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Original article

Geographic access to mammography facilities and frequency of mammography screening

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A R T I C L E I N F O

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A B S T R A C T

Purpose: To assess the association between geographic access to mammography facilities and women's mammography utilization frequency.
Methods: Using data from the population-based 1995–2007 Wisconsin Women's Health study, we used proportional odds and logistic regression to test whether driving times to mammography facilities and the number of mammography facilities within 10 km of women's homes were associated with mammography frequency among women aged 50–74 years and whether associations differed between Rural-Urban Commuting Areas and income and education groups.
Results: We found evidence for nonlinear relationships between geographic access and mammography utilization (nonlinear effects of driving times and facility density, *P*-values .01 and .005, respectively). Having at least one nearby mammography facility was associated with greater mammography frequency among urban women (1 vs. 0 facilities, odds ratio 1.26, 95% confidence interval, 1.09–1.47), with similar effects among rural women. Adding more facilities had decreasing marginal effects. Long driving times tended to be associated with lower mammography frequency. We found no effect modification by income, education, or urbanicity. In rural settings, mammography nonuse was higher, facility density smaller, and driving times to facilities were longer.
Conclusions: Having at least one mammography facility near one's home may increase mammography utilization, with decreasing effects per each additional facility.

Introduction

While there has been a recent controversy about benefits and harms, optimal starting age and frequency of mammography screening [1–3], there is broad consensus that mammography screening can detect breast cancer early and reduce mortality [4]. Specific breast cancer screening recommendations have changed over time, but for women aged 50–74 years, mammography screening every 1–2 years has been consistently recommended since the 1980s [5–7]. Screening uptake varies by social characteristics; for example, racial minorities and low-socioeconomic status women use mammography screening less often than white, middle-class women [8,9].

Since the 1990s, mammography utilization appears to have plateaued or even decreased [10,11]. At the same time, there was a decrease in the number of mammography facilities, potentially reducing geographic access to mammography services [12]. Urban sprawl and limited public transportation make most Americans dependent on personal vehicle use [13,14]. Among lowest income

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groups in the United States, there is a disproportionate number of households without a car [15]. Social gradients in geographic and transportation access have been recognized as determinants of health care utilization and may reinforce existing social disparities in mammography utilization [16,17].

In this analysis, we aimed to assess how driving times and geographic availability of mammography facilities relate to frequency of mammography screening among women without breast cancer and whether these associations differ between rural and urban settings. We hypothesized that decreased geographic access would be related to lower frequency of mammography screening use, and that this relationship would be strongest for low-income and low-education groups. We additionally hypothesized that long driving times and fewer geographically available mammography facilities would impact rural more than urban populations.

Materials and methods

Study population

The Wisconsin Women's Health Study was a series of population-based case-control studies at the University of Wisconsin. Women with a history of breast cancer were the cases and women without were the controls [18]. We only included controls in this analysis because our outcome was mammography screening frequency before any breast cancer diagnosis. We obtained informed consent from study participants, and the University of Wisconsin Health Sciences Institutional Review Board approved the study.

Subject eligibility has been described in detail elsewhere [18–21]. A 70.2% of eligible Wisconsin participants enrolled in the study. Briefly, women randomly selected from lists of licensed drivers were eligible to participate as controls if they had no personal history of breast cancer, had a listed telephone number, and if they were able to complete a standardized telephone interview. We restricted our analysis to women aged 50–74 years at baseline who participated between 1995 and 2007 because screening recommendations existed for this age group consistently during the study period and because we had access to data on mammography facilities since 1995. During recruitment, not all questionnaire versions contained questions on income. Income is likely a confounder of geographic access in relation to mammography use. To avoid potential misclassification for a large number of participants, we excluded women who were not asked about income at baseline ($n = 1184$) rather than imputing these incomes.

Six thousand seventy-five women were eligible for our analysis. Of these, we excluded 145 women (2.4%) because of missing data on mammography use. Comparing these women with the women in the final sample, excluded women were more likely to be postmenopausal (95% vs. 87%), less likely to have used postmenopausal hormones (24% vs. 47%), less likely to have a family history of breast cancer (13% vs. 16%), less likely to be white (93% vs. 96%), and more likely to have missing data across all variables (data not shown).

Data collection

In telephone interviews, we collected information on family history of breast cancer, frequency of mammography screening, postmenopausal hormone use, race, education, income, and household size. Information on the number and locations of mammography facilities between 1995 and 2007 was obtained from the US Food and Drug Administration, which has maintained administrative records on certified mammography facilities in the United States since 1994 [22]. Although all participants lived in Wisconsin, we accounted for mammography facilities in adjacent states close to the Wisconsin border because some participants may have traveled to surrounding states for screening.

Measures

The outcome in our analytical models was mammography frequency, measured as the self-reported number of screening mammograms in the past 5 years translated into an annual frequency. Primary exposures were driving times to nearby mammography facilities and the number of mammography facilities near a woman's home. Driving times were measured as the shortest driving time to a mammography facility near a woman's home and were determined in two steps: using ArcGIS 10.0 Generate Near Table functionality, for each woman we identified the two closest (Euclidean distance) certified mammography facilities in the year of her study participation. Afterward, we used the Google Maps Distance Matrix application program interface via the R-package httr [23] to determine for which of the two facilities driving time was the shortest. Google Maps Distance Matrix application program interface limits the number of requests to 2500 per 24 hours. Therefore, driving times were calculated over 10 week days, each day around the same time to make traffic conditions comparable. Mammography facility density was defined as the number of certified mammography facilities within a 10-km radius around each woman's residential address in the year of her participation and estimated using ArcGIS 10.0 buffer/intersect functionalities.

We used DAGitty [24] to draw our conceptual model as a directed acyclic graph (DAG) (Fig. 1) to decide which covariates to include in our analysis. DAGs are depictions of researchers' beliefs to qualitatively explain outcomes by potential determinants [25]. If a DAG correctly depicts the relationships, it identifies confounders and mediators, that is, which variables to include and exclude from statistical models. Based on our DAG, we chose two confounder models. One included the minimal sufficient adjustment set for estimating the total effects of our exposures, which would sufficiently control for confounding if our DAG correctly identified all relationships. The minimal sufficient adjustment set included family income, persons per household, education, race, and mammography capacity, that is, the number of mammography machines available per 10,000 women aged 40 years and older in a county. The second model additionally adjusted for age, family history, and indicators of neighborhood deprivation by Census Tract: population fraction below the poverty line, median 1999 income, population fraction without a vehicle, population fraction without a high school degree and with at least a college degree; and by county: the population fraction without health insurance. Data on health insurance were only collected for a minority of participants and therefore not included in our main models, but only in our sensitivity analyses.

Geospatial analysis

Methods for geocoding have been described elsewhere [22,26]. Each participant was assigned a corresponding 2000 Census Tracts, county, and Rural-Urban Commuting Area (RUCA) code [27]. Mammography facilities were geocoded by street address, using ArcGIS software (version 9.2, ESRI, Redlands, CA). Mobile mammography facilities were assigned to the county of their mailing address [22]. To describe regional patterns, we fit a semivariogram model and a kriging interpolation of mammography utilization frequency in Wisconsin using the R packages sp, gstat, spatstat, maps, and geoR [28–32]. Using the R jitter() function [33], we jittered the coordinates of 24 randomly selected participants of 48 participants who had duplicate geocoordinates due to rounding.

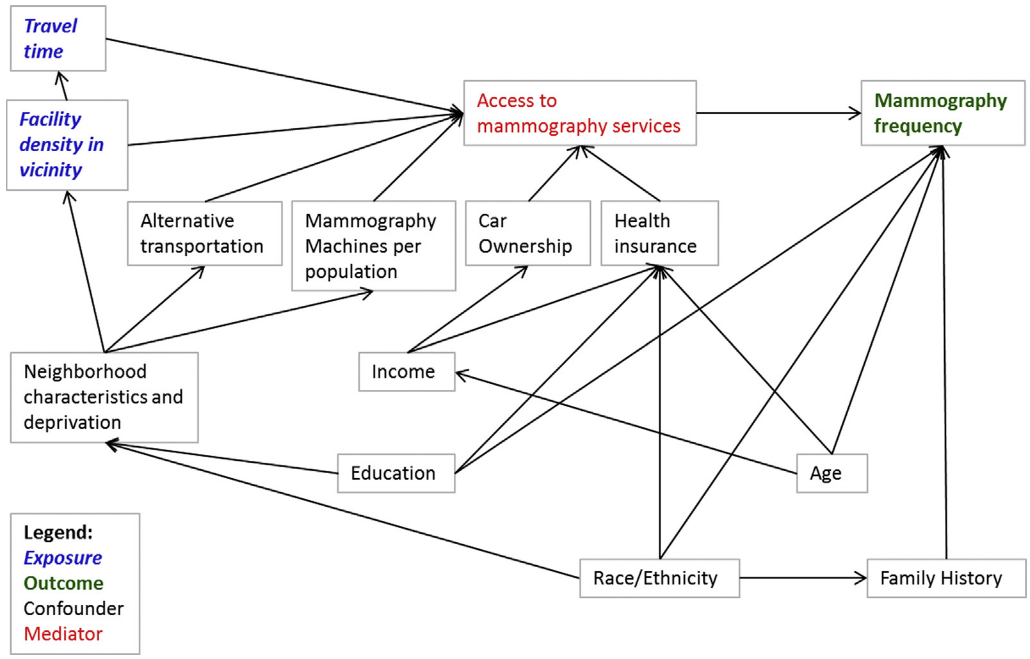

Fig. 1. Directed acyclic graph of the associations between driving time and mammography facility density within residential neighborhood and frequency of mammography screening use.

Statistical analysis

We excluded women with missing outcome data but used multiple imputation (five data sets) in the SAS MI procedure [34] to impute missing main exposure and confounder values, that is, education (16 missing), race (28 missing), family history (130 missing), and income (660 missing), and in the case of 38 women who could not be geocoded: driving time and facility density and their Census Tract and County level confounders.

To test the associations of driving time and mammography facility density with mammography frequency, we used ordered multinomial regression (proportional odds model) in the SAS 9.3 GLIMMIX and MIANALYZE procedures [35,36]. We ran the regressions as multilevel models, grouping participants by residential 2000 Census Tracts to account for potential neighborhood clustering. We tested for nonlinear relationships between our main exposures and the outcome by including cubic splines of driving time and facility density. Splines can capture nonlinear effects that are not easily captured by polynomials. We tested for interaction between our main exposures and RUCA codes, income, and education levels, and reran the final model stratified by these same variables. In addition, we ran a logistic regression, modeling the odds of a mammography frequency greater or equal to 0.5 (equivalent to at least one mammogram in two years) compared to a frequency below 0.5. Model selection was carried out on the proportional odds model; only the final model was also run as logistic regression.

Results

Table 1 shows selected characteristics at baseline of the study population. Most participants were non-Hispanic white. When comparing women reporting no screening in the past 5 years (nonusers) to women reporting at least annual mammography screening, nonusers had fewer mammography facilities near their homes, were less likely to be white, to have a family history of breast cancer, to have gone through menopause, and to have used postmenopausal hormones, and they had lower income and education levels. The proportion of women from rural areas was similar in all utilization groups, except for nonusers, which were disproportionally rural (χ^2 test, $P < .0001$). Table 2 summarizes the distribution of driving times and facility densities in rural versus urban settings. Urban women had more facilities near their homes and shorter driving times. Almost half (48%) of rural women had no facility within a 10-km radius around their home.

The heat map from our kriging analysis in Figure 2 visualizes average utilization patterns in Wisconsin. Utilization above average is shaded in blue and below average in red. Utilization is consistently above average where many facilities are regionally clustered, especially in large urban areas (Milwaukee, Madison, and Green Bay) and below average where facility density is sparse.

Odds ratios (ORs) of more frequent mammography utilization from the proportional odds models are shown in Table 3, with results from both the minimal adjustment set model and the model with more potential confounders. Nonlinear effects of driving time and facility density were significant in both models (nonlinear effects of driving time, P-values .003 and .01, respectively; nonlinear effects of facility density, P-values .003 and .005, respectively). After stratifying the model with more confounders by urban versus rural RUCA codes, driving time remained significant among rural women (nonlinear effects of driving time, P-value .02), and facility density remained significant among urban women (nonlinear effects of facility density, P-value .005). Interactions of the main exposures with urban versus rural RUCA codes and with income and education were not significant.

The final model included more potential confounders beyond the minimal adjustment set, nonlinear effects of the main exposures, no interaction terms, and was stratified by urban versus rural RUCA codes. Among urban women, having one mammography facility within a 10-km radius was associated with more frequent mammography utilization (1 vs. 0 facilities, OR 1.26, 95% confidence interval [CI], 1.08–1.47). More facilities increased the odds of more frequent screening, but the effect decreased with each added facility and became insignificant with 2–3 nearby facilities (2 vs. 1

Table 1
Baseline characteristics of participants by mammography screening frequency, (n = 5930), Wisconsin Women's Health Study, 1995–2007

Characteristics	Annual frequency of mammography screening					*P*
	Total	0 times	<0.5 times	0.5–0.9 times	≥1 times	
	% (n = 5930)	% (n = 596)	% (n = 968)	% (n = 894)	% (n = 3472)	
Age, y						
50–59	49.9	46.8	50.5	55.6	48.8	
60–69	47.0	48.2	45.4	40.2	49.0	
≥70	3.1	5.0	4.1	4.3	2.1	<.00001
Driving time to closest mammography facility, min						
<5	27.4	27.5	27.5	25.6	27.8	
5–10	31.7	30.2	31.2	31.8	32.1	
11–20	29.7	29.7	28.8	30.8	29.6	
>20	11.2	12.6	12.5	11.9	10.4	.61
Number of mammography facilities within a 10-km radius, N						
0	28.1	31.0	31.6	28.6	26.4	
1–2	29.8	33.4	28.5	29.6	29.5	
3	7.8	6.5	7.2	6.3	8.6	
>3	34.4	29.0	32.6	35.5	35.5	.0014
Number of mammography machines per 10,000 women aged 40+ years in county, N						
0–1	24.6	29.2	26.0	26.0	23.0	
2–3	42.9	43.3	42.4	42.8	43.0	
>3	32.5	27.5	31.6	31.2	34.0	.0070
Race/ethnicity						
White, non-Hispanic	95.8	94.3	95.1	94.7	96.5	
Other	4.2	5.7	4.9	5.3	3.5	.010
Menopausal status						
Premenopausal	14.2	16.4	18.2	18.6	11.6	
Postmenopausal	85.8	83.6	81.8	81.4	88.4	<.00001
Family history of breast cancer						
Yes	16.4	12.2	13.8	15.0	18.1	
No	83.6	87.8	86.2	85.0	81.9	.000098
Postmenopausal hormone use						
Never	53.1	84.9	70.7	57.6	41.6	
Ever	46.9	15.1	29.3	42.4	58.4	<.00001
Family income						
≤$30,000	33.0	53.5	41.4	32.0	27.4	
$30,001–50,000	30.2	25.8	29.2	29.1	31.5	
$50,001–100,000	27.9	16.9	24.4	27.3	30.8	
>$100,000	8.9	3.7	5.0	11.6	10.2	<.00001
Education						
No high school degree	7.3	15.4	8.4	7.5	5.6	
High school degree	42.8	49.8	42.7	38.9	42.6	
Some college	26.6	23.3	29.0	28.4	26.0	
College degree	23.3	11.4	19.9	25.2	25.8	<.00001
Urbanicity						
Urban	64.2	56.4	62.1	65.2	65.8	
Rural	35.8	43.6	37.9	34.8	34.2	.000063

facility, OR 1.18, 95% CI, 1.05–1.33; 3 vs. 2 facilities, OR 1.06, 95% CI, 1.00–1.12). When comparing the effects of 2 versus 0, 3 versus 0, and 4 versus 0 nearby facilities, the OR were essentially identical, indicating a plateau effect when adding more facilities if there are already one or two facilities in the vicinity. In the rural model, effects of facility density were similar, albeit not statistically significant. Contrary to our hypothesis, driving times of 20 versus 10 minutes were associated with increased odds of more frequent screening among rural women (OR 1.46, 95% CI, 1.09–1.97). There was generally a trend toward decreased ORs with long driving times, but ORs for moderate versus short driving times were inconsistent. OR of having had at least 1 mammogram in two years (logistic regression, Table 4) were close to the OR from the proportional odds model. Estimated effects stratified by income (Q1 vs. higher incomes) and education (no vs. at least college degree) were also similar (Supplemental Tables 1 and 2).

We conducted sensitivity analyses on our final model (data not shown). Although postmenopausal hormone use and marital status were not confounders in our DAG, we reran the final model including an indicator of postmenopausal hormone use and an

Table 2
Distributions of driving times and facility density, urban versus rural, (n = 5930), Wisconsin Women's Health Study, 1995–2007

Main exposures	Minimum	First quartile	Median	Mean	Third quartile	Maximum
Number of mammography facilities within a 10-km radius, N						
Urban	0	1	4	6.9	10	39
Rural	0	0	1	0.8	1	14
Driving time to closest mammography facility, min						
Urban	0.02	4.4	6.9	8.4	11.4	37.4
Rural	0.2	5.8	12.2	13.7	19.7	138.8

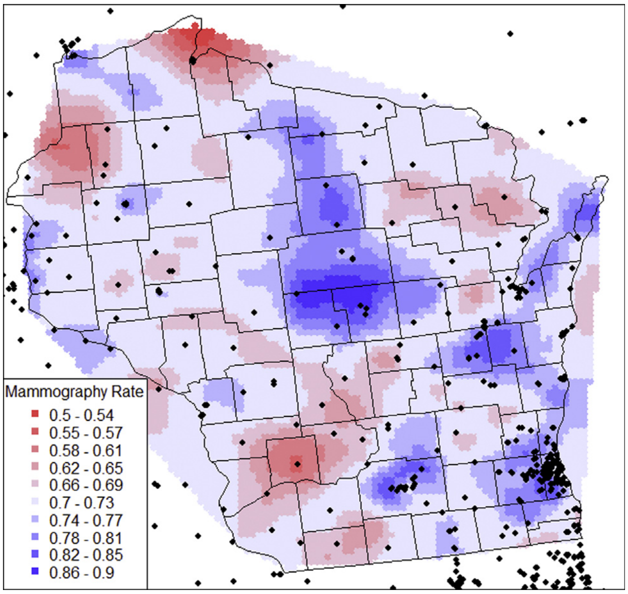

Fig. 2. Estimated spatial pattern of average annual mammography utilization in Wisconsin relative to location of mammography facilities (black points) ($n = 5930$), Wisconsin Women's Health Study, 1995–2007.

indicator of living with a partner. We also reran the final model without imputing missing variables and another version excluding mammography facilities outside Wisconsin. Neither of these changes substantially altered the estimated effects of our main exposures. We reran the final model for a reduced sample of women ($n = 759$) with and without an indicator of having health insurance. Having health insurance slightly attenuated the effect of facility density among urban women (1 vs. 0 facilities while controlling for insurance, OR 1.18, 95% CI, 0.74–1.88, vs. without controlling for health insurance, OR 1.24, 95% CI, 0.78–1.99), but in both model versions, the pattern still indicated increased odds of screening use with higher facility density, with decreasing marginal effects per added facility. Finally, in a model with only linear effects, effects of driving time were not significant, and the OR for driving time and facility density were close to 1.

Discussion

We found that having one or two mammography facilities within a 10-km radius may increase mammography frequency among women without breast cancer, increasing the odds of more frequent utilization by 15%–50%, but adding more than two facilities had decreasing marginal effects. Our kriging interpolation confirmed that mammography utilization was highest where facilities were regionally clustered. With long driving times, there was a tendency toward decreased odds of screening among rural women, but other driving time comparisons were inconsistent. We found no evidence of effect modification of geographic access by income or education or by urbanicity. However, rural women had fewer mammography facilities near their homes and longer driving times to facilities and were more likely to have reported no mammogram in the past 5 years.

Findings from similar studies have been inconsistent. Khan-Gates [37] reviewed articles relating geographic access variables to mammography use. Among those, Meersman et al [38] found reduced odds of a recent mammogram if only 0–1 mammography facilities were located near a woman's home, but the odds of screening hardly changed for 2–10 nearby facilities. We similarly found that higher facility density within a 10-km radius was nonlinearly associated with greater odds of more frequent utilization, without measurable marginal benefits when more than 2–3 facilities were available. This correlation between high facility density and greater utilization frequency was also confirmed by our kriging analysis.

Other studies examined the relationships between driving distance to mammography facilities and utilization. Meersman et al [38] found no association between distance to facilities and mammography utilization; Engleman et al [39] found that with each additional 5 miles of distance, odds of screening use decreased by 3%; Khang found that women living closer to mammography

Table 3
Odds ratios of more frequent mammography screening use by geographic access, ($n = 5930$), Wisconsin Women's Health Study, 1995–2007

Main exposures	Minimal confounder model*, nonlinear effects, urban	Minimal confounder model*, nonlinear effects, rural	Full confounder model†, nonlinear effects, urban	Full confounder model†, nonlinear effects, rural
	OR (95% CI)			
Driving time				
Marginal effects				
20 versus 10 min	1.09 (0.77–1.54)	**1.39 (1.03–1.87)**	1.09 (0.77–1.55)	**1.46 (1.09–1.97)**
30 versus 20 min	0.64 (0.37–1.08)	0.89 (0.76–1.04)	0.64 (0.38–1.09)	0.93 (0.79–1.08)
40 versus 30 min	0.48 (0.20–1.15)	**0.69 (0.53–0.89)**	0.49 (0.20–1.16)	**0.71 (0.54–0.92)**
Short driving times as reference				
30 versus 10 min	0.69 (0.38–1.26)	1.24 (0.86–1.78)	0.70 (0.38–1.28)	1.35 (0.94–1.96)
40 versus 10 min	0.34 (0.09–1.28)	0.85 (0.55–1.31)	0.34 (0.09–1.31)	0.96 (0.61–1.49)
Number of mammography facilities within a 10-km radius				
Marginal effects				
1 versus 0 facilities	**1.22 (1.05–1.42)**	1.17 (0.92–1.49)	**1.26 (1.08–1.47)**	1.21 (0.95–1.53)
2 versus 1 facilities	**1.15 (1.03–1.29)**	1.10 (0.94–1.30)	**1.18 (1.05–1.33)**	1.12 (0.96–1.32)
3 versus 2 facilities	1.05 (0.99–1.11)	1.00 (0.87–1.15)	**1.06 (1.00–1.12)**	1.00 (0.87–1.15)
4 versus 3 facilities	0.98 (0.93–1.02)	0.93 (0.76–1.13)	0.97 (0.92–1.02)	0.92 (0.75–1.12)
No nearby facilities as reference				
2 versus 0 facilities	**1.40 (1.08–1.83)**	1.29 (0.88–1.91)	**1.49 (1.14–1.96)**	1.35 (0.91–2.01)
3 versus 0 facilities	**1.48 (1.07–2.03)**	1.29 (0.84–2.00)	**1.58 (1.15–2.18)**	1.35 (0.87–2.10)
4 versus 0 facilities	**1.44 (1.04–2.00)**	1.20 (0.75–1.91)	**1.53 (1.10–2.13)**	1.24 (0.77–2.00)

CI = confidence interval.
Significant results (95% confidence interval does not include 1.00) indicate in bold.
* Model adjusts for education, income, number of household members, race, and mammography capacity.
† Model adjusts for education, income, number of household members, race, and mammography capacity, age, family history of breast cancer, and indicators of neighborhood deprivation by Census Tract: population fraction below the poverty line, median 1999 income, population fraction without a vehicle, population education levels, population fraction without health insurance (by county).

Table 4
Odds ratios of at least one mammogram in two years by geographic access, (n = 5930), Wisconsin Women's Health Study, 1995–2007

Main exposures	Full confounder model, nonlinear effects, urban	Full confounder model, nonlinear effects, rural
	OR (95% CI)	
Driving time		
Marginal effects		
20 versus 10 min	1.07 (0.71–1.64)	**1.56 (1.10–2.23)**
30 versus 20 min	0.68 (0.35–1.31)	0.94 (0.78–1.14)
40 versus 30 min	0.54 (0.18–1.57)	**0.70 (0.51–0.96)**
Short driving times as reference		
30 versus 10 min	0.73 (0.35–1.51)	1.47 (0.96–2.27)
40 versus 10 min	0.39 (0.08–2.04)	1.03 (0.61–1.75)
Number of mammography facilities within a 10-km radius		
Marginal effects		
1 versus 0 facilities	**1.29 (1.06–1.55)**	1.26 (0.95–1.68)
2 versus 1 facilities	**1.20 (1.04–1.38)**	1.19 (0.98–1.45)
3 versus 2 facilities	1.06 (0.98–1.14)	1.08 (0.90–1.30)
4 versus 3 facilities	0.96 (0.91–1.02)	1.00 (0.78–1.29)
No nearby facilities as reference		
2 versus 0 facilities	**1.54 (1.10–2.15)**	1.51 (0.93–2.43)
3 versus 0 facilities	**1.63 (1.09–2.43)**	1.63 (0.95–2.80)
4 versus 0 facilities	**1.57 (1.04–2.37)**	1.63 (0.90–2.97)

CI = confidence interval.
Significant results (95% confidence interval does not include 1.00) indicate in bold.
Models adjust for education, income, number of household members, race, and mammography capacity, age, family history of breast cancer, and indicators of neighborhood deprivation by Census Tract: population fraction below the poverty line, median 1999 income, population fraction without a vehicle, population education levels, and population fraction without health insurance (by county).

facilities were more likely to complete workup after an abnormal mammogram [16]. Some [40] but not all [41–43] studies have suggested that longer driving distances or driving times may be related to later stage of breast cancer at diagnosis, which is associated with poorer survival. These inconsistent findings parallel our inconclusive results with regard to driving time. We found some evidence of a nonlinear effect of driving times on mammography utilization, and a tendency toward reduced mammography utilization with long driving times among rural women, but inconsistent ORs when comparing moderate to short driving times.

Other studies evaluated the number of mammography machines per population as main exposure. Elkin et al [22] found that in counties with inadequate availability of mammography screening machines, odds of screening use was reduced by 13%–15%. Elting et al [44] found that the presence of a mammography facility in the county was associated with increased odds of mammography utilization. Other studies found no association [45–47]. Included as a confounder in our study, mammography capacity per population was not significantly associated with mammography utilization in our models (data not shown).

A strength of our study is that we allowed for nonlinear effects of our main exposures, which was not done in previous studies we reviewed and may have captured effects more accurately. We found evidence that driving times and facility density were nonlinearly related to mammography utilization, while a strictly linear model did not detect any statistically or clinically significant effects. Our study also has limitations. All women in our study had a driver's license because of the sampling frame, but we had no data on individual car access. Pucher et al [15] showed that owning at least one car per household is common in the United States but becomes less common for lowest income groups. These lowest income groups may be less likely to have participated in our study, which could have prevented us from detecting effect modification by income. Furthermore, women aged 50–74 years may be more likely to have access to a car compared with younger age groups. Mammography is used infrequently, which may make geographic access less relevant compared with other considerations regarding mammography utilization, for example, time off work and child care. We did not include health insurance in our main models. In a sensitivity analysis, including health insurance slightly attenuated but generally confirmed our findings. Our findings cannot be generalized to other medical services. Another limitation in our study is a historic discrepancy between driving times, which we estimated in 2015, and our mammography use measures that we collected during 1995–2007. This could have created nondifferential exposure misclassification, possibly biasing our effect estimates toward the null.

Conclusions

Our analysis emphasizes that relationships can be nonlinear. According to our findings, the availability of one or two mammography facility near women's homes may indeed increase mammography screening utilization, but effects plateau with more than two nearby facilities. While we found no evidence of effect modification by urbanicity, we did find that geographic access to mammography facilities was more restricted in rural than in urban areas, and that mammography utilization was below average where facility density was sparse. From a public health perspective, identifying areas without any nearby mammography facilities may be one means to address underuse and nonuse of mammography services among eligible women, especially in rural areas.

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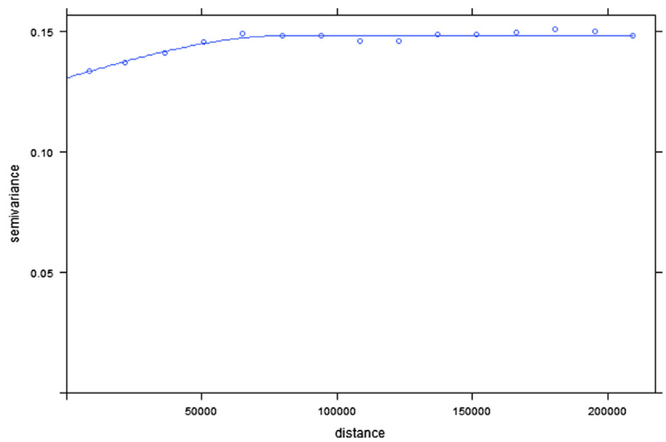
Appendix



Supplemental Fig. 1. Semivariogram of annual mammography utilization in Wisconsin (n = 5930), Wisconsin Women's Health Study, 1995–2007.

Supplemental Table 1
Odds ratios of more frequent mammography screening use by geographic access, stratified by income and education (n = 5930), Wisconsin Women's Health Study, 1995–2007

Main exposures	Annual per capita income ≤ $11,250	Annual per capita income > $11,250	At least college degree	No college degree
	OR (95% CI)			
Driving time				
Marginal effects				
20 versus 10 min	1.28 (0.87–1.90)	**1.25 (1.04–1.62)**	1.04 (0.65–1.66)	**1.27 (1.00–1.62)**
30 versus 20 min	0.76 (0.57–1.03)	0.91 (0.77–1.07)	0.78 (0.60–1.01)	0.91 (0.76–1.08)
40 versus 30 min	**0.58 (0.35–0.97)**	**0.76 (0.60–0.98)**	**0.68 (0.46–1.00)**	0.76 (0.56–1.03)
Short driving times as reference				
30 versus 10 min	0.98 (0.60–1.59)	1.13 (0.81–1.59)	**0.81 (0.44–1.50)**	1.16 (0.86–1.56)
40 versus 10 min	0.43 (0.26–1.22)	0.87 (0.55–1.35)	**0.55 (0.26–1.16)**	0.88 (0.56–1.39)
Number of mammography facilities within a 10-km radius				
Marginal effects				
1 versus 0 facilities	1.15 (0.90–1.48)	**1.23 (1.06–1.42)**	1.15 (0.90–1.48)	**1.21 (1.06–1.38)**
2 versus 1 facilities	1.10 (0.91–1.33)	**1.16 (1.05–1.29)**	1.11 (0.92–1.33)	**1.15 (1.04–1.26)**
3 versus 2 facilities	1.02 (0.93–1.11)	**1.06 (1.00–1.12)**	1.03 (0.94–1.13)	**1.05 (1.00–1.10)**
4 versus 3 facilities	0.96 (0.89–1.04)	0.98 (0.93–1.03)	0.98 (0.90–1.06)	0.97 (0.93–1.02)
No nearby facilities as reference				
2 versus 0 facilities	1.27 (0.82–1.96)	**1.43 (1.11–1.83)**	1.28 (0.82–1.98)	**1.39 (1.10–1.74)**
3 versus 0 facilities	1.29 (0.78–2.15)	**1.51 (1.13–2.03)**	1.31 (0.78–2.21)	**1.45 (1.10–1.90)**
4 versus 0 facilities	1.24 (0.75–2.06)	**1.49 (1.11–1.99)**	1.28 (0.76–2.16)	**1.41 (1.07–1.85)**

CI = confidence interval
Significant results (95% confidence interval does not include 1.00) indicate in bold.

Supplemental Table 2
Odds ratios of at least one mammogram in two years by geographic access, stratified by income and education (n = 5930), Wisconsin Women's Health Study, 1995–2007

Main exposures	Annual per capita income ≤ \$11,250	Annual per capita income > \$11,250	At least college degree	No college degree
	OR (95% CI)			
Driving time				
Marginal effects				
20 versus 10 min	1.33 (0.85–2.09)	1.27 (0.92–1.75)	0.96 (0.52–1.76)	**1.33 (1.01–1.77)**
30 versus 20 min	0.76 (0.55–1.05)	0.96 (0.80–1.16)	0.79 (0.57–1.11)	0.93 (0.77–1.14)
40 versus 30 min	**0.56 (0.32–0.99)**	0.82 (0.62–1.09)	0.72 (0.43–1.20)	0.77 (0.54–1.08)
Short driving times as reference				
30 versus 10 min	1.01 (0.58–1.74)	1.23 (0.81–1.86)	0.76 (0.35–1.67)	1.24 (0.88–1.76)
40 versus 10 min	0.57 (0.24–1.31)	1.01 (0.60–1.70)	0.55 (0.21–1.43)	0.95 (0.57–1.60)
Number of mammography facilities within a 10-km radius				
Marginal effects				
1 versus 0 facilities	1.16 (0.87–1.54)	**1.32 (1.10–1.59)**	1.24 (0.89–1.74)	**1.26 (1.08–1.48)**
2 versus 1 facilities	1.11 (0.90–1.37)	**1.22 (1.07–1.40)**	1.17 (0.91–1.51)	**1.18 (1.05–1.33)**
3 versus 2 facilities	1.03 (0.94–1.14)	**1.07 (1.00–1.15)**	1.06 (0.94–1.21)	**1.06 (1.00–1.12)**
4 versus 3 facilities	0.98 (0.90–1.07)	0.97 (0.91–1.03)	0.98 (0.88–1.11)	0.97 (0.92–1.02)
No nearby facilities as reference				
2 versus 0 facilities	1.29 (0.79–2.12)	**1.61 (1.17–2.22)**	1.46 (0.81–2.62)	**1.49 (1.14–1.97)**
3 versus 0 facilities	1.33 (0.75–2.38)	**1.73 (1.19–2.52)**	1.55 (0.78–3.09)	**1.58 (1.14–2.18)**
4 versus 0 facilities	1.31 (0.74–2.32)	**1.68 (1.15–2.44)**	1.52 (0.76–3.05)	**1.52 (1.10–2.11)**

Significant results (95% confidence interval does not include 1.00) indicate in bold.