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Differential Access to Breast Magnetic Resonance Imaging Compared with Mammography and Ultrasound

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Introduction: For high-risk women, breast magnetic resonance (MR) is the preferred supplemental imaging option, but spatial access differences may exacerbate disparities in breast care.

Methods: This was a cross-sectional study examining distance between ZIP codes and the nearest breast imaging facility (MR, mammography, ultrasound) using 2023 data from the Food and Drug Administration and the American College of Radiology. Linear regression was used to assess distance differences controlling for Area Deprivation Index (ADI), urbanicity, and population size. Analyses were conducted in 2024.

Results: Among the 29,629 ZIP codes with an ADI and known urbanicity, unadjusted mean distance to breast MR was 23.2±25.1 miles (SD) compared with 8.2±8.3 for mammography and 22.2±25.0 for ultrasound. Hence, the average distance to breast MR facilities was 2.8 times further than to mammography facilities. ADI and urbanicity were associated with increased distance to the nearest breast imaging facility. The additional miles associated with the least advantaged areas compared with most advantaged areas was 12.2 (95%CI: 11.3, 13.2) for MR, 11.5 miles (95%CI: 10.6, 12.3) for ultrasound, and 2.4 (95%CI: 2.1, 2.7) for mammography. Compared with metropolitan areas, the additional miles to breast MR facilities was 23.2 (95%CI: 22.5, 24.0) for small/rural areas.

Conclusions: Spatial access is substantially better for mammography sites compared with breast MR or ultrasound sites. Given these findings, consideration of options to mitigate the impact of differential access should be considered. For example, mammography sites could offer contrast-enhanced mammography. Future research should examine the feasibility and effectiveness of this and other options.

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INTRODUCTION

In order to increase early cancer detection, the American College of Radiology (ACR) first encouraged in 2018 the use of supplemental screening modalities (i.e., advanced imaging tools, including breast magnetic resonance [MR], breast ultrasound, and now contrast-enhanced mammography) in women with elevated risk and/or those with dense breast tissues—approximately one-half of women.[1−5] Currently, reporting requirements to inform women of their breast density vary by state, but the Food and Drug

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Administration (FDA) national reporting requirement will become effective September 10, 2024.[6] While breast MR is the preferred supplemental screening option due to high sensitivity in high-risk women,[1−5] it might not be widely available for all women due to access differences associated with cost and distance. To prevent the widening of existing breast cancer disparities, it is imperative to examine spatial access limitations to breast MR to inform future policies.

Previous studies have shown that, on average, rural residents and individuals with lower socioeconomic status are more likely to be diagnosed with regional or distant (late-stage) breast cancer and have worse outcomes.[7−12] The Area Deprivation Index (ADI) has been employed by various studies to better elucidate its association with delayed diagnosis, more aggressive cancers, survival, and treatment differences for breast cancer.[7,8,12−14] Separate from ADI and other socioeconomic factors, rural versus urban residence is generally associated with lower cancer survival. [15−17] The most deprived areas and/or rural areas are unsurprisingly associated with lower cancer screening rates including breast cancer screening.[18−20] A recent systematic review noted that disentangling the roles of socioeconomic factors and urbanicity is needed.[15]

The primary aim of this study was to examine the relative distance to breast imaging facilities with MR compared to facilities offering mammography or ultrasound. Access to advanced imaging modalities is critical for breast cancer outcomes, so better understanding how more local facilities could be harnessed to provide these services is necessary. This study examined for each modality the association of socioeconomic status (as measured by the ADI) and urbanicity with distance to breast imaging facilities to quantify their relationship with distance-related screening access to breast imaging.

METHODS

Study Sample

This retrospective, cross-sectional study was based on deidentified and publicly available data. As such, there was no requirement for IRB approval. This study used the STROBE guidelines for reporting observational studies.[21]

The ZIP code served as the unit of analysis. For each ZIP code, the distance (i.e., spatial access) to each ZIP code with an accredited breast imaging facility was computed. The distance to the ZIP code of the nearest facility was used. Hence, this distance is used as a proxy for the distance from patient residence to nearest breast imaging facility. This was done for MR, mammography, and ultrasound facilities in the 50 states plus the District of Columbia and Puerto Rico.

Measures

Data from the FDA and the ACR were used to identify all accredited breast imaging facilities. The FDA data identify Mammography Quality Standards Act (MQSA)-certified mammography facilities (FDA-certified facilities) as of October 4, 2023.[22] There were 8,836 FDA-certified facilities across 5,942 unique ZIP codes. ACR accreditation data were used to identify all accredited breast imaging programs as of September 11, 2023.[23] ACR is an FDA-approved accreditation body and its accreditation types include mammography, breast MR, and breast ultrasound. There were 8,582 mammography, 2,125 breast MR, and 2,549 breast ultrasound accredited programs, which mapped to 5,768, 1,724, and 1,998 unique ZIP codes, respectively. There was substantial overlap between FDA-certified and ACR-accredited mammography facilities with a few facilities only in the FDA data or only in the ACR data. Preliminary analysis showed substantially similar results from either data source (not presented); therefore, for the final analysis, this study combined the FDA and ACR data for mammography facilities to provide greater reliability of the estimates. These combined data are referred to as accredited mammography facilities of which there were 8,937, which mapped to 6,000 unique ZIP codes.

The dependent variable was the distance to the nearest breast imaging facility. Using the latitude and longitude of ZIP code centroids, the arc distance (i.e., the shortest distance between 2 points on the spherical global) in miles was computed between all ZIP codes and ZIP codes with accredited breast imaging programs by modality. For each ZIP code, the distance to the nearest ZIP code with an accredited program was used. For ZIP codes that include an accredited program with a particular modality, the distance to that program is zero miles. Excel was used to compute the arc distance to the nearest imaging facility by imaging type using the formula for spherical distance (Microsoft).

The independent variables were ADI, urbanicity, and population size. The 2021 ADI was used for relative socioeconomic advantage by ZIP code.[24] The ADI values are national percentiles from most advantaged (1st) to least advantaged (100th) neighborhoods. The ADI is based on 5 years of the American Community Survey data (2017−2021) and incorporates 17 socioeconomic measures across income, education, employment, and housing quality.[24−26] The median ADI percentile for all neighborhoods in a ZIP code was used to approximate ADI at the ZIP code level. As ADI is based on the American Community Survey, only ZIP codes included in that survey have an ADI.

The urbanicity (metropolitan and commuting area [metropolitan], micropolitan and commuting area

Table 1. Descriptive statistics for distance in miles to the nearest accredited facility

Variable	Breast MR, mean (SD)	Breast ultrasound, mean (SD)	Mammography, mean (SD)
Overall	23.2 (25.1)	22.2 (25.0)	8.2 (8.3)
Urbanicity			
Metropolitan	10.8 (12.7)	10.1 (12.2)	5.3 (5.5)
Micropolitan	30.5 (25.9)	28.8 (24.9)	8.8 (6.5)
Small/rural	43.0 (28.3)	42.1 (29.0)	13.3 (10.6)
ADI quartile			
1st (most advantaged)	6.2 (13.0)	6.0 (12.9)	3.1 (4.3)
2nd	15.1 (22.8)	14.5 (23.2)	6.5 (7.7)
3rd	24.4 (24.6)	23.2 (24.6)	8.9 (8.4)
4th (least advantaged)	32.3 (25.6)	31.1 (25.4)	10.3 (8.5)
Population size quartile			
1st (smallest)	40.1 (28.9)	39.1 (29.0)	14.0 (9.5)
2nd	27.4 (22.6)	26.1 (22.7)	10.8 (7.1)
3rd	18.0 (20.6)	16.9 (20.1)	6.2 (6.3)
4th (largest)	7.6 (13.8)	7.1 (13.7)	1.9 (3.0)

Distance was measured as the distance between ZIP code centroids, n=29,629. There were 2,125 accredited breast MR programs in 1,724 unique ZIP codes, and 2,549 accredited breast ultrasound programs in 1,998 unique ZIP codes. There were 8,937 accredited mammography facilities in 6,000 unique ZIP codes. ADI = Area Deprivation Index.

[micropolitan], small town and commuting area/rural area [small/rural]) of each ZIP code was categorized using the 2010 rural-urban commuting area codes.[27] Similarly, the 2020 U.S. Census data were used for population size by ZIP code,[28] which this study categorized in quartiles across all ZIP codes from the smallest (1st quartile) to largest (4th quartile) population (1st, 2nd, 3rd, 4th, unknown). The study was limited to ZIP codes with an ADI percentile with known urbanicity.

Statistical Analysis

Multivariable linear regression with bootstrapped standard errors (with 100 replicates) was used to assess the distance in miles to the nearest accredited breast imaging facility using ADI, urbanicity, and population size covariates. This statistical analysis was performed separately for MR, ultrasound, and mammography. As the association with ADI and distance may differ by urbanicity, these regression analysis for each facility type were stratified by urbanicity while controlling for population size. Using the estimates from the regression model, this study estimated by population quartile the distance to the nearest breast imaging facility for the median ADI. The variance inflation factor was used to check for collinearity. Statistical significance was assessed at α=0.05. All statistical analyses were performed with Stata 18 (StataCorp). Analyses were conducted in 2024.

RESULTS

In 2023, there were 41,704 U.S. Zip codes.[29] There were 29,635 ZIP codes (71.1%) with ADI data and 41,164 (98.7%) with urbanicity data. From the ZIP codes with ADI, 6 were excluded due to missing urbanicity. Hence, there were 29,629 ZIP codes with both ADI and urbanicity data.

The unadjusted (i.e., not controlling for other covariates) mean distance in miles to the nearest accredited program was 23.2±25.1 (SD) for breast MR, 22.2±25.0 for breast ultrasound, and 8.2±8.3 for mammography (Table 1). Hence, the mean distance was 65% less to mammography than MR facilities ($p<0.001$) and comparable between ultrasound and MR facilities (ultrasound 4% less, $p<0.001$). Mean distances varied by urbanicity, ADI, and population size. For example, by urbanicity, the mean distance to breast MR was 10.8±12.7 and 43.0±28.3 miles for metropolitan and small/rural, respectively. The like figures for mammography were 5.3±5.5 miles for metropolitan and 13.3±10.6 miles for small/rural.

Unadjusted mean distance in miles similarly increased with ADI quartiles from the most advantaged quartile (6.2±13.0) to the least advantaged quartile (32.3±25.6) for breast MR facilities with smaller distances for mammography: 3.1±4.3 and 10.3±8.5, respectively (Table 1). Similarly, unadjusted distance by population size decreased from 40.1±28.9 miles for areas in the smallest population quartile to 7.6±13.8 for areas in the largest population quartile for breast MR facilities. The pattern was similarly decreasing for the other modalities, with a similar magnitude for ultrasound but less for mammography (Table 1). The spatial distribution of mammography, ultrasound, and MR was described in Figure 1 and Appendix Table 1.

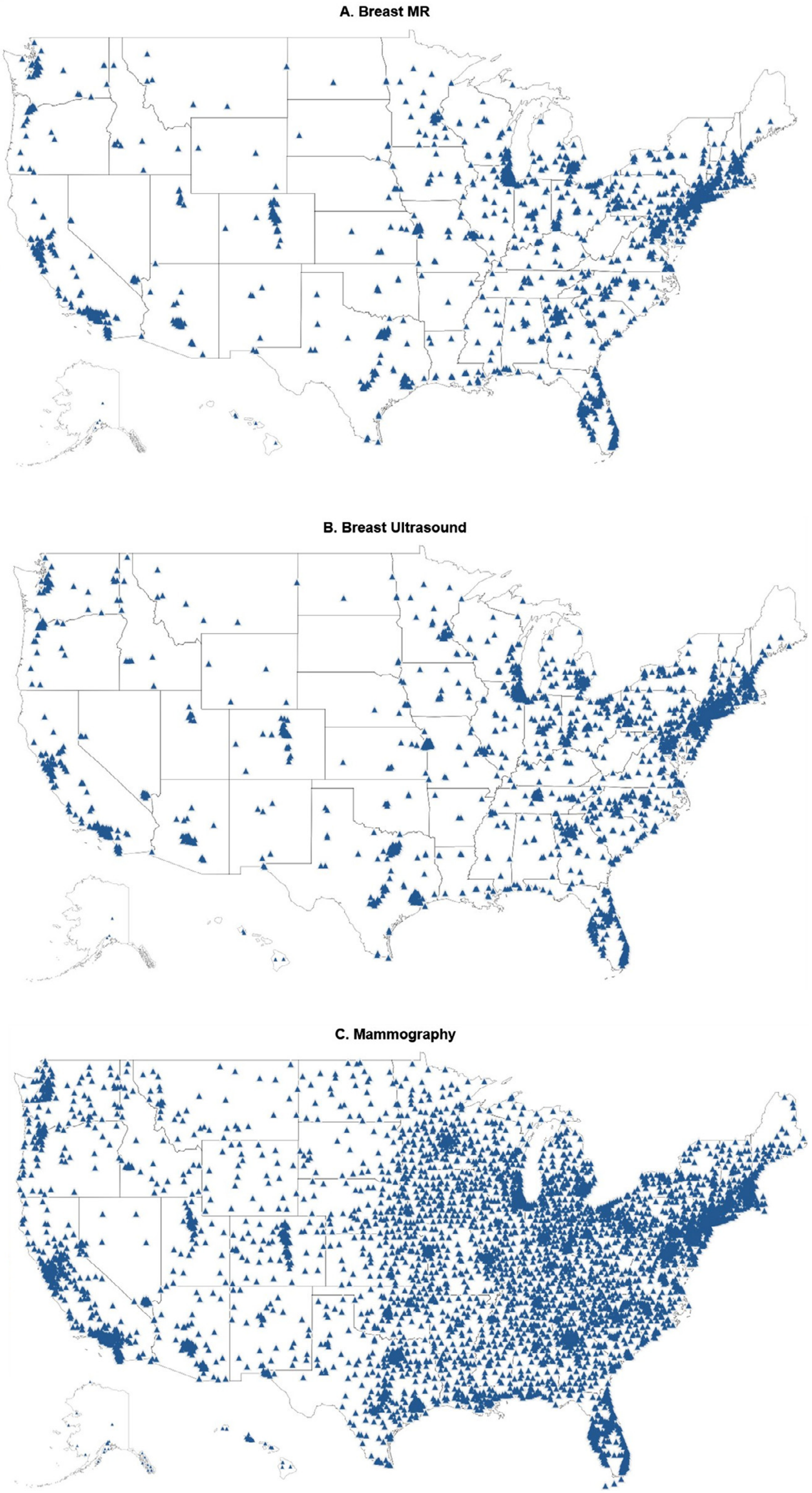

Figure 1. Accredited mammography, breast MR, and breast ultrasound programs.
Note: MR = magnetic resonance.

Table 2. Linear regression results for distance (miles) to nearest accredited facility, by facility type

Variables	Breast MR, coefficient (95% CI)	Breast ultrasound, coefficient (95% CI)	Mammography, coefficient (95% CI)
ADI (10 percentiles)	**1.22** (1.13, 1.32)	**1.15** (1.06, 1.23)	**0.24** (0.21, 0.27)
Urbanicity (ref: metropolitan)			
Micropolitan	**13.66** (12.76, 14.56)	**12.98** (12.04, 13.91)	**0.60** (0.39, 0.82)
Small/rural	**23.24** (22.51, 23.97)	**23.43** (22.82, 24.08)	**3.52** (3.27, 3.76)
Pop. quartile (ref: 1st, smallest)			
2nd	**-8.63** (-9.39, -7.87)	**-8.80** (-9.56, -8.04)	**-2.61** (-2.87, -2.35)
3rd	**-12.52** (-13.26, -11.77)	**-12.71** (-13.41, -12.01)	**-6.45** (-6.71, -6.19)
4th, largest	**-15.87** (-16.56, -15.18)	**-15.40** (-16.02, -14.79)	**-9.56** (-9.79, -9.33)
Unknown	**-12.87** (-14.99, -10.75)	**-13.19** (-15.31, -11.07)	**-6.05** (-7.22, -4.88)
Constant	**16.19** (15.40, 16.99)	**15.71** (14.97, 16.45)	**10.30** (10.00, 10.59)

Note: Boldface indicates statistical significance (p<0.05). ADI = Area Deprivation Index.

The multivariable linear regression analyses controlling for urbanicity and population size showed that adjusted distance increased 1.22 (95%CI: 1.13, 1.32) miles for every 10-percentile increase in the ADI (becoming less advantaged) for breast MR facilities with a similar magnitude for ultrasound: 1.15 (95%CI: 1.06, 1.23) miles. In contrast, the like figure for mammography facilities was 0.24 (95%CI: 0.21, 0.27) miles. Hence, the difference between the most and least advantaged areas (percentiles) was 12.2, 11.5, and 2.4 miles for MR, ultrasound, and mammography, respectively (Table 2).

When the linear regression analyses were stratified by both modality and urbanicity while controlling for population size, the results show different patterns for ADI distance association across metropolitan, micropolitan, and small/rural areas (Table 3 and Appendix Figure 1). For metropolitan areas, distance in miles to breast MR increased 1.29 (95%CI: 1.23, 1.35) for each decile increase in the ADI. The like figures were 1.02 (95%CI: 0.96, 1.08) for ultrasound and 0.36 (95%CI: 0.34, 0.39) for mammography. Hence, the association of ADI and distance was about one-third for mammography what it was for MR. For small/rural areas, this pattern was similar but more pronounced than for metropolitan areas: 1.46 (95%CI: 1.16, 1.76) miles for MR and 1.91 (95%CI: 1.60, 2.21) miles for ultrasound while not statistically different for mammography, -0.03 (95%CI: -0.13, 0.07) miles.

While urbanicity and population size were correlated (ρ=-0.42, variance inflation factor = 1.29), they were not collinear. The statistical analyses showed that for the lowest population quartile, the average distance in miles to a MR facility was 20.3 (95%CI: 19.6, 21.0) for metropolitan, 36.6 (95%CI: 34.9, 38.4) for micropolitan, and

Table 3. Linear regression results for increased miles to nearest imaging facility for a 10-percentile-ADI increase

Urbanicity	Breast MR, coefficient (95% CI)	Breast ultrasound, coefficient (95% CI)	Mammography, coefficient (95% CI)
Metropolitan	**1.29** (1.23, 1.35)	**1.02** (0.96, 1.08)	**0.36** (0.34, 0.39)
Micropolitan	0.11 (-0.38, 0.60)	0.49 (0.01, 0.97)	0.08 (-0.03, 0.19)
Small/rural	**1.46** (1.16, 1.76)	**1.91** (1.60, 2.21)	-0.003 (-0.13, 0.07)

Note: Boldface indicates statistical significance (p<0.05). The ADI coefficient was specific to separate linear regressions for samples stratified by both facility type and urbanicity. All regressions control for population size quartile. Coefficients for population size and intercept are not shown. ADI = Area Deprivation Index.

46.4 (95%CI: 45.3, 47.5) for small/rural. Distances were similarly increasing for miles to a mammography facility but of a lower magnitude: 10.1 (95%CI: 9.8, 10.5) miles for metropolitan, 12.0 (95%CI: 11.6, 12.4) miles for micropolitan, and 16.3 (95%CI: 15.9, 16.7) miles for small/rural (Appendix Figure 2).

For the highest population quartile, there were significant differences in distance across levels of urbanicity for breast MR (6.0 miles [95%CI: 5.8, 6.2] for metropolitan and 21.8 miles [95%CI: 19.4, 24.1] for small/rural) and ultrasound (5.6 miles [95%CI: 5.4, 5.8] for metropolitan and 19.6 miles [95%CI: 16.8, 22.4] for small/rural) (Appendix Figure 2). In contrast, there were no significant differences between metropolitan (2.2 miles, 95%CI: 2.1, 2.2) and small/rural (1.9 miles, 95%CI: 0.9, 2.9) for mammography. Generally, distance decreased across increasing population quartiles for all modalities and for metropolitan and small/rural areas (i.e., 20.3 miles [95%CI: 19.6, 21.0] for the lowest quartile compared with 6.0 miles [95%CI: 5.8, 6.2] for the highest quartile) for breast MR. However, for micropolitan areas specifically, distance to advanced breast imaging was highest for areas in the lowest population size quartile, but there was not a meaningful distance difference across the remaining three population size quartiles. (Appendix Figure 2).

DISCUSSION

This study found that the average distance to ZIP codes with breast MR facilities was 2.8 times further than to mammography facilities, and the distance to ultrasound and MR were comparable. There was also a substantial urban/non-urban difference in distance to breast imaging facilities with MR or ultrasound, whereas for areas in the highest population quartile, there was no urban/non-urban distance difference to mammography facilities. Compared to the most advantaged areas as measured by the ADI, the additional distance from the least advantaged areas to ZIP codes with the nearest facility was substantially higher for breast MR and ultrasound (12.2 and 11.5 miles, respectively) than for mammography (2.4 miles).

New guidelines suggest that breast MR can be recommended for the approximate 50% of women with dense breasts (a known risk factor for breast cancer).[2−5] When breast MR is not available or contraindicated, breast ultrasound and/or contrast-enhanced mammography have been recommended as supplemental imaging techniques. While breast ultrasound is an alternative to breast MR, the results indicate that it is similarly distant from patients as breast MR. From an equity perspective, it is desirable to have no distance differences, but that is economically unrealistic, as economic factors have been shown to drive access differences for breast imaging.[30,31] Specifically, economics are unlikely to support bringing MR screening equally close (in terms of eliminating differences by ADI and urbanicity) to all women who qualify for it. Given this reality, other options to mitigate the impact of these differences on outcomes need to be pursued.

To this end, contrast-enhanced mammography can be offered as an add-on technology at facilities with existing mammography capabilities using the same equipment at costs substantially less than the costs associated with breast MR. As with all new technologies, some training would be required and radiologist engagement is needed to oversee the administration of contrast agents.[2,3] While this approach would not solve differences in breast MR access, it has the potential to mitigate the more important outcome differences, such as mortality disparities, to the degree that contrast-enhanced mammography has been shown to have comparable diagnostic performance to breast MR.[2,3,5,32] While expansion of contrast-enhanced mammography at existing mammography facilities may lessen disparities associated by distance, it is not the only option. Other options may include education and transportation support, but the costs and benefits of each option need to be considered. Future study should explore the feasibility and impact of alternatives.

Given the association of ADI and urbanicity, understanding the individual contributions of each is needed. The present study accomplished that objective by statistically estimating the separate contribution of ADI and urbanicity as it relates to distance access to breast imaging facilities. The results show that ADI and urbanicity both matter for distance, but urbanicity has the larger impact, consistent with prior research that found median travel times to breast imaging facilities were 4-8-fold longer for rural than urban residents.[33] For urbanicity, the results show significant distance differences comparing metropolitan ZIP codes to both small/rural ZIP codes and, to a lesser extent, micropolitan ZIP codes. Such distance differences may contribute to disparities associated with rural residence, including lower screening rates, more late-stage breast cancer diagnoses, and lower cancer survival. Specifically, a systematic review found that rural residence was associated with 19% higher odds of late-stage breast cancer than urban residence.[34] Subsequent research has similarly shown that rural-urban differences in late-stage diagnosis persist.[10,17] Given that consistent breast screening is likely to detect cancers earlier, such rural-urban differences in late-stage breast cancer have been attributed to lower screening utilization in rural vs urban areas.[18,35,36] Ultimately, the combined effect of lower screening rates and greater odds of late-stage cancers for rural residents yields a higher mortality rate for rural residents compared with urban residents.[16,17] Note that eliminating screening differences across urbanicity will likely not eliminate mortality differences as disparities in timely treatment and access to treatment likely have an impact as well. Future research should explore these issues.

As measured by the ADI, this study found a small distance difference to mammography facilities compared with the large distance difference for MR between the most and least advantaged areas. Note that these distance differences may still underrepresent the true access gap for less advantaged areas given that transportation times vary depending on the patient's transportation mode. For example, an Atlanta-based study found that the median public versus private transportation times were 51 and 6 minutes, respectively.[37] Not surprisingly, longer travel times are associated with lower adherence to screenings and such spatial access challenges are larger in majority non-Hispanic Black populations.[37−39] Further, the findings relative to ADI expand on previous studies, which found that the most advantaged areas (top 3 percentiles) had greater access to breast imaging facilities[40] and advanced imaging facilities generally[41] than the least advantaged areas (bottom 3 percentiles). This study expands on the literature to show the association of ADI with distance across the entire ADI spectrum and to understand the interaction between ADI and urbanicity.

Limitations

This study has limitations. First, distance between ZIP codes was estimated using 5-digit rather than the more granular 9-digit ZIP codes; there may be differences at the 9-digit ZIP code level. Hence, it is only a proxy for the distance between ZIP codes and ZIP codes with imaging facilities. Second, this distance is the arc distance. It is highly correlated with, but not the same as drive time.[42] Third, the study does not include ZIP codes not covered by the American Community Survey, upon which the ADI is based. Generally, these are ZIP codes assigned to post office boxes and business or industrial districts.[24] Fourth, distance is one measure of access. Other measures of access include insurance coverage, cultural factors, availability of examination slots, late clinic hours, or weekend hours. It is possible that spatially closer clinics are deficient in such ways. The study data do not include these variables, which should be considered for future studies. Fifth, ADI data are reported at the 9-digit ZIP code level. Hence, using the median of these ADI values for the ADI of the 5-digit ZIP code limits the granularity for estimating the impact of ADI on distance. Finally, while all mammography facilities are required to be certified, there is no such requirement for breast MR or ultrasound facilities; hence, uncertified facilities are not represented in our data.

CONCLUSIONS

This study found that the average distance from ZIP codes to the nearest ZIP code with a facility offering advanced breast imaging techniques is much farther compared with mammography facilities. In addition to distance differences by facility type, there are marginal distance differences for both ADI and urbanicity, such that distance is farther for less advantaged and rural areas, and these differences are larger for urbanicity than ADI. Given these findings, consideration of options to mitigate the impact of differential access should be considered. For example, mammography sites could offer contrast-enhanced mammography as an alternative screening option to mitigate the more important breast cancer outcome disparities for women with elevated breast cancer risk and/or dense breast tissue who live far from breast MR facilities. Future research should examine the feasibility and effectiveness of this and other options for mitigating disparities.

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SUPPLEMENTAL MATERIAL

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