reduce disparities in leveraging AI and digital technologies by rural hospitals and clinics. Additional resources for community engagement and program funding are made available by the Centers for Disease Control and Prevention, the Health Resources and Services Administration, and the National Center for Advancing Translational Sciences.[140,141]

CONCLUSIONS

Rural health disparities clearly exist with several contributing factors, many of which are directly related to SDHs. Health care accessibility, especially for specialist care, represents a key component of SDHs that is more apt to be directly modifiable by clinicians and health care organizations. Numerous opportunities exist to address both clinical and research needs in rural populations. We suggest that the AAAAI and allergist/immunologist community focus on delivering high-value care by improving access to allergy/immunology specialists, optimizing community health collaborations, and using innovative science and technology in the patient's personal and social context, leading to health equity. This effort requires community partnership and stakeholder engagement in the rural communities to ultimately eliminate rural health disparities.

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