Comparing Magnetic Resonance Imaging and Computed Tomography Machine Accessibility Among Urban and Rural County Hospitals in Wisconsin

Benjamin Burdorf, MD; William MacDonald, MD; Pravallika Kesarla, BS; Samantha Burdorf, MBA

ABSTRACT

Introduction: There is higher disease incidence and worse outcomes in rural America when compared to urban America. In states like Wisconsin, where 32.9% of the population resides in rural areas, this is particularly worrisome. The Center for Healthcare Quality and Payment Reform found that 30% of rural hospitals in the US are at risk of closing due to financial instability. A substantial cost to rural hospitals is the provision of radiologic services. Thus, the study investigated if a disparity exists in availability of magnetic resonance imaging (MRI) and computed tomography (CT) machines among Wisconsin's urban and rural county hospitals.

Methods: Wisconsin hospitals were asked how many MRI and CT machines were carried at their facility. This information was compiled in a spreadsheet and cross-referenced with the county in which it resided, along with the county's population, urban-rural classification, and land area in square miles.

Results: We found that the state of Wisconsin compared favorably with the national average in terms of the number of persons and square miles per MRI and CT machine. When comparing Wisconsin counties based on their urban-rural classification, a disparity exists in rural counties regarding square mileage per CT and MRI machine.

Conclusions: With distance for service creating a barrier to accessibility, rural county residents would benefit from more in-hospital MRI and CT machines. Based on these findings, further research is warranted to investigate the potential vulnerability of other rural populations regarding accessibility to radiologic resources.

INTRODUCTION

The US Food and Drug Administration and the Centers for Disease Control and Prevention report that rural America faces higher disease incidence in conjunction with worse outcomes than urban areas and note that difficulty accessing health care resources was a major contributing factor.[1,2] This disparity is concerning, particularly because the US Census Bureau reports that 20% of the country's population resides in a rural area.[3] In Wisconsin, 32.9% of the population is rural,[4] and the state has 58 Critical Access Hospitals (CAHs) – the sixth highest total in the country.[5] Further, despite government assistance, in 2024, the Center for Healthcare Quality and Payment Reform found that 30% of rural hospitals in the US are not financially sustainable and risk closing.[6] Although there are many financial hurdles facing rural hospitals, one that is particularly substantial is affording the installation, maintenance, and operation of computed tomography (CT) and magnetic resonance imaging (MRI) machines.[7]

In light of the serious pressures on rural hospitals, this report aims to assess whether a discrepancy exists in the accessibility of MRI and CT machines between Wisconsin's urban and rural county hospitals. Of note, a literature review did not identify research investigating this question for the state of Wisconsin; however, this report closely mirrors prior work completed by the corresponding author for the state of Minnesota.[8]

• • •

Author Affiliations: Department of Radiology, Aurora St. Luke's Medical Center, Milwaukee, Wisconsin (B Burdorf, MacDonald); Rosalind Franklin School of Medicine, North Chicago, Illinois (Kesarla); Augsburg University, Minneapolis, Minnesota (S Burdorf).

Corresponding Author: Benjamin Burdorf, MD, Aurora St. Luke's Medical Center, 2900 W Oklahoma Ave, Milwaukee, WI 53215, email benjamin.burdorf@aah.org; ORCID ID 0000-0003-0643-2632

Table. In-hospital Magnetic Resonance Imaging and Computed Tomography Machine Data by Wisconsin County and Rural-Urban Classification Using Their Respective Populations and Land Areas

Locale	County	Population	Land (Mi^2)	MRIs	CTs	Person/MRI	Mi^2/MRI	Person/CT	Mi^2/CT
Rural	Adams	21226	646	0	1	N/A	N/A	21226	646
Rural	Ashland	16039	1045	1	3	16039	1045	5346	348
Rural	Barron	46843	863	4	5	11711	216	9369	173
Rural	Burnett	17036	822	0	1	N/A	N/A	17036	822
Rural	Clark	34691	1210	0	2	N/A	N/A	17346	605
Rural	Crawford	16007	571	1	1	16007	571	16007	571
Rural	Dodge	88282	876	3	4	29427	292	22071	219
Rural	Door	30526	482	1	1	30526	482	30526	482
Rural	Dunn	45651	850	1	1	45651	850	45651	850
Rural	Grant	51276	1147	2	3	25638	573	17092	382
Rural	Green Lake	19220	349	1	1	19220	349	19220	349
Rural	Jackson	20836	988	1	1	20836	988	20836	988
Rural	Jefferson	85784	556	1	2	85784	556	42892	278
Rural	Juneau	26866	767	1	1	26866	767	26866	767
Rural	Lafayette	16877	634	0	1	N/A	N/A	16877	634
Rural	Langlade	19559	871	1	1	19559	871	19559	871
Rural	Lincoln	28376	879	0	2	N/A	N/A	14188	439
Rural	Manitowoc	81172	589	2	2	40586	295	40586	295
Rural	Marinette	41988	1399	1	2	41988	1399	20994	700
Rural	Monroe	46109	901	2	4	23055	450	11527	225
Rural	Oneida	38212	1113	2	5	19106	556	7642	223
Rural	Pepin	7410	232	0	1	N/A	N/A	7410	232
Rural	Polk	45709	914	3	3	15236	305	15236	305
Rural	Portage	70718	801	1	3	70718	801	23573	267
Rural	Price	14179	1254	0	1	N/A	N/A	14179	1254
Rural	Richland	17090	586	1	1	17090	586	17090	586
Rural	Rusk	14186	914	1	1	14186	914	14186	914
Rural	Sauk	65777	831	3	4	21926	277	16444	208
Rural	Sawyer	18559	1257	1	1	18559	1257	18559	1257
Rural	Shawano	40886	893	1	1	40886	893	40886	893
Rural	Taylor	19975	975	1	1	19975	975	19975	975
Rural	Trempealeau	30899	733	0	2	N/A	N/A	15450	366
Rural	Vernon	31060	792	0	2	N/A	N/A	15530	396
Rural	Vilas	23763	857	0	1	N/A	N/A	23763	857
Rural	Walworth	105380	555	2	2	52690	278	52690	278
Rural	Washburn	16911	797	0	2	N/A	N/A	8456	399
Rural	Waupaca	51488	748	1	1	51488	748	51488	748
Rural	Waushara	24999	626	0	1	N/A	N/A	24999	626
Rural	Wood	73993	793	5	7	14799	159	10570	113
Urban	Brown	270036	530	10	8	27004	53	33755	66
Urban	Calumet	52718	318	0	1	N/A	N/A	52718	318
Urban	Chippewa	66807	1008	0	1	N/A	N/A	66807	1008
Urban	Columbia	58193	766	1	2	58193	766	29097	383
Urban	Dane	568203	1197	14	15	40586	86	37880	80
Urban	Douglas	44144	1304	0	1	N/A	N/A	44144	1304
Urban	Eau Claire	106837	638	4	5	26709	159	21367	128
Urban	Fond du Lac	103836	720	3	2	34612	240	51918	360
Urban	Green	36816	584	1	2	36816	584	18408	292
Urban	Iowa	23865	763	1	1	23865	763	23865	763
Urban	Kenosha	167817	272	2	2	83909	136	83909	136
Urban	La Crosse	120294	452	3	4	40098	151	30074	113
Urban	Marathon	137958	1545	3	6	45986	515	22993	257
Urban	Milwaukee	918661	241	25	37	39942	10	29634	8
Urban	Oconto	39633	998	1	2	39633	998	19817	499
Urban	Outagamie	192127	638	4	5	48032	159	38425	128
Urban	Ozaukee	93009	233	3	4	31003	78	23252	58
Urban	Racine	195846	333	4	7	48962	83	27978	48
Urban	Rock	164060	718	7	7	23437	103	23437	103
Urban	Sheboygan	117841	511	2	3	58921	256	39280	170
Urban	St. Croix	96017	722	4	4	24004	181	24004	181
Urban	Washington	137688	431	2	3	68844	215	45896	144
Urban	Waukesha	410434	550	11	18	37312	50	22802	31
Urban	Winnebago	170718	434	4	8	42680	109	21340	54

Abbreviations: Mi^2, square miles; MRI, magnetic resonance imaging; CT computed tomography.

METHODS

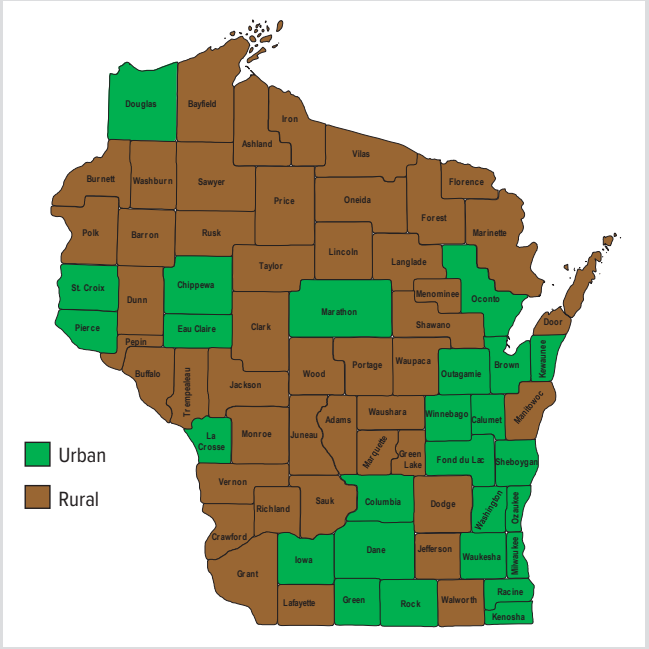
All Wisconsin hospitals listed in the Wisconsin Hospital Association directory were contacted via their general phone line.[9] Hospitals that provided services to an exclusive subset of the population, such as veterans or Native Americans, were excluded. Researchers explained the study's objective to either a Radiology Department technician or the hospital's director of Radiology, then asked how many MRI and CT machines they carried at their facility and whether each unit was permanent or part of a mobile service. After this information was obtained for each hospital, it was cross-referenced with the county in which it resided, along with the county's population, land area in square miles,[10] and urban-rural classification (Figure 1).[11] The number of persons and square mileage per MRI and CT machine for each county was generated (Table). Mobile units were excluded (Figure 2). Microsoft Office was used to map densities and determine percentile rankings (Figures 3 and 4). The data were further analyzed in Excel by grouping counties into their respective urban-rural classifications (Figure 1) to determine how they compared collectively (Figure 5). Data for the state of Wisconsin as a whole were compared to US data from the Organisation for Economic Co-operation and Development (OECD).[12]

RESULTS

CT Machine Accessibility

Of Wisconsin's 72 counties, 9 counties did not have an in-hospital CT machine. Based on urban-rural classification (Figure 1), 7 counties without an in-hospital CT machine were rural and 2 were urban (Figure 3). Wisconsin averaged fewer people per CT machine (n = 26039) than the national average (n = 37024). Wisconsin's urban counties averaged 29011 per CT machine, while rural counties averaged 18551 (Figure 5). In terms of square miles per county per CT machine, the state of Wisconsin averaged 239 versus the national average of 395. Wisconsin's

Figure 1. Wisconsin County Map with Urban-Rural Classifications According to the Wisconsin Hospital Association



urban counties averaged 216 square miles per CT machine and rural counties averaged 407 (Figure 5). Data by county for persons per CT machine and square miles per CT machine are shown in Figure 3 and the Table.

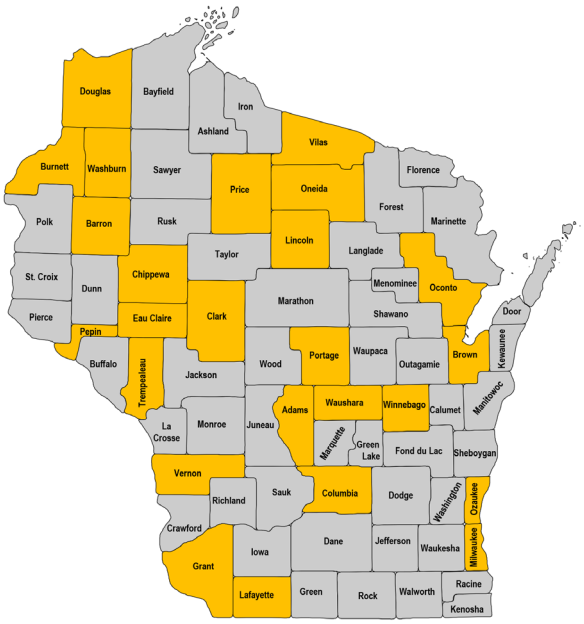
MRI Machine Accessibility

Twenty-four of Wisconsin's 72 counties did not have an in-hospital MRI machine. Based on urban-rural classification (Figure 1), 19 counties without an in-hospital MRI machine were rural and 5 were urban (Figure 4). Fourteen of the 24 utilized a mobile MRI service (Figure 2). The state of Wisconsin averaged fewer people per MRI machine (n=38 382) than the national average (n = 55 773). Wisconsin's urban counties averaged 39 390 people per MRI machine, while rural counties averaged 32 568 (Figure 5). In terms of square miles per county per MRI machine, the state of Wisconsin averaged 352 versus the national average of 595. Wisconsin's urban counties averaged 294 square miles per MRI machine, while rural counties averaged 714 (Figure 5). Data by county for persons per MRI machine and square miles per MRI machine are shown in Figure 4 and the Table.

DISCUSSION AND CONCLUSIONS

There are no established guidelines regarding the recommended number of MRI or CT machines based on population or square miles. This raises the question of how to determine an appropriate value for adequate representation in a given population. For guidance, we used data from the OECD to generate national averages to compare with state-level statistics. Overall, Wisconsin performed better than the nation in terms of MRI and CT machines per person and square miles (Figure 5).

Figure 2. Wisconsin County Map and Table Highlighting Usage of Mobile Magnetic Resonance Imaging Services



County	Hospitals with Mobile MRI	County	Hospitals with Mobile MRI
Adams	1	Oconto	1
Barron	1	Oneida	1
Brown	1	Ozaukee	1
Burnett	1	Pepin	1
Chippewa	1	Portage	2
Clark	2	Price	1
Columbia	1	Trempealeau	2
Douglas	1	Vernon	2
Eau Claire	1	Vilas	1
Grant	1	Washburn	2
Lafayette	1	Waushara	1
Lincoln	1	Winnebago	1
Milwaukee	2		

When examining the urban-rural classifications for persons per MRI and CT machine, the data showed that rural populations were better represented than urban populations (Figure 5). Although rural populations have fewer people per MRI and CT machine, the distance to these resources is what serves as the barrier. This is illustrated by examining square mileage per MRI and CT machines by urban-rural classification. For square mileage per CT machine, Wisconsin's rural counties averaged 407 – higher than the national average of 395 and almost double the 216 seen in Wisconsin's urban counties. Because CT machines play a vital role in acute care, the value of their accessibility cannot be understated.

However, the greatest disparity shown by this research involves MRI machines. The average square mileage per MRI machine in Wisconsin's rural counties is 714, which is greater than the national average of 595 and more than double the 294 seen in the state's urban counties. Granted, mobile MRI services

Figure 3. Wisconsin County Maps with Color Spectrums Illustrating the Percentile Performance Among Counties with (A) In-hospital Computed Tomography (CT) Machines by Persons per CT Machine and (B) Square Mileage per CT Machine

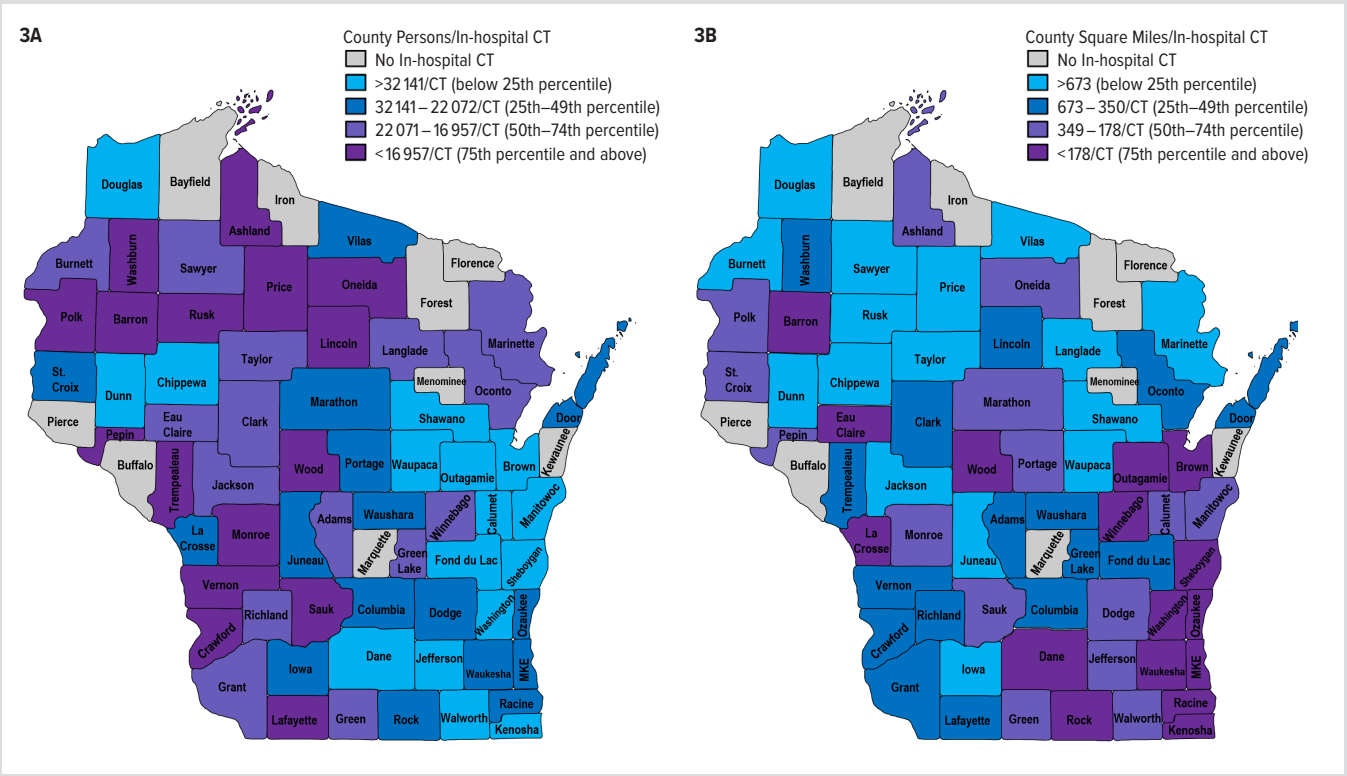


Figure 4. Wisconsin County Maps with Color Spectrums Illustrating the Percentile Performance Among Counties with (A) In-hospital Magnetic Resonance Imaging (MRI) Machine by Persons per MRI Machine and (B) Square Mileage per MRI Machine

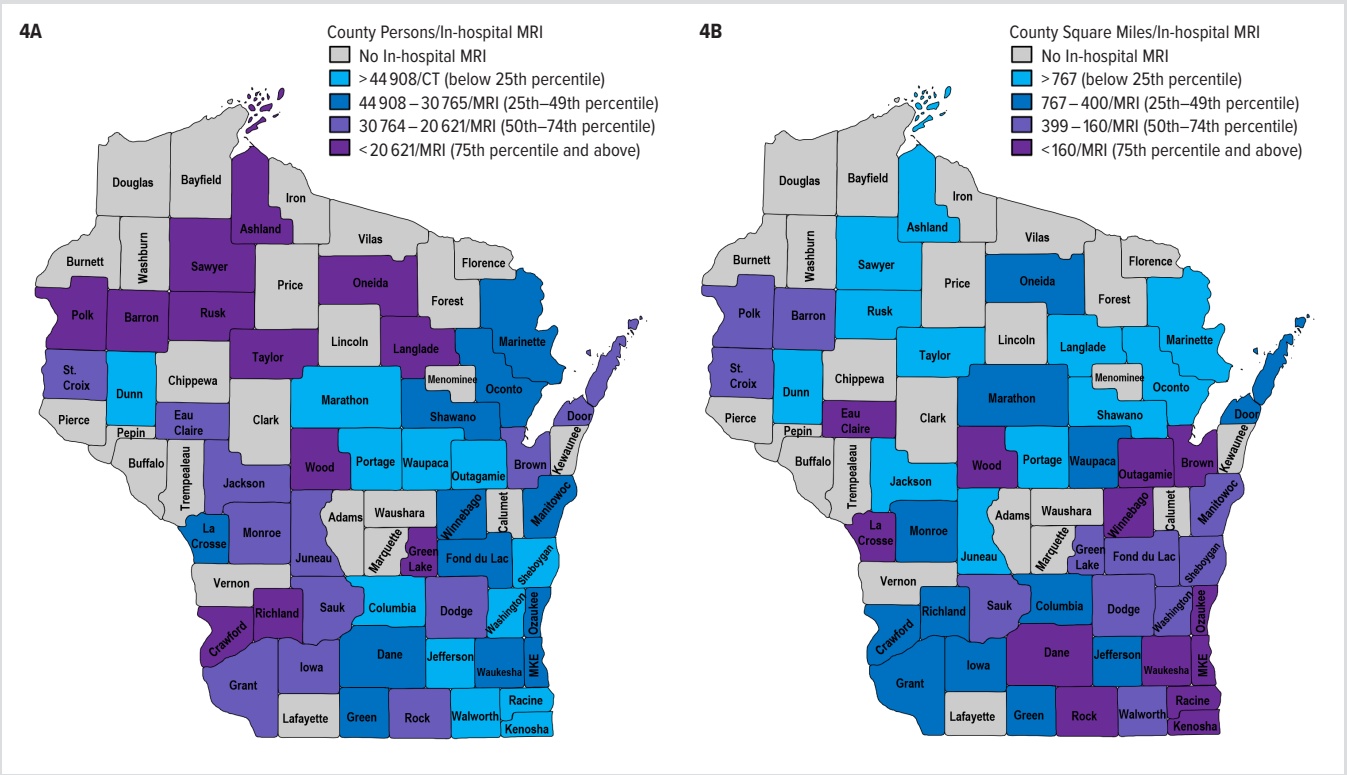
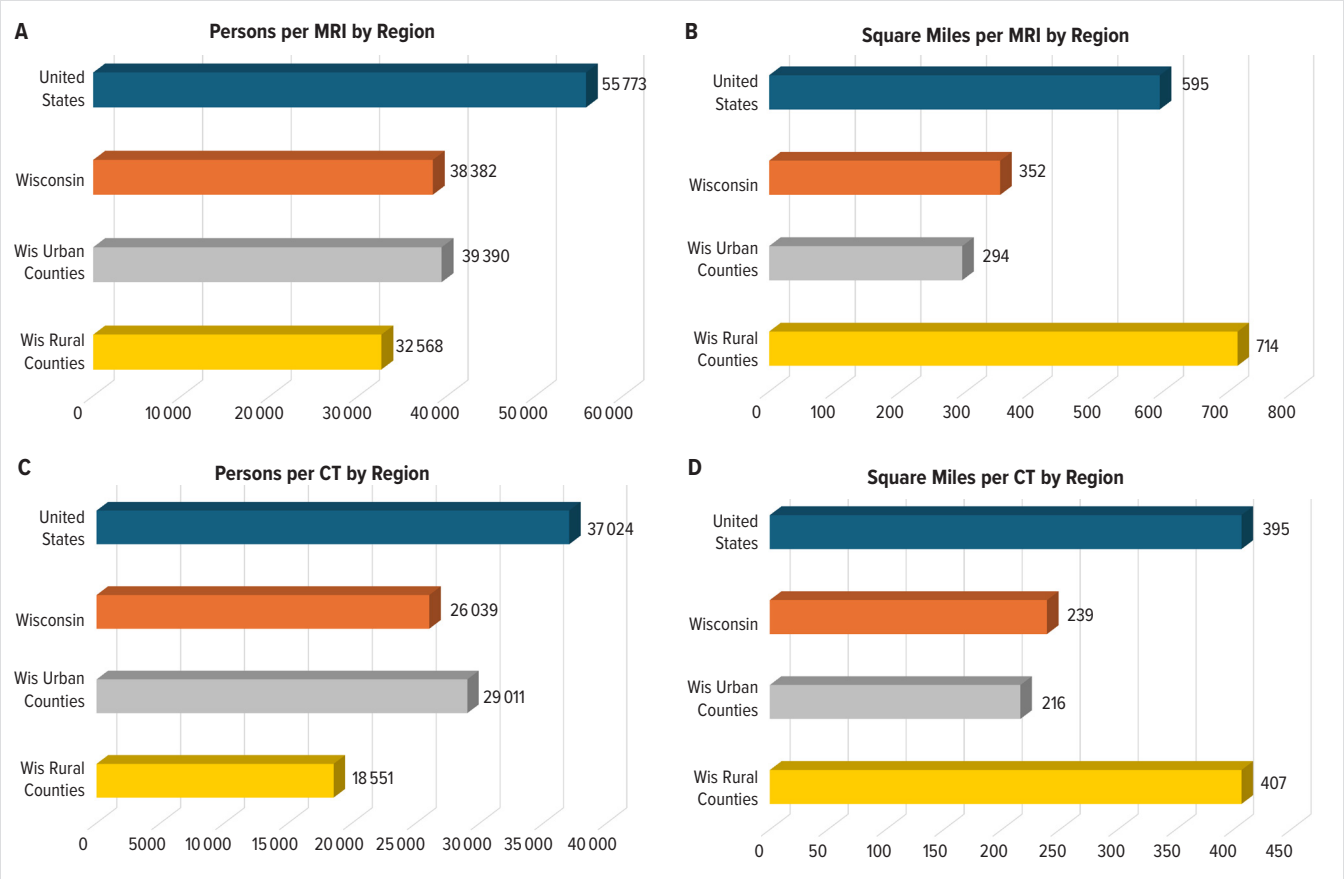


Figure 5. Bar Graphs Portraying National, State and Urban-Rural Classification Performance by (A) Persons per Magnetic Resonance Imaging (MRI) Machine, (B) Square Miles per MRI Machine, (C) Persons per Computed Tomography (CT) Machine, and (D) Square Miles per CT Machine



partially address this misrepresentation. Hospitals that utilize mobile MRI services indicated that MRI availability ranged anywhere from 2 days a week to once every 2 weeks. This means that the majority of rural patients must arrange an additional visit or, with more time-sensitive health concerns, travel to a different health facility, thereby creating inadvertent barriers for people in rural communities.

As reported by the Association of American Medical Colleges, the long distances and time required to receive health services often result in those who need care delaying or avoiding it altogether.[13] If a rural patient has to make another appointment or travel to another facility for radiologic services, they must again face any challenges they overcame for their initial visit. Thus, rural hospitals would benefit from the implementation of in-hospital CT and MRI machines.

Limitations

Potential sources of error in this research include inaccurate information relayed by contacted radiology technologists. There were a few instances where, when asked how many MRI and CT machines their facility had, technologists provided answers that also included the machines at hospital-affiliated outpatient service centers. In addition, it is possible that some newer hospitals were not contacted, as 2 hospitals listed on the Wisconsin Hospital Association's website had been closed for almost a year, highlighting the possibility that information had not been updated within that time.

Another limitation is the exclusion of outpatient radiology centers. It would be logical to investigate to what extent outpatient radiology centers fulfill the disparities revealed in the rural setting by this research. Unfortunately, this would be difficult to determine with no referenceable database tracking these facilities.

Future directions for research include better characterizing the effect of limited accessibility to MRI and CT machines on a community's health, determining the ideal square mileage per MRI and CT machine for a given population, and exploring ways to make these resources more affordable in rural settings. Although these questions are unanswered, we can draw a reasonable conclusion from the data presented here. When comparing Wisconsin counties by their urban-rural classification, disparity exists regarding the square mileage per CT and MRI machine in rural counties. Given the primary root of accessibility issues

residing in distance for service, patients would benefit from more rural county in-hospital MRI and CT machines. Based on these findings, it is pertinent to conduct further research to investigate the potential vulnerability of other rural populations and their access to radiologic resources.

Funding/Support: None declared.

Financial Disclosures: None declared.

REFERENCES

1. Rural health. US Food and Drug Administration. Published June 22, 2021. Archived May 25, 2024. Accessed May 16, 2024. https://web.archive.org/web/20240525213517/https://www.fda.gov/consumers/minority-health-and-health-equity-resources/rural-health

2. About rural health. Centers for Disease Prevention and Control. Updated May 16, 2024. Accessed May 16, 2024. https://www.cdc.gov/rural-health/php/about/index.html

3. Nation's urban and rural populations shift following 2020 Census. United States Census Bureau. Revised April 4, 2024. Accessed May 16, 2024. https://www.census.gov/newsroom/press-releases/2022/urban-rural-populations.html

4. Urban and rural. United States Census Bureau. Revised December 16, 2024. Accessed May 16, 2024. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html

5. Historical CAH Data. Flex Monitoring Team. Updated July 2025. Accessed May 16, 2024. https://www.flexmonitoring.org/historical-cah-data-0

6. Center for Healthcare Quality and Patient Reform. Rural hospitals at risk of closing. Updated June 2025. Accessed May 16, 2024. https://chqpr.org/downloads/Rural_Hospitals_at_Risk_of_Closing.pdf

7. Khaliq AA, Deyo D, Duszak R Jr. The impact of hospital characteristics on the availability of radiology services at critical access hospitals. *J Am Coll Radiol.* 2015;12(12 Pt B):1351-1356. doi:10.1016/j.jacr.2015.09.008

8. Burdorf BT. Comparing magnetic resonance imaging and computed tomography machine accessibility among urban and rural county hospitals. *J Public Health Res.* 2021;11(1):2527. doi:10.4081/jphr.2021.2527

9. Hospital Member Directory. Wisconsin Hospital Association. Updated 2025. Accessed May 18, 2024. https://www.wha.org/AboutWHA/WIHospitals

10. Wisconsin. United States Census Bureau. Updated 2023. Accessed May 18, 2024. https://data.census.gov/profile/Wisconsin?g=040XX00US55

11. WISH: urban and rural counties. Wisconsin Dept of Health Services. Updated April 25, 2024. Accessed May 18, 2024. https://www.dhs.wisconsin.gov/wish/urban-rural.htm

12. Medical technology availability. Organization for Economic Co-operation and Development. Updated 2024. Accessed August 3, 2024. https://data-viewer.oecd.org/?chartId=1b2be263-74ab-498e-9d3b-6bd59bbe37c6

13. Warshaw R. Health disparities affect millions in rural U.S. communities. AAMC. October 31, 2017. Accessed August 5, 2024. https://www.aamc.org/news/health-disparities-affect-millions-rural-us-communities

advancing the art & science of medicine in the midwest

WMJ

WMJ (ISSN 2379-3961) is published through a collaboration between The Medical College of Wisconsin and The University of Wisconsin School of Medicine and Public Health. The mission of *WMJ* is to provide an opportunity to publish original research, case reports, review articles, and essays about current medical and public health issues.

Visit www.wmjonline.org to learn more.