Prototyping an Information System to Address Geographic Disparities in Cardiac Rehabilitation Access in the United States

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ABSTRACT

In the United States, about 695,000 people die each year from some form of heart disease. Cardiac rehabilitation (CR) is designed to help patients recover from and prevent further heart disease. This paper addresses the underutilization of CR and proposes an Information System based tool to assist health care providers, public health advocates and decision makers locate and eliminate potential barriers preventing people from participating in CR. At the county level, data was downloaded and combined into a comma separated value (CSV) file. CSV files containing every acute care and critical access hospital, all AACVPR certified CR centers, and additional CR centers (self reported) have been made publicly accessible. A filtering of hospitals that do not have a CR center within 30 miles was done using Python programming language to get the target dataset for analysis. Once the data was cleaned and filtered, the open source graphing library, Plotly, was used to visualize the dataset. Tailored to the demographic, each filtered dataset will be different allowing different conclusions to be drawn from the map created. This tool will be beneficial to hone in on areas in need of CR and is particularly useful in helping identify hospitals who may benefit from additional CR services. This tool will be even more useful once a dataset for hospitals pertaining to the treatment received or a dataset for CR centers that contains patient capacity becomes available.

KEYWORDS

Cardiac rehabilitation (CR), Heart disease, Geographic Barriers, Data Collection, Data Analysis, Visualization, Plotly, Hospitals, CR centers

1 INTRODUCTION

Heart disease is the number one cause of death in the United States (US) (approximately 695,000 deaths per year) [1]. Recovering from and preventing further heart disease seems like a daunting task, but it can be done with cardiac rehabilitation (CR) [2]. CR is a specialized program that engages the patient in physical activity, educates on healthier lifestyles, and provides support to reduce stress and improve mental health [2]. The goal of the Centers for Disease Control's (CDC) and the Centers for Medicare & Medicaid Services' (CMS) Million Hearts program is to reach 70% of eligible patients participating in CR; currently about 24% of eligible patients take part across the US [3–6]. With heart disease being so prevalent, it is crucial that CR is available to everyone who needs it. With 220 CR centers closing due to the COVID-19 pandemic [7], the availability of CR has become even more sparse than it once was.

The majority of literature on CR covers the existing problems and limitations that prevent CR accessibility [3–7]. Several authors have also addressed ways to improve access such as removing co-pays for CR, expanding hours of service, and offering transportation support [3–9]. This paper outlines the initial stages of developing an information system implementation tool designed for use by public health officials and healthcare providers. The tool aims to provide a more targeted approach for officials to focus their efforts, including options for virtual, home-based, and hybrid alternatives.

1.1 Related Work

According to Janet et al., travel time impacts CR enrollment and if the drive exceeds 60 minutes, enrollment significantly drops [10]. These findings are crucial for understanding participation barriers and shaping the framework for considering commute time in healthcare utilization. Additionally, it has been shown that age affects the outcomes of CR depending on risk factors, but overall CR provides benefits for all ages [11].

Duncan et al. (2023) identified geographic barriers as a significant factor in enrollment in CR [12]. If we can target the places where geography is an issue, "CR deserts", we can come up with potential solutions for those areas. Beatty et al. (2021) discovered that there is variation in CR participation rates across hospitals and geographic regions with some patterns emerging [13]. Best practices (e.g., referral automation, centralized referrals) from certain hospitals and regions can be applied to other hospitals and regions to improve performance. https://www.overleaf.com/project/659c00ec93be7cfaafcc27bd The CDC has created an interactive Information System (atlas) for CR use that allows one to assess eligibility rates, participation and completion rates as well as number of

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sessions completed by region. This provides a useful tool to asses the CR participation [14].

There are various factors contributing to low CR enrollment, such as limited capacity as well as challenges to accommodate a patient's needs [9, 15]. If we can eliminate these factors, it is possible to see a significant increase in CR enrollment. Home based CR (HBCR) is noted to be a feasible alternative for non-high-risk patients who are unable attend in-person rehabilitation [8], presenting a solution to one of the previously mentioned factors. Pack et al.'s 2014 analysis of CR capacity in the US found that even with a moderate expansion of CR facilities the US would only be able to facilitate 45% of qualified patients enrolling [16]. In their 2022 analysis, Varghese et al. noted the closure of many CR facilities in COVID [7], exacerbating the problem.

2 METHODOLOGY

2.1 Data Collection

The United States Census Bureau provided annual estimates of the US population, allowing for a breakdown into state and county populations [17]. Hospital information, including crucial statistics such as longitude/latitude coordinates, hospital bed-size capacity, and hospital type, was compiled from the Homeland Infrastructure Foundation-Level Data (HIFLD), obtained from federal sources and state departments [12]. The American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) [18] provides a state-by-state lookup of all AACVPR certified CR centers in America. These sites were accessed from the cardiacrehabfinder.com website, made available by Movn Health, which also includes CR sites that can register to be listed [19]. Geographic and demographic data, including county-by-county land area from the Environmental Protection Agency [20], as well as county-by-county median age and income from Open Intro [21], were also incorporated to provide a comprehensive understanding of the factors influencing CR outcomes.

2.2 Data cleaning, filtering, and calculated values

Hospitals were selectively filtered to include only acute care and critical access hospitals. This involved the exclusion of military, non-US, closed, children's, chronic disease, long-term care, psychiatric rehabilitation, women's, and special hospitals from the dataset. To consolidate relevant county-level information, a merge operation was performed on datasets containing population, land area, mean income, and mean age. This integrated dataset was then saved to a Comma Separated Value (CSV) file for further analysis. Additionally, any unused columns from imported CSV files were systematically removed, ensuring a streamlined dataset for subsequent analysis.

2.3 Use of Plotly Software

Plotly is an open source graphing library used for creating interactive graphs and maps in multiple programming languages [22]. Section VI details more information on the use of Plotly for visualization purposes.

3 DATA WRANGLING

Hospitals in the HIFLD dataset lack a centralized data collection point leading to variations in reported information across different sources. When combining datasets from diverse sources, gaps in information may arise for certain hospitals. For example, while many hospitals report the number of beds (bed size), some do not. In cases where bed size is crucial for

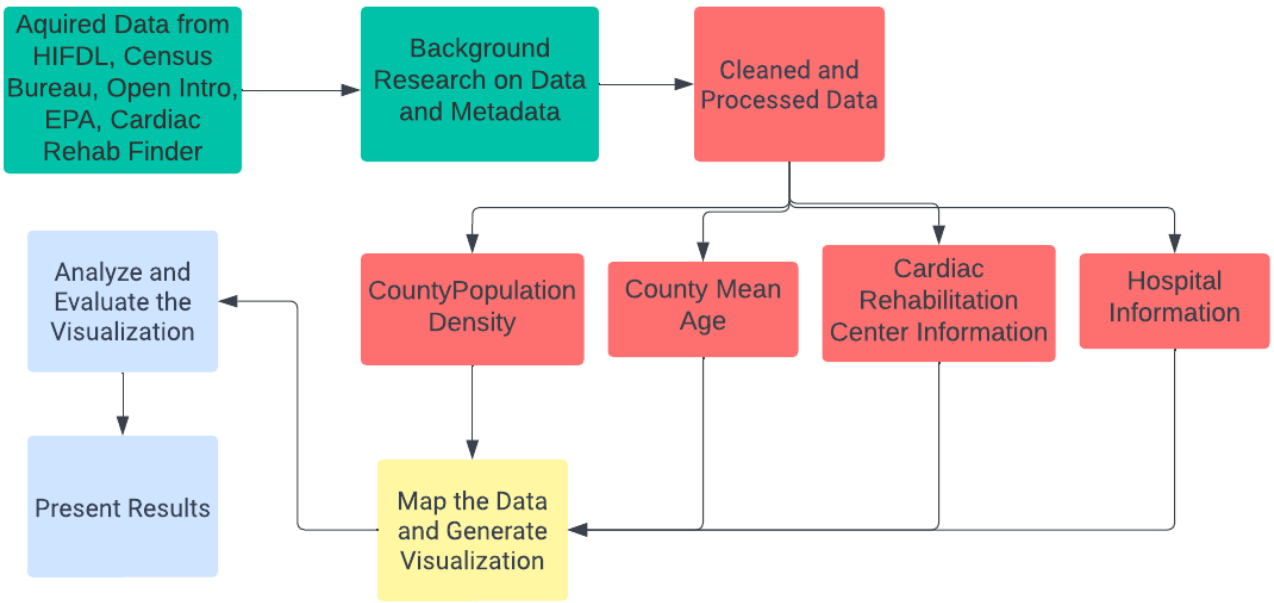

Figure 1. Conceptual Information Model

calculations, hospitals lacking this information were omitted. The HIFLD dataset contained comprehensive information; details not needed for this analysis (i.e., owner type, trauma level, helipad) were subsequently omitted.

Obtaining comprehensive datasets on CR centers presented challenges. Existing sources primarily covered CR hospitals, neglecting self-standing centers. We used the data aggregated on the cardiacrehabfinder.com website which included AACVPR certified sites and self reported sites.

County-level information, though sourced from government datasets, lacked consolidation into a single source. Each county was assigned a FIPS (Federal Information Processing Series) code [17], facilitating the merger of three datasets containing population, land area, and mean age and income. This merged dataset was then saved to a CSV for further analysis.

These data wrangling steps were essential to address inconsistencies, missing information, and the need for comprehensive datasets, ensuring the integrity and reliability of the data for subsequent analysis.

4 UNCERTAINTIES

We used only publicly available data in our model. Our analysis is also limited by several factors: lack of hospital patient admission/discharge data/rates, treatment diagnoses, CR center capacity, and county geographical characteristics (i.e., urban, rural, suburban, metro.).

Due to the lack of information on the number of patients seeking cardiac treatment, we rely on the overall number of beds a hospital has to draw general conclusions. Similarly, knowing the incoming patient rate could reveal whether the existing CR centers can adequately serve the patient population. The absence of data on specific center capacity also means we can only draw preliminary conclusions based on the centers presence.

While population density might offer some clues about county geography, understanding the specific infrastructure is crucial. Detailed infrastructural information would allow us to definitively determine whether the current number of rehabilitation centers is sufficient for the population size they service within that county.

Although not addressed in this study, it is acknowledged that the socioeconomic makeup and patient demographics within a county may play a significant role in determining which counties need the most attention. This can be used as a premise for future investigation and mapping.

4.1 Freshness of Data

The hospital dataset acquired from the HIFLD was last updated September 20, 2023 [23]. The United States Census Bureau's population dataset was last updated July 1, 2022 [17]. The data on all CR centers in the US from Cardiac Rehab Finder was published in 2023 [19]. The data on land area from the U.S. Environmental Protection Agency was last updated April 2016 [20]. The mean income and age by county datasets obtained from Open Intro was last updated in 2019 [21].

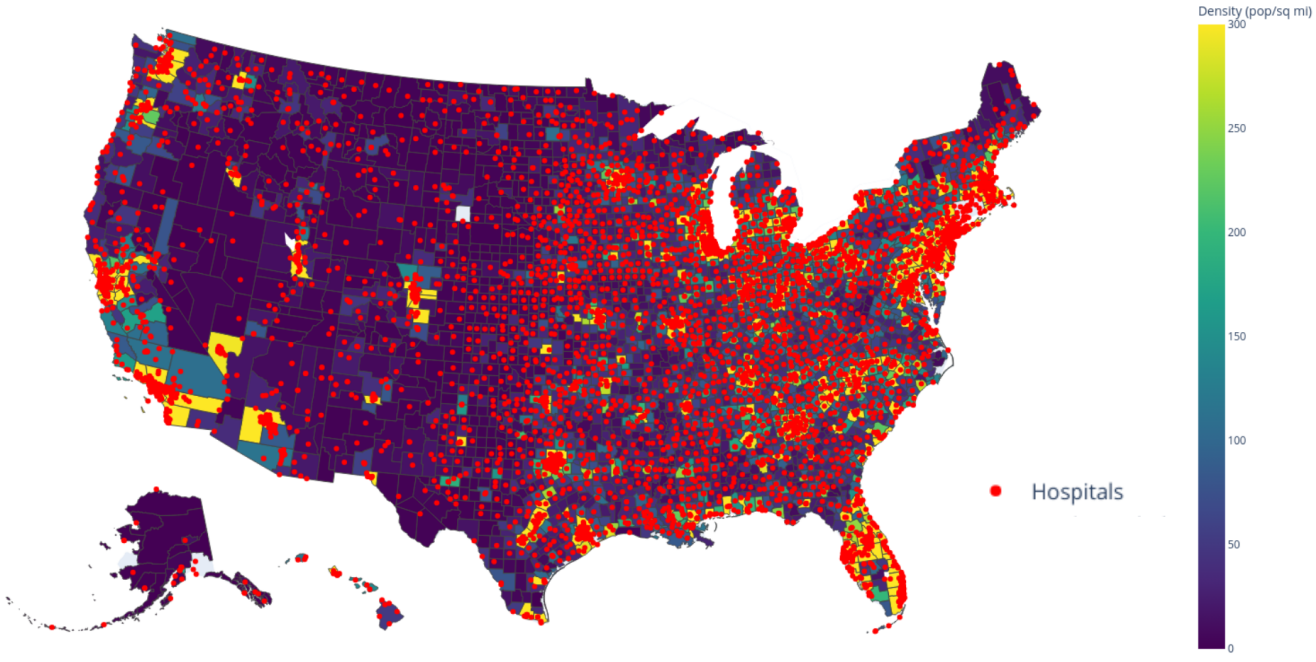

Figure 2. Hospitals (Acute Care/Critical Access) in the US With Population Density Map

5 CONCEPTUAL INFORMATION MODEL

The conceptual information model shows the necessary components in generating the visualizations discussed as well as the process.

Figure 1 contains a conceptual information model pertaining to the use case of the project.

6 PROTOTYPE IMPLEMENTATION

6.1 Design Considerations and Decisions

This research focused on implementing an information system that visualizes where CR intervention is most needed.

6.1.1 Plotly Plotly is an open source graphing library used for creating interactive graphs and maps in multiple programming languages [22]. Plotly provides many ways to visualize data. Plotly allows for easy interactive map creation which is highly customizeable. Since data processing was already being done in python, Plotly was easily integrated into the process as it has a python package that can be installed. Using Plotly's mapping functions, several plots were made. These plots could then be merged into one visualization to be able to generate potential hypotheses.

6.2 Visualizations

All interactive visualizations and source code can be found and downloaded from this Github Page [24]. Six visualizations were created for this project, but there is opportunity for many more.

6.2.1 Hospitals (Acute Care/Critical Access) in the US With Population Density Map Figure 2 shows the hospitals in the US plotted with red dots. The counties in the map are color-coded based on the population density. This coloring was chosen to illustrate higher density populations having a higher concentration of hospitals. This visualization serves as a base allowing comparison with the following figures noted in this manuscript. Hover data pertaining to county and hospital information is also presented.

6.2.2 Cardiac Rehabilitation Centers and Hospitals (Acute Care/Critical Access) in the US with Age Figure 3 represents CR centers and hospitals in the US. Blue dots represent the CR centers and red dots represent the hospitals. The counties on the map are colored based on the mean age in that county. The interactive map allows users to hover over counties, hospitals, and CR centers to see all relevant information. This map is intended to provide easy analysis on counties by age.

6.2.3 Cardiac Rehabilitation Centers and Hospitals (Acute Care/Critical Access) in the US with Population Density Figure 4 is similar to figure 3, except that the map coloring is based on population density as opposed to age.

6.2.4 Hospitals (Acute Care/Critical Access) Without a Cardiac Rehabilitation Center Within 30 Miles Figure 5 presents a visualization of all hospitals without a CR center within 30 miles. On average, 55 minutes of driving equates to 29 miles [25]. The distance 30 miles was chosen based on the fact that once commute times exceeded 60 minutes CR enrollment rates significantly decrease [10]. These hospitals are displayed over a population density map to be able to assess where there is the most need based on population.

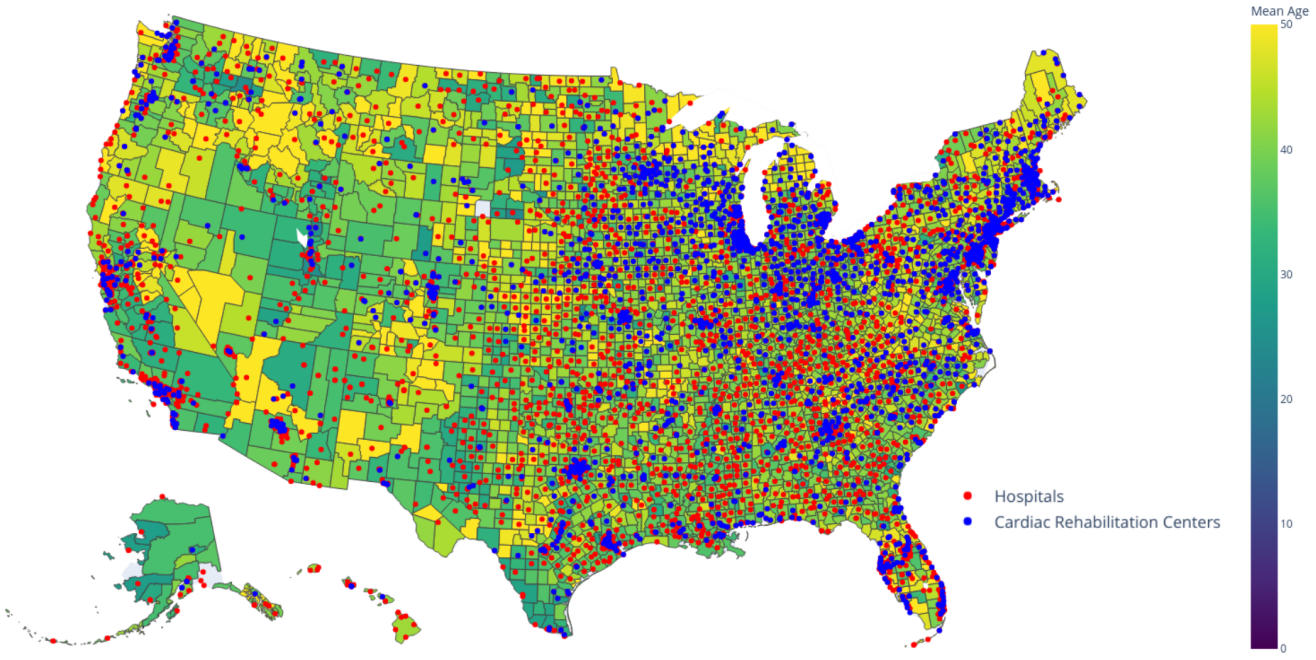

Figure 3. Cardiac Rehabilitation Centers and Hospitals (Acute Care/Critical Access) in the US with Age

6.2.5 Hospitals (Acute Care/Critical Access) Without a Cardiac Rehabilitation Centers Within 30 Miles and Cardiac Rehabilitation Centers Figure 6 is identical to figure 5 with the addition of CR centers plotted.

6.2.6 Hospitals (Acute Care/Critical Access) Without a Cardiac Rehabilitation Center Within 30 Miles and Cardiac Rehabilitation Centers Example: Los Angeles County, California Figure 7 shows a potential use of the map in figure 6. Zooming in on Los Angeles County, California we can see the distribution of CR centers. Within the county, there are 12 CR centers servicing a population of over 9 million and 117 hospitals with a total bed-size capacity of 25,820. This bed-size capacity divided amongst the 12 CR centers gives a ratio of 1 CR center to 2,152 beds. Depending on the max capacity of a CR center, this may present patient accessibility issues. We can also see that there are two hospitals that do not have a center within a 30 mile radius.

7 DECISIONS FOR POLICY MAKERS

Depending on the target demographic (e.g., mid-west states vs north-east states, population density cutoff), new mappings can be produced. In order to facilitate more accurate estimates of access to CR, it is imperative to address the challenges faced in this project such as the lack of easily accessible cardiac admission data at all hospitals and a comprehensive listing of all CR centers regardless of certification across the nation. Considering hospitals play a vital role in saving lives, governments should be able to leverage large amounts of data to identify areas for improvement. In order to combat the issues faced, as referenced above, consider the following propositions for data collection across all health related facilities:

1. Develop consensus driven data collection standards
2. Centralize data collection
3. Make data public

The main issue in creating meaningful visualizations was the inconsistent data and formatting. Although the information was accurate, different states have different details/types of reporting (e.g., New York State has a cardiac surgery registry while other states do not [26]). While the HIFLD [23] provides a central database with many data points, the data was compiled from different sources, mostly at the state level. The dataset also did not include metrics on the treatment type and hospital admission and discharge information. A consensus driven approach would call for experts across the country to agree on the most useful data and reporting standards.

Centralized data collection is also important. If health facilities are obliged to report all their metrics in a standard format, there would be fewer discrepancies in the content of the data. Once every facility reports the same data, a centralized database can easily be facilitated. This can be done by collecting data at a state level and aggregating it at a national level. The alternative is to have each facility report their data to a single source at a national level.

Finally, making data public is essential for providing transparency, accountability, and fostering collaboration within

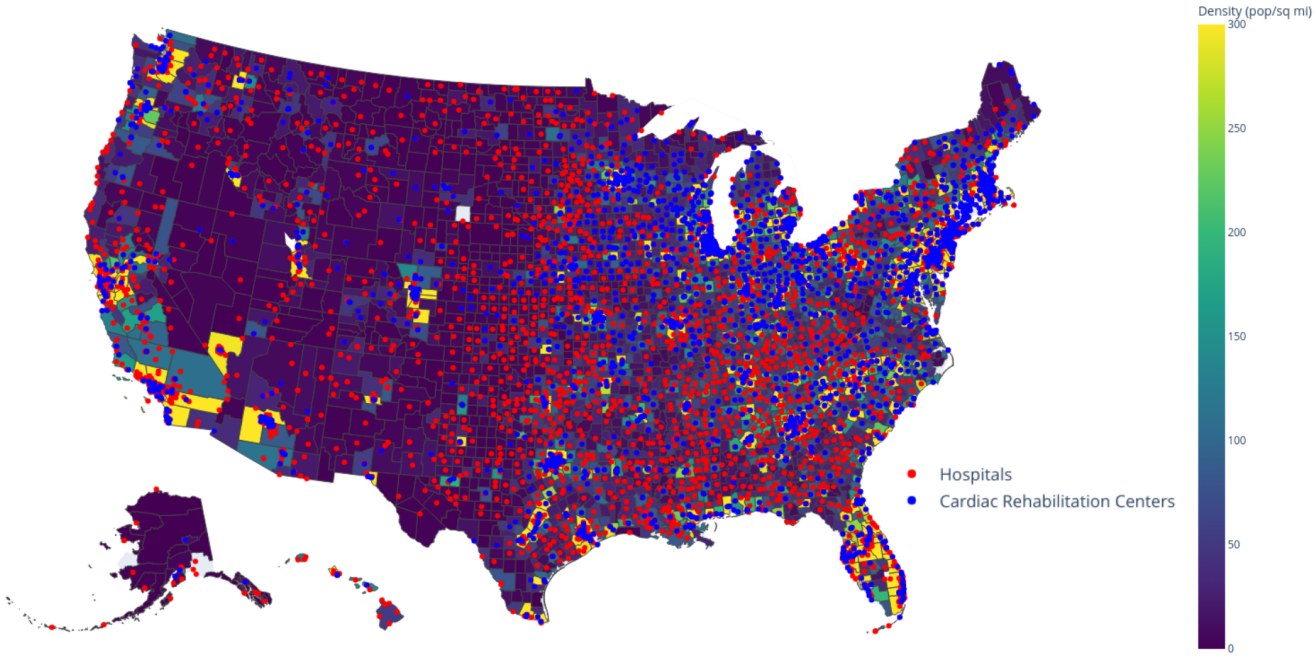

Figure 4. Cardiac Rehabilitation Centers and Hospitals (Acute Care/Critical Access) in the US with Population Density

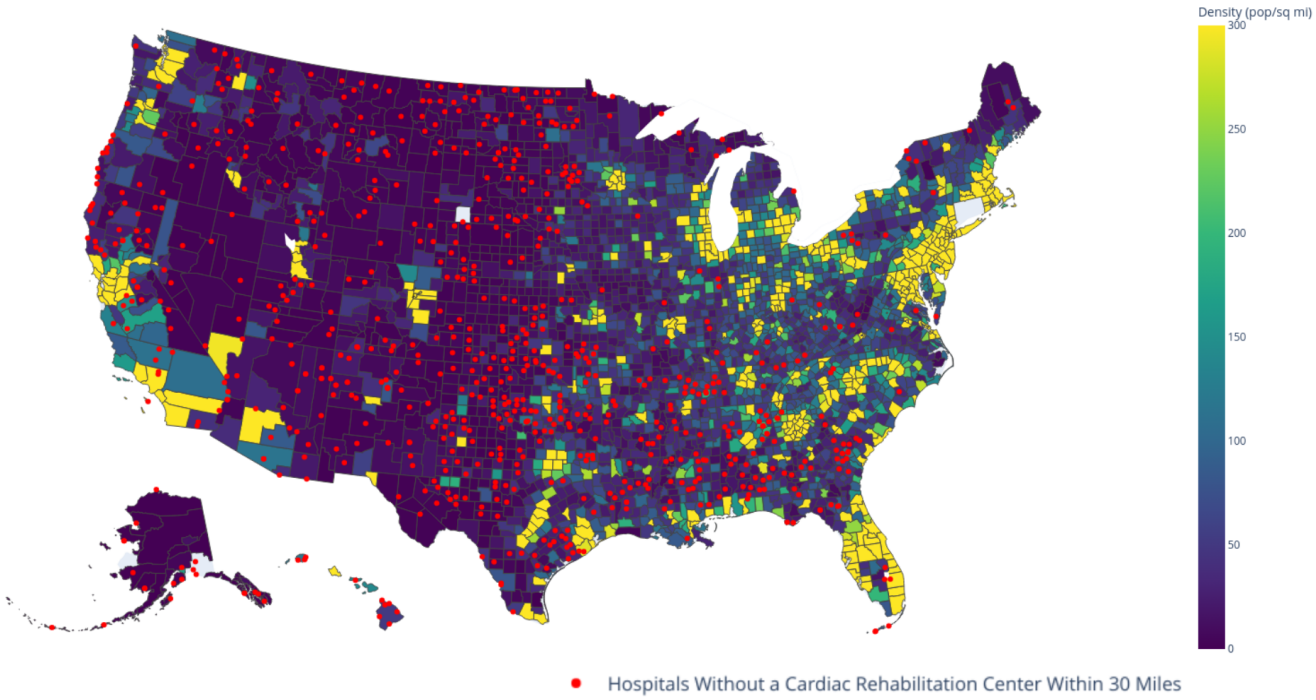

Figure 5. Hospitals (Acute Care/Critical Access) Without Cardiac Rehabilitation Centers Within 30 Miles

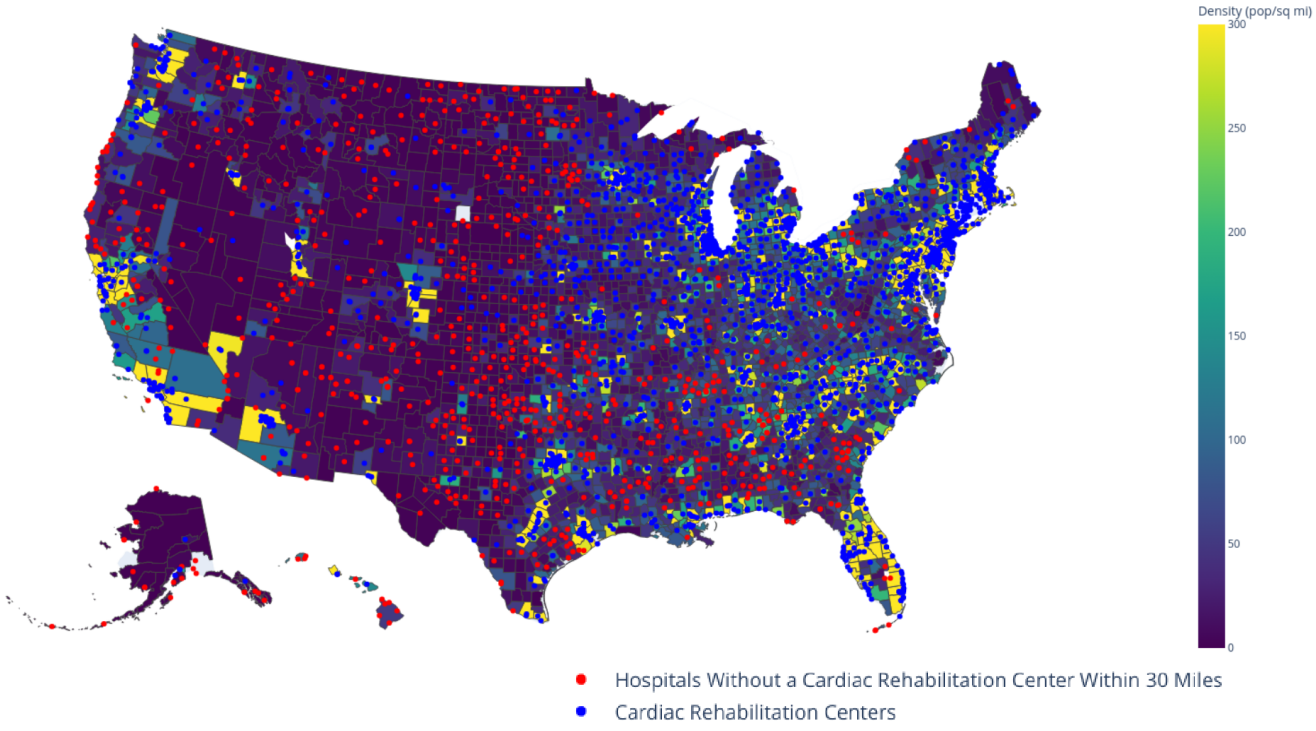

Figure 6. Hospitals (Acute Care/Critical Access) Without Cardiac Rehabilitation Centers Within 30 Miles and Cardiac Rehabilitation Centers

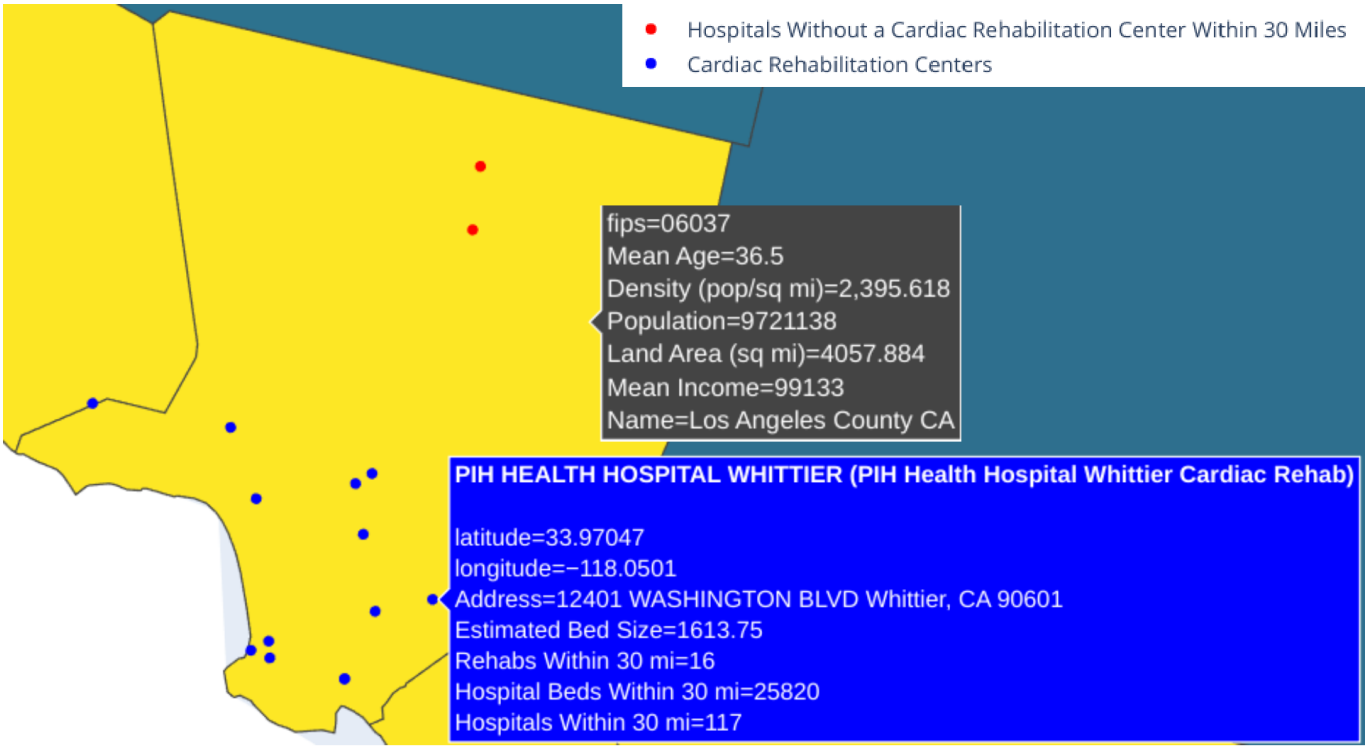

Figure 7. Hospitals (Acute Care/Critical Access) Without a Cardiac Rehabilitation Center Within 30 Miles and Cardiac Rehabilitation Centers Example: Los Angeles County, California

the healthcare system. Publicly accessible data enables researchers, healthcare professionals, and the public to contribute to healthcare improvements.

Overall, these propositions can lay the foundation for improving the healthcare infrastructure, contributing to better health outcomes nationwide.

8 CONCLUSION

Cardiac rehabilitation (CR) plays an important role in recovering from heart disease, yet access to CR can to be improved. A system that can create visualizations of areas with a lack of CR or high demand for CR due to a dense population, can provide valuable insight for researchers. Public health officials can analyze these visualizations to strategically target areas most in need of CR services.

This paper introduces a mapping tool designed to create interactive visualizations of hospitals in need of CR services on a map of the US. The tool also plots current CR centers to provide insight on population density, estimated volume of patients, and the proximity of CR facilities and hospitals. These comprehensive visualizations provide CR providers, including alternative CR providers (i.e., virtual, home-based, hybrid), with the necessary information to start expansion initiatives.

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