Evaluation of Distribution Fairness of Hospital Health Resources in Wisconsin

Using Spatial Database to Identify the Distribution of Hospital Health Resources

Dong Gai, Mingrui Huang – Dec 17, 2022
University of Wisconsin – Madison

Introduction

The problem of health care resource allocation has long been a problem in every country in the world, even in the more resource-rich United States, and it is causing increasing concern among health policy experts and physicians. In other words, in the present situation, especially during a pandemic, the health system is exposed to many problems. According to the article "Access to Health Service," barriers to health care include, among others, lack of health insurance, lack of transportation, and limited health care resources. Among these, inconvenient and unreliable transportation may interfere with people's continued access to health care, which is associated with many people suffering from advanced manifestations of certain diseases such as cancer.

In addition, in another article, "Health Disparities: Gaps in Access, Quality, and Affordability of Medical Care," the authors point out that disparities in access to health care, treatment modalities, and differential outcomes persist across racial and ethnic groups. While the United States has an abundance of healthcare facilities and cutting-edge technology that is the envy of the rest of the world, misallocation of resources, inadequate healthcare infrastructure in many communities, and inefficiencies resulting from the disconnect in our financial spending on health insurance has contributed to disparities and inequities in health systems in different regions. According to statistics, “infant mortality for black babies remains nearly 2.5 times higher than for white babies, and the life expectancy for black men and women remains at nearly

one-decade fewer years of life compared with their white counterparts."

Most importantly, the Covid-19 pandemic remains a major issue for global public health systems, posing significant challenges to the delivery of healthcare services and the allocation and accessibility of healthcare resources. According to the article "Access to Healthcare during COVID - 19", authors state that although the implementation of telemedicine modalities to maintain patient care in many places and the assessment and classification of patients in this way has improved the efficiency of services to some extent, the health threat posed by viruses to vulnerable populations has a significant impact due to their lack of access to telemedicine. However, health is a fundamental human right, and equal access to health resources is a basic right for everyone, regardless of race, economic or social status. Everyone should have the right to access health. Therefore, assessing whether the distribution of hospital resources is equitable and well-accessible is an important process in our quest to achieve an equitable health system.

Dataset

In this study, we combine multiple data sets to evaluate the hospital resource distribution in Wisconsin based on the census tract level. We use the point data of Wisconsin's hospital, COVID-19 Wisconsin cases, and the Trauma Centers data from the Wisconsin Department of Health Service, Wisconsin's census tract boundary shape file, and the population distribution from the GIS Open Data Home to evaluate the relationship between the hospital location and the population distribution. In addition, we also find the hospitals' patients' datasets from the WHA Information Center and the Wisconsin doctor database from DOCTORDATABASE.COM, but these data are not free, if we need to do further research in the future, we can get the data here.

Conceptual Design

As we can see, Figure 1 is the ER-diagram of our database. It has 7 entities, i.e. Hospital, Census Tracts, Disease, Doctor, County, Hospital Disease, and Census Disease, which are represented as rectangular boxes. The connection of these ellipses to each entity represents the attributes that each entity has. For example, the entity of the hospital has the attributes of hospital ID, hospital name, address, and hospital level. The underlined attribute represents the primary key. Hospital Id is the primary key for the hospital entity, which means that every data in this column is unique. We can find the specific hospital according to this attribute. The diamond

boxes represent the relationship between two entities. For instance, a doctor only can work for one hospital. A hospital must have more than one doctor. A disease may not have a hospital disease case or may have one or more hospital disease cases. However, a hospital disease case exactly belongs to one disease. This is the ER- diagram of our database.

Next, Figure 2 is the logical design of our spatial database. In this screenshot, we can see that each box represents one entity, and each entity contains its own attributes and foreign keys. Boxes are connected by relationship. For example, hospital disease contains two attributes (case number and death number) and two foreign keys (Hospital ID and disease ID) which allows the hospital disease table to connect to both the hospital table and the disease table. In this figure, in each table, the attribute pointed by the tail of the arrow represents the foreign key, and the attribute pointed by the head of the arrow represents the primary key.

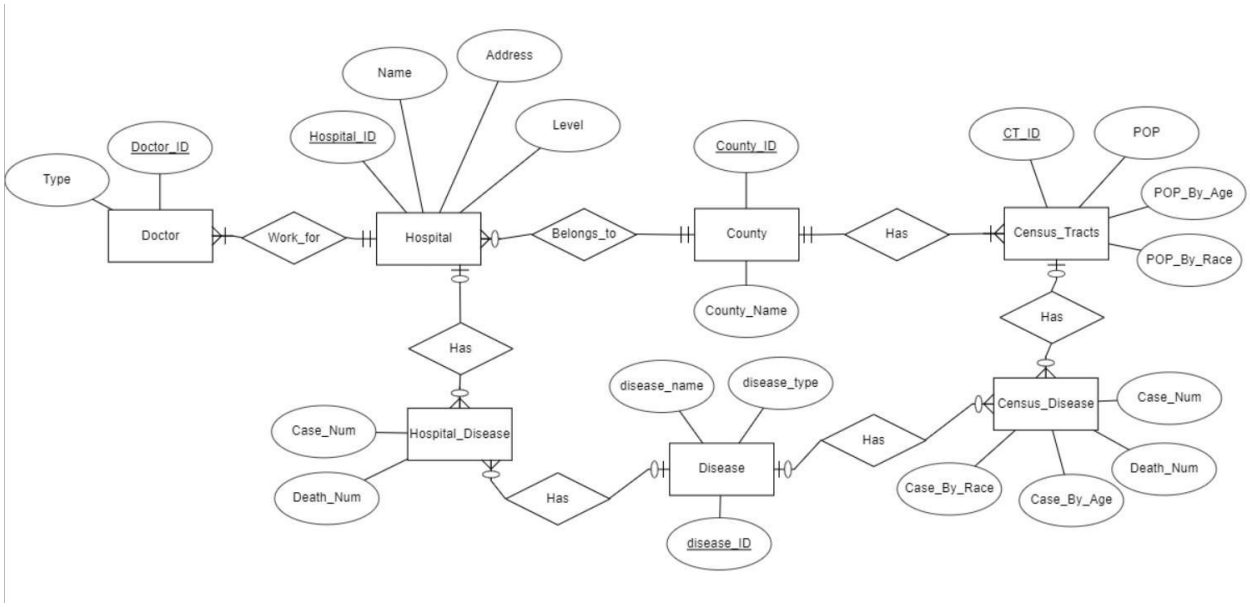

Figure 1: ER-diagram of the Database

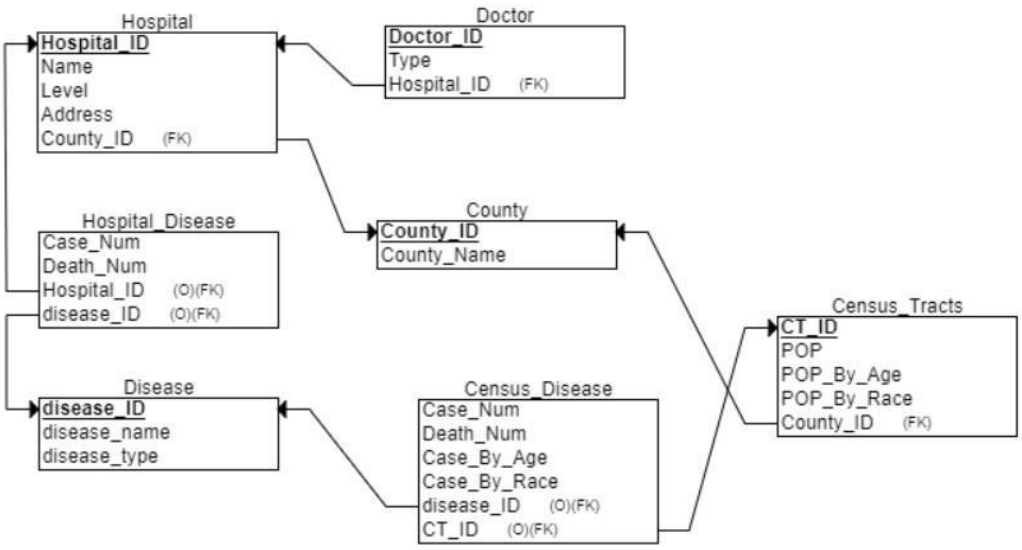

Figure 2: The Relational Model of the Database

Question

In this project, our team seeks to answer multiple questions based on the database:

- The comparison of Wisconsin population distribution and the number of hospitals at the county level.
- The summary of hospitals' level in each county
- The comparison of the population distribution of races and the number of hospitals.
- The comparison of the population distribution of races and the trauma level of hospitals.
- What is the relationship between the population distribution of race and the impact of COVID – 19?
- Is there any correlation between the proportion of older people and the census tracts' covid positive or death rate?

Methods and Results

a. To find the counties' population and the number of hospitals

```
SELECT COUNT(H.countyid), C.geoname, C.pop
FROM wi_hospitals AS H
RIGHT JOIN wi_county AS C
ON ST_Contains(C.geom, H.geom)
GROUP BY C.geoid
ORDER BY C.pop DESC;
```

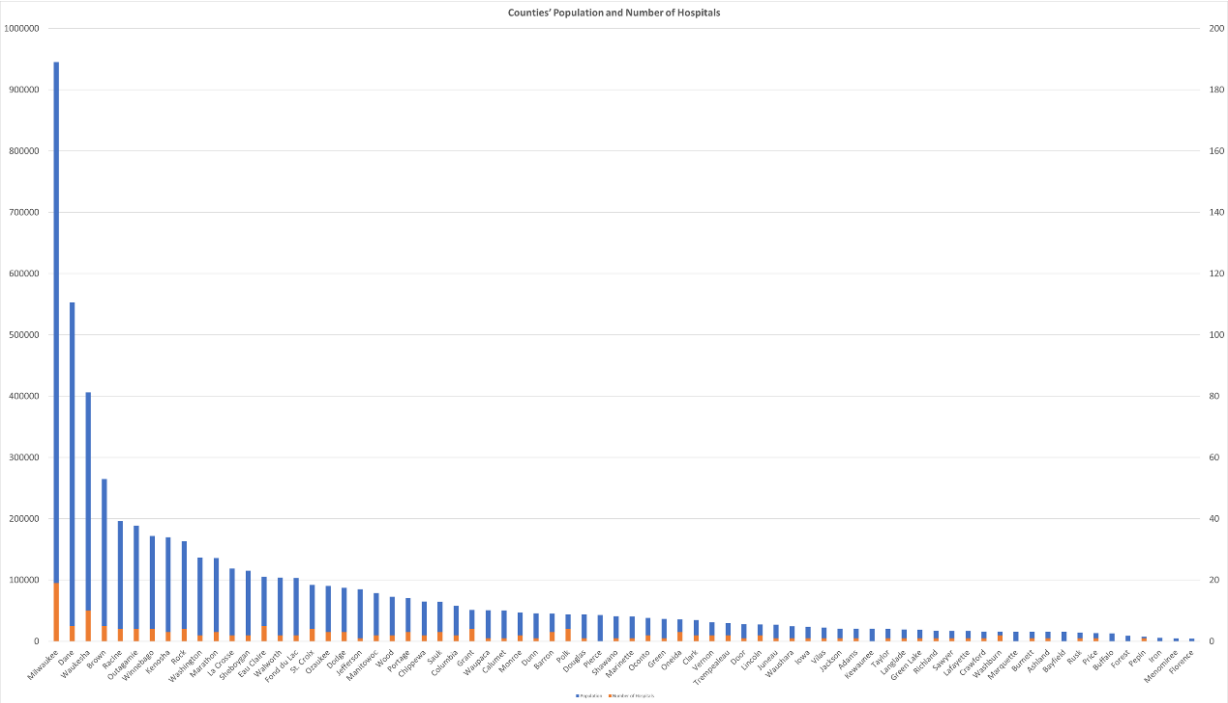

Figure 3: the population and number of hospitals of each county

As we can see in Figure 3, Milwaukee, Dane, and Waukesha County have the top 3 populations in Wisconsin. Milwaukee county has the most hospitals. However, Dane County has a smaller number of hospitals. This is out of proportion. Most importantly, several counties don't have at least one hospital, especially Pierce County. This county has around 50000 people but no hospital. People here may have problems with hospital accessibility.

b. To summarize the hospitals' level in each county

```
SELECT COUNT(H.countyid), C.geoname, H.trauma_l
FROM wi_hospitals AS H
RIGHT JOIN wi_county AS C
ON ST_Contains(C.geom, H.geom)
GROUP BY C.geoid, H.trauma_l
ORDER BY C.geoname;
```

As we can see in Figure 4, only Milwaukee and Dane County have the trauma level I hospital which is a comprehensive regional resource that is a tertiary care facility central to the trauma system. Around 8 counties have the trauma level II hospital which is able to initiate definitive care for all injured patients. However, trauma levels IV and V only can provide the evaluation and prepares patients for transfer to higher levels of care. ("Trauma Center Levels Explained")

Furthermore, more than half of counties only have hospitals level below trauma III, which means that many people may not able to get appropriate treatment the first time after getting injured. Then, according to the population, Waukesha County also should build at least one trauma level I hospital. Grant and St.Crolx counties only have trauma level IV hospitals. In this case, there is no way for them to obtain corresponding health resources.

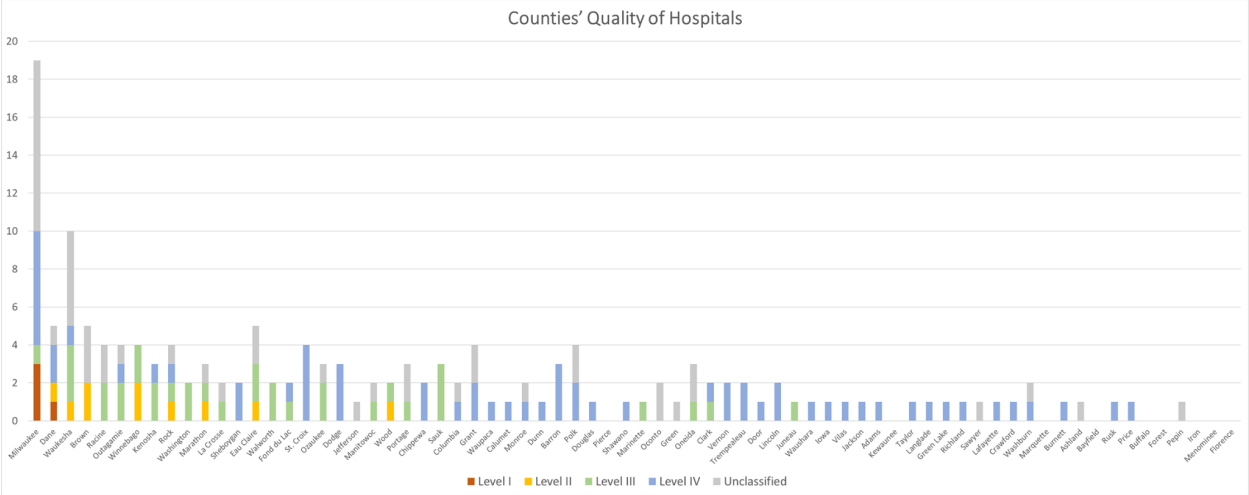

Figure 4: the number of hospitals in each level in each county

Table For Counties' Quantity and Quality of Hospitals

County Name	Level I	Level II	Level III	Level IV	Unclassified	Number of Hospitals	Population
Milwaukee	3	0	1	6	9	19	945016
Dane	1	1	0	2	1	5	552536
Waukesha	0	1	3	1	5	10	406172
Brown	0	2	0	0	3	5	264610
Racine	0	0	2	0	2	4	195802
Outagamie	0	0	2	1	1	4	188766
Winnebago	0	2	2	0	0	4	171631
Kenosha	0	0	2	1	0	3	169671
Rock	0	1	1	1	1	4	163084
Washington	0	0	2	0	0	2	136445
Marathon	0	1	1	0	1	3	135593
La Crosse	0	0	1	0	1	2	118502
Sheboygan	0	0	0	2	0	2	115240
Eau Claire	0	1	2	0	2	5	105260
Walworth	0	0	2	0	0	2	103953
Fond du Lac	0	0	1	1	0	2	102902
St. Croix	0	0	0	4	0	4	91838
Ozaukee	0	0	2	0	1	3	90043
Dodge	0	0	0	3	0	3	87336
Jefferson	0	0	0	0	1	1	85038
Manitowoc	0	0	1	0	1	2	78757
Wood	0	1	1	0	0	2	72560
Portage	0	0	1	0	2	3	71032
Chippewa	0	0	0	2	0	2	64737
Sauk	0	0	3	0	0	3	64449
Columbia	0	0	0	1	1	2	57668
Grant	0	0	0	2	2	4	51021
Waupaca	0	0	0	1	0	1	50664
Calumet	0	0	0	1	0	1	50209
Monroe	0	0	0	1	1	2	46582
Dunn	0	0	0	1	0	1	45452
Barron	0	0	0	3	0	3	45090
Polk	0	0	0	2	2	4	43794
Douglas	0	0	0	1	0	1	43702
Pierce	0	0	0	0	0	0	42700
Shawano	0	0	0	1	0	1	40786
Marinette	0	0	1	0	0	1	40262
Oconto	0	0	0	0	2	2	38383
Green	0	0	0	0	1	1	36603
Oneida	0	0	1	0	2	3	35751
Clark	0	0	1	1	0	2	34720
Vernon	0	0	0	2	0	2	30861
Trempealeau	0	0	0	2	0	2	29681
Door	0	0	0	1	0	1	27889
Lincoln	0	0	0	2	0	2	27566
Juneau	0	0	1	0	0	1	26908
Waushara	0	0	0	1	0	1	24326
Iowa	0	0	0	1	0	1	23640
Vilas	0	0	0	1	0	1	22356
Jackson	0	0	0	1	0	1	20630
Adams	0	0	0	1	0	1	20498
Kewaunee	0	0	0	0	0	0	20386
Taylor	0	0	0	1	0	1	20318
Langlade	0	0	0	1	0	1	19119
Green Lake	0	0	0	1	0	1	18908
Richland	0	0	0	1	0	1	17258
Sawyer	0	0	0	0	1	1	16700
Lafayette	0	0	0	1	0	1	16646
Crawford	0	0	0	1	0	1	16021
Washburn	0	0	0	1	1	2	15712
Marquette	0	0	0	0	0	0	15585
Burnett	0	0	0	1	0	1	15557
Ashland	0	0	0	0	1	1	15415
Bayfield	0	0	0	0	0	0	15242
Rusk	0	0	0	1	0	1	14022
Price	0	0	0	1	0	1	13245
Buffalo	0	0	0	0	0	0	13033
Forest	0	0	0	0	0	0	8960
Pepin	0	0	0	0	1	1	7271
Iron	0	0	0	0	0	0	5698
Menominee	0	0	0	0	0	0	4546
Florence	0	0	0	0	0	0	4298

c. To find the population of Races and the number of hospitals

```
CREATE TEMP TABLE tempm AS(
SELECT *
FROM wi_census_tracts
WHERE total_popu != 0
AND cast((black_alon+american_i+asian_alon+pacific_is+some_other) as decimal(7,2))/cast(total_popu
as decimal(7,2)) > 0.5 );

SELECT ct.geoid, ct.namelsad
 FROM tempm AS ct, wi_hospitals AS h
 WHERE ST_Contains(
 ST_Buffer(h.geom, 5000, 'quad_segs=8'), ct.geom)
 GROUP BY ct.geoid, ct.namelsad;
```

According to this query, we find that minority-dominant census tracts do not have any hospitals in the 5km range. Result: 48/122(39.3%)

We also used the same way to query non-minority dominant census tracts, and they also don't have any hospitals in 5 km range. Result: 1122/1382 (81.2%)

d. To find the population distribution of race and the quality of hospitals.

```
CREATE TEMP TABLE temph AS(
SELECT *
    FROM wi_hospitals h
WHERE h.trauma_l = 'Level I'
OR h.trauma_l = 'Level II'
OR h.trauma_l = 'Level III' );


SELECT ct.geoid, ct.namelsad, cast((black_alon+american_i+asian_alon+pacific_is+some_other) as
decimal(7,2))/cast(total_popu as decimal(7,2)) AS Percentage
FROM temph h, wi_census_tracts ct
WHERE total_popu != 0
AND ST_Contains(ST_Buffer(h.geom, 5000, 'quad_segs=8'), ct.geom )
GROUP BY ct.geoid, ct.namelsad
ORDER BY Percentage DESC;
```

According to this query, we find minority dominant census tracts have at least one level I – III hospital in the 5 km range. (Result: 6/122 (4.9%)). Non-minority dominant census tracts have at least one level I-III hospital in the 5 km range. (Result: 137/1382(9.9%))

In addition, we find that the hospitals do not contain any minority-dominant census tracts, but it contains several non-minority-dominant census tracts. (Result: 61/1382 (4.4%)) This shows that the distribution of hospitals in Wisconsin is still somewhat inequitable. Because most hospitals are located in the non-minority dominant census tract, non-minority people need to spend more time and effort accessing health resources. This is also a reflection of inequity.

e. To find the population distribution of race and the impact of COVID-19.

```
SELECT ct.namelsad,
cast(dct.pos_cum_cp as decimal(7,2))/cast(total_popu as decimal(7,2)) AS pos_rate,
cast(dct.dth_cum_cp as decimal(7,2))/cast(pos_cum_cp as decimal(7,2)) AS dth_rate,
cast((black_alon+american_i+asian_alon+pacific_is+some_other) as decimal(7,2))/cast(total_popu as
decimal(7,2)) AS Percentage
FROM wi_census_tracts ct
LEFT JOIN diseases_ct dct
ON ct.geoid = dct.geoid
WHERE total_popu != 0
AND cast(dct.pos_cum_cp as decimal(7,2))/cast(total_popu as decimal(7,2)) > 0.3
AND cast(dct.dth_cum_cp as decimal(7,2))/cast(pos_cum_cp as decimal(7,2)) > 0.01
ORDER BY Percentage DESC;
```

In this query, we find that 226 census tracts' covid positive rate is higher than 30% and the death rate is higher than 1%, 16 of them are minority dominant (16/122. 13.1%), 210 are non-minority dominant (210/1382, 15.2%), which means that relatively higher number of non-minority dominant census tracts have the high positive rate than minority dominant census tracts. In this way, the medical resource should be distributed by the proportion of positive rate that non-minority dominant census tract should allocate relatively more medical resources.

f. To find the correlation between the proportion of older people (up to 65 years old) and the census tracts' covid positive rate/death rate.

```
SELECT ct.namelsad,
cast(dct.pos_cum_cp as decimal(7,2))/cast(total_popu as decimal(7,2)) AS pos_rate,
cast(dct.dth_cum_cp as decimal(7,2))/cast(pos_cum_cp as decimal(7,2)) AS dth_rate,
cast(ct.total65_up as decimal(7,2))/cast(total_popu as decimal(7,2)) AS Percentage
FROM wi_census_tracts ct
LEFT JOIN diseases_ct dct
ON ct.geoid = dct.geoid
WHERE total_popu != 0
ORDER BY dth_rate DESC;
```

After we get the table by this query, we got the data of the proportion of old people, the positive rate, and the death rate at the census tract level. In this case, we did two linear regression models for the data in R Studio.

First, we use the percentage of old people as y and the percentage of the positive rate as x. Second, we use the percentage of death rate as x to do the linear regression. In this case, we find that both the positive rate and death rate have a positive correlation with the percentage of

old people. The death rate is a little bit stronger in correlation than the positive rate, which a coefficient is 3.944556e+00. Therefore, the census tracts have a high proportion and need more healthcare resources.

Conclusion

To sum up, through this project we found that the distribution of hospitals in Wisconsin is relatively equitable, but that Milwaukee, Dane, and Waukesha are the main counties in terms of population, so they should be allocated relatively more healthcare resources. Most importantly, through our analysis, we found that most of the census tracts where minorities are concentrated generally have fewer hospitals and health resources. They have these problems in terms of accessibility to hospitals. This is one of the problems of healthcare equity. These problems were found through the analysis of the database we designed.

However, In the future, if we want to do further research on this project and have access to these data, we will do more analysis through our database. According to the article “Equity in Distribution of Heath Care Resources; Assessment of Need and Access, Using Three Practical Indicators”, authors find that we can use the Gini coefficient to assess equality in the distribution of beds and doctors at the population level. And the value ranges from 0 to 1. 0 represents perfect equality. 1 represents maximum inequality. This is a great and powerful way to evaluate health fairness.

Reference

"Access to Health Services." Access to Health Services - Healthy People 2030, https://health.gov/healthypeople/priority-areas/social-determinants-health/literature-summaries/access-health-services.

Riley, Wayne J. "Health Disparities: Gaps in Access, Quality and Affordability of Medical Care." Transactions of the American Clinical and Climatological Association, U.S. National Library of Medicine, 2012, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3540621/.

Núñez, Alicia, et al. "Access to Healthcare during COVID-19." International Journal of Environmental Research and Public Health, U.S. National Library of Medicine, 14 Mar. 2021, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7999346/.

Omrani-Khoo, Habib, et al. "Equity in Distribution of Health Care Resources; Assessment of Need and Access, Using Three Practical Indicators." Iranian Journal of Public Health, U.S. National Library of Medicine, Nov. 2013, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4499072/.