Examining the Spatial Varying Effects of Sociodemographic Factors on Adult Cochlear Implantation Using Geographically Weighted Poisson Regression

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Objective: To (i) demonstrate the utility of geographically weighted Poisson regression (GWPR) in describing geographical patterns of adult cochlear implant (CI) incidence in relation to sociodemographic factors in a publicly funded healthcare system, and (ii) compare Poisson regression and GWPR to fit the aforementioned relationship.
Study Design: Retrospective study of provincial CI Program database.
Setting: Academic hospital.
Patients: Adults 18 years or older who received a CI from 2020 to 2021.
Intervention(s): Cochlear implant.
Main Outcome Measure(s): CI incidence based on income level, education attainment, age at implantation, and distance from center, and spatial autocorrelation across census metropolitan areas.
Results: Adult CI incidence varied spatially across Ontario (Moran's $I = 0.04$, $p < 0.05$). Poisson regression demonstrated positive associations between implantation and lower income level (coefficient = 0.0284, $p < 0.05$) and younger age (coefficient = 0.1075, $p < 0.01$), and a negative association with distance to CI center (coefficient = −0.0060, $p < 0.01$). Spatial autocorrelation was significant in Poisson model (Moran's $I = 0.13$, $p < 0.05$). GWPR accounted for spatial differences (Moran's $I = 0.24$, $p < 0.690$), and similar associations to Poisson were observed. GWPR further identified clusters of implantation in South Central census metropolitan areas with higher education attainment.
Conclusions: Adult CI incidence demonstrated a nonstationary relationship between implantation and the studied sociodemographic factors. GWPR performed better than Poisson regression in accounting for these local spatial variations. These results support the development of targeted interventions to improve access and utilization to CIs in a publicly funded healthcare system.
Key Words: Cochlear implant—GWPR—Public policy—Sociodemographic factors—Spatial modeling.

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INTRODUCTION

Despite growing attention to the health and socioeconomic consequences of untreated hearing loss, cochlear implant (CI) use remains low globally (1–3). Previous studies assessing barriers to hearing loss care among adults have demonstrated considerable differences in countries with two-tier healthcare systems (i.e., privately and publicly funded healthcare is available), such as in the United States, United Kingdom, and Australia (4–8). In Canada, which uses a single-payer healthcare system, sociodemographic disparities have been cited as barriers to access and utilization of several health services despite publicly funding (9–11). However, there are few published data on the effects of sociodemographic factors on adult CI access in Canada.

In medical research, traditional regressions, such as Poisson models, have been used widely to explore the relationship between a health outcome/procedure and its associated variables, such as demographic or environmental factors (12,13). However, such approaches ignore potential spatial variations in the relationships between the outcome and its predictive factors (14). As such, these techniques result in bias by generating average estimates for an entire study region without considering geographical variations that may be present (14). It is important to understand the local spatial differences across a region when developing and assessing healthcare policies. To address this issue, studies have started using the geographically weighted Poisson regression (GWPR) method to map spatial variations in these relationships (15–18).

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To the best of our knowledge, no study has reported on the distribution of adult CIs in relation to the sociodemographic factors of different regions using GWPR in a two-tier or single-payer healthcare system. Identifying areas with low implantation rates and their associated sociodemographic factors is important for developing targeted approaches to improve access and utilization of adult CIs.

Given the potential of GWPR to guide healthcare decision making with spatial data analysis, the objectives of this pilot study were to (i) demonstrate the utility of GWPR in describing geographical distribution of adult CI incidence in relation to sociodemographic factors in a publicly funded healthcare system, and (ii) compare traditional Poisson regression and GWPR to fit the relationship between adult cochlear implantation incidence and associated sociodemographic factors.

MATERIALS AND METHODS

Ethics clearance was granted by Sunnybrook Health Sciences Center Research Ethics Board, certificate 2205.

Study Site

This study was conducted in Ontario, Canada. This province accounts for 10.13% of Canada's land and 38.26% of its population (19). Ontario is divided into 45 census metropolitan areas (CMAs) (19), where a CMA is defined by one or more adjacent municipalities centered around a population core and has a population of at least 100,000, of which at least 50,000 live in the core (20).

Data Source

All adults 18 years or older who received a CI from 2020 to 2021 at the largest CI center in a large academic hospital in Toronto, Ontario, were selected using a provincial CI Program database. Of note, there are three Ontario CI centers. Demographic data including postal code, gender, age at implantation, and occupation were collected for each participant. The data were input into a webapp, *Pollarisintelligence.com*, which was developed by an independent data sourcing organization, Manifold Data Mining Inc., based in Ontario, to model the Program data against historical and projected Statistics Canada Census results. Using postal code, household counts aggregated by CMA for each participant were obtained for each year via the webapp. Zero counts were applied to remaining CMAs with no postal code for a total of 30 CMAs. Weighted household size, income, age at implantation, education level, and distance from CI center for each CMA were obtained based on historical and projected Census data using the webapp. All results from webapp were tested and validated against historical Census data with a confidence level of 95%.

Study Variables

The dependent variable was the number of adult CIs (18 yr or older) serviced at this center. Independent variables included income level, education attainment, age at implantation, and distance from CI center, which were available at the CMA level. CMA population size per year served as the control variable.

The independent variable income was stratified into three levels using Statistics Canada's four-group parsimonious categorization of income adequacy, which is reported in Canadian dollars (CAD), based on an average participant household size of 2.9 from our CI recipient cohort: "lower income" defined as less than CAD $20,000 total household income, "middle income" defined as CAD $20,000 to $79,000 total household income, and "upper income" defined as greater than or equal to CAD $80,000 total household income. Education attainment was stratified into three groups: "no education" representing no certificate, diploma, or degree; "high school" indicating a high school diploma or equivalent; and "postsecondary plus" indicating a postsecondary certificate, diploma, or degree. Age at implantation was stratified into two groups based on reporting of Census Program data: "young" representing age less than 65 years, and "old" representing age greater than or equal to 65 years. Distance from CI center was reported in kilometers.

Statistical Analysis

Analysis was performed using RStudio (version 1.1.453; RStudio, Boston, MA). Descriptive statistics were used to characterize implantation and the sociodemographic variables, and then Poisson regression and GWPR were used to explore these associations. The "GWmodel" package from RStudio was used to map the distribution of implantation incidence in relation to these factors.

Implantation incidence was measured as the number of CIs per CMA population per 100,000 persons. Shapefiles, which are digital vector storage formats for geographic location and associated attribute information, were used to create the geographical representation data for Ontario and its CMAs (21). The shapefiles were merged with our data.

Traditional regression analysis was performed based on the assumption that the implantation incidence follows the Poisson distribution. The fitting formula of the analysis is expressed as follows:

$$\ln O_i = \beta_0 + \beta_{1\text{–}3}(\text{Income}) + \beta_{4\text{–}6}(\text{Education}) + \beta_{7\text{–}8}(\text{Age}) + \beta_9(\text{Distance}) + \varepsilon_i$$

where O_i represents implantation incidence in CMA_i, β_0 is the global intercept, and β_j (j = 1, 2, …) are model parameters corresponding to different levels of each independent variable. For example, for income, β_j (j = 1, 2, 3) are parameters corresponding to the associated levels: "lower," "middle," and "upper" incomes. For education attainment, β_j (j = 4, 5, 6) are parameters corresponding to the respective levels: "no education," "high school," and "postsecondary plus." For age at implantation, β_j (j = 7, 8) are parameters corresponding to "young" and "old." For the variable distance, β_j (j = 9) corresponds to "distance to the CI center." ε_I is the error term of CMA_i.

GWPR can capture spatial heterogeneity and determine the local association between the variable of response and independent variables. This is reflected by coefficients, which often vary with different geographic locations. The general formula of GWPR is expressed as follows:

$$\ln O_i = \beta_0(u_i, v_i) + \beta_{1-3}(u_i, v_i)(\text{Income}) + \beta_2(u_i, v_i)(\text{Education}) + \beta_3(u_i, v_i)(\text{Age}) + \beta_4(u_i, v_i)(\text{Distance}) + \varepsilon_i$$

where (u_i, v_i) represents the two-dimensional coordinates of CMA_i, and the other parameters are denoted similarly to those in the Poisson regression described previously. The equation was estimated for each CMA based on observations in neighboring CMAs, and each CMA was weighted by its distance from CMA_i. Geographic weighting was taken into account through the bi-square kernel-type function in the RStudio package (Boston, MA).

When data from one region correlate with data from a neighboring region, spatial autocorrelation occurs. GWPR removes this correlation by correcting for nonstationary spatial relationships. To assess spatial autocorrelation of both models, Moran's I coefficient was used (22). The range of the Moran's I is from −1 (indicating perfect dispersion) to +1 (indicating perfect correlation). A Moran's I equal to zero implies no spatial autocorrelation.

The lowest corrected Akaike information criteria (AICc) score, which also indicates goodness of fit, was used to determine whether the Poisson regression or GWPR yielded a better model fit.

RESULTS

A total of 164 adults received a CI; however, 14 adults were excluded because of invalid postal codes or postal codes representing no resident habitants. The final sample included 150 adult CI recipients in 14 different CMAs between 2020 and 2021, and analysis was performed on this sample. The mean (standard deviation) age was 62.4 (15.6) years at the time of implantation, and the majority was male (53%). Forty percent of participants had missing data for occupation, and thus, no analysis was performed. The 10 CMAs with the highest incidence rates included CMAs located in South Central and Southeastern Ontario: Wasaga Beach, Kawartha Lakes, Peterborough, Hamilton, Brantford, Oshawa, Barrie, Toronto, Sault Ste. Marie, and Kingston. Lower incidences were observed in CMAs located in Northern and Southwestern Ontario as indicated by lighter blue colors on the map (Fig. 1). The global Moran's I coefficient (Moran's $I = 0.04$, $p < 0.05$) indicated that the implantation incidence had positive autocorrelation or clustered patterns across Ontario.

Summary of Parameters in the Poisson Regression

Table 1 displays results for Poisson regression. "Lower" and "middle" income levels were positively associated with the occurrence of implantation when controlling for all other variables (coefficient = 0.0284 and $p < 0.05$, and coefficient 0.2568 and $p < 0.001$, respectively; Table 1). These positive associations indicated greater likelihoods of implantation. Adults younger than 65 years had a positive relationship with the occurrence of implantation (coefficient = 0.1075, $p < 0.01$). "Distance from CI center" was significantly negatively associated with the occurrence of implantation; meaning that if the distance from a CI center increased, the probability of implantation decreased (coefficient = −0.0060, $p < 0.01$). No other variables were predictors of implantation.

The model's residuals exhibited positive spatial autocorrelation (Moran's $I = 0.13$, $p < 0.05$), suggesting that the Poisson model is insufficient to address the nonstationary spatial relationships. The AICc was 63.98.

Summary of Parameters in the GWPR

Further GWPR with spatial varying intercept and independent variables yielded a lower AICc of 53.98 (Table 2). No spatial autocorrelation of residuals was observed in the model (Moran's $I = 0.24$, $p < 0.690$), suggesting that GWPR captured the spatial autocorrelation observed in the Poisson model.

Table 2 presents a summary of parameter estimates in the multivariable GWPR, which includes the following: the minimum, first quartile, median, third quartile, and maximum values. The distributions of the predictive variables over the 30 Ontario CMAs are shown in Figures 2–4; the darker blue colors on the map indicate a higher value of a local parameter estimate. Figures 2–4 display patterns of spatial variation, indicating that the parameters are not equal for all CMAs.

The local parameter estimates of "lower" and "middle" income levels were positively associated with the incidence

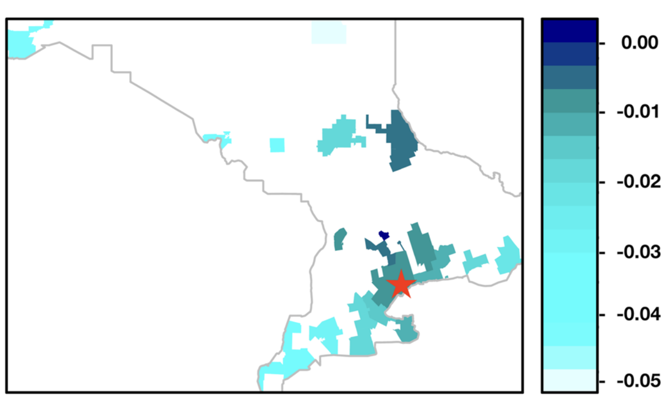

FIG. 1. Incidence of adult cochlear implantation across census metropolitan areas (CMAs) in Ontario, Canada. The cochlear implant center in this study is indicated by a red star. The incidence of adult cochlear implantation for each CMA per 100,000 persons was calculated and displayed on a map of Ontario, Canada. Lighter blue colors indicate smaller indices, and darker blue colors indicate greater indices.

TABLE 1. *Summary of parameters in the Poisson regression model*

	Variables	Coefficient	Standard Error	*z*	*p*
Income	Lower income	0.0284	0.0114	2.4900	<0.050
	Middle income	0.2568	0.0170	15.0790	<0.001
	Upper income	−0.0030	0.0055	−0.5450	0.5857
Education	No education	−0.0245	0.0614	−0.3980	0.6900
	High school diploma	−0.0453	0.0733	−0.6180	0.5360
	Postsecondary Education or Higher	−0.0490	0.1225	−0.4000	0.6890
Age	Young	0.1075	0.0507	2.1210	<0.050
	Old	0.0245	0.0179	1.3710	0.6950
Distance	Distance from CI center	−0.0060	0.0021	−2.8700	<0.010

Corrected Aikake information criterion: 63.98. Moran's $I = 0.13$, $p < 0.05$.

of implantation across all CMAs (Fig. 2). Adults with “upper income” level demonstrated a negative association with all CMAs, as indicated by negative coefficients. Adults with “high school diploma” level of education were negatively associated with implantation across all CMAs (Fig. 3). GWPR revealed patterns of spatial variation with “no education” and “postsecondary plus” levels as shown by the large coefficient ranges of −0.1124 to 0.0235 and −0.1568 to 0.0311, respectively (Table 2, Fig. 3). For both of these education levels, CMAs in Southwestern Ontario were negatively associated with implantation, and CMAs in North Central Ontario were positively associated with implantation. The local parameter estimates of both “young” age group were more positively associated with implantation than the “old” age group (Fig. 4). Increasing distance from the CI center was negatively associated with implantation (Fig. 4). The coefficients were negative for all CMAs, indicating that as distance from the CI center increased, implantation decreased. CMAs in Northern Ontario were more likely to receive a CI as demonstrated by greater coefficient scores.

DISCUSSION

The incidence of adult cochlear implantation varied across Ontario and was shown to have a nonstationary relationship with the sociodemographic factors. Although the Poisson regression performed well, it represented only the association for Ontario as a whole and ignored spatial context. On the contrary, the GWPR was able to capture the local variations in the relationships between adult CI incidence and sociodemographic factors for each CMA, thus demonstrating its utility in assessing CI distribution. Clusters of CMAs with different CI incidences were identified (Fig. 1), whereas the maps in Figures 2–4 show different spatial distributions of CIs according to predicting variables. It is important to be aware of these spatial patterns and how sociodemographic barriers vary between regions when implementing strategies to reduce sociodemographic disparities in adult CI use, and the GWPR method is effective in achieving this.

The current literature suggests that income is a barrier to CI access in the United States and United Kingdom (23–25). In these two-tier healthcare systems, adults of lower financial status are less likely to undergo implantation. Our study shows the opposite of these studies and suggests that those of lower socioeconomic status have greater likelihoods of receiving an implant in Canada's public healthcare system. Both Poisson and GWPR models demonstrated that adults of lower and middle income status were more likely to receive a CI. In the Poisson model, “upper income” did not seem to be a significant predictor of implantation; however, the GWPR showed that most adults in Ontario with an “upper income” level were less likely to receive a CI suggesting a negative relationship. This was reflected by negative local coefficients in all CMAs (Table 2). The GWPR also showed minimal spatial variation across the CMAs, implying an overall negative association between implantation and “upper income” (Fig. 2). In the United States and United Kingdom, CIs are inequitably distributed to adults with higher income levels because of fewer concerns regarding financial cost, insurance reimbursement, equipment maintenance, and travel time for appointments (24–26). In Canada's single-payer system, CIs are publicly funded by individual provinces and do not require additional insurance coverage. Canadian adults from lower socioeconomic status are likely more willing to seek out CIs because there are no upfront costs related to assessment, equipment purchasing,

TABLE 2. *Summary statistics of local geographically weighted Poisson regression*

	Variables	Minimum	Lower Quartile	Median	Upper Quartile	Maximum
Income	Lower income	0.0158	0.0176	0.0205	0.0280	0.0518
	Middle income	0.2311	0.2352	0.2376	0.2421	0.2943
	Upper income	−0.0078	−0.0059	−0.0048	−0.0039	−0.0004
Education	No education	−0.1124	−0.0493	−0.0130	−0.0012	0.0235
	High school diploma	−0.0895	−0.0595	−0.0381	−0.0297	−0.0163
	Postsecondary education or higher	−0.1568	−0.0606	−0.0414	0.0010	0.0311
Age	Young	0.0671	1.0590	1.0942	1.1630	1.2716
	Old	0.0079	0.0227	0.0237	0.0252	0.0339
Distance	Distance from CI center	−0.1810	−0.0135	−0.0064	−0.0056	−0.009

Corrected Aikake information criterion: 58.70. Moran's $I = 0.24$, $p < 0.690$.

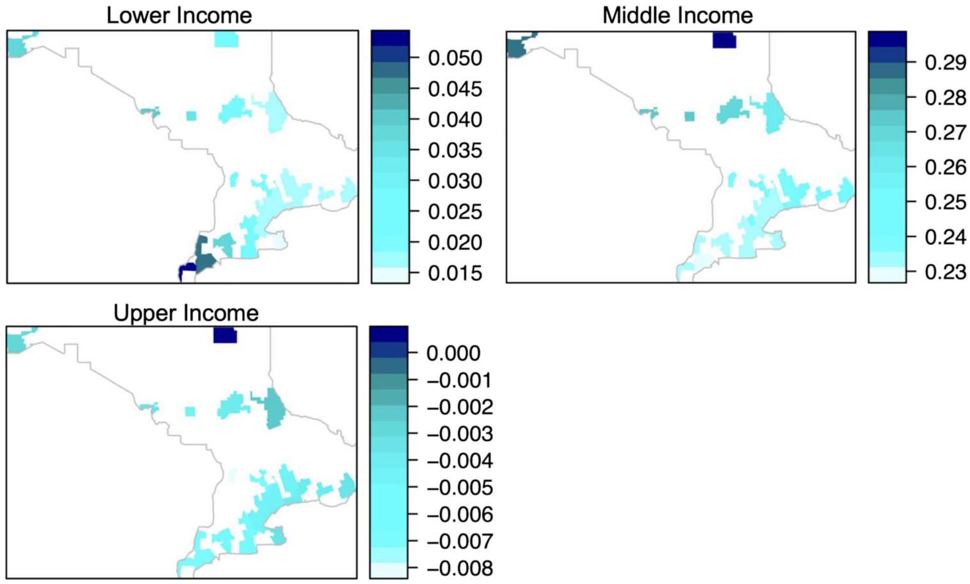

FIG. 2. Spatial distribution of cochlear implants by income levels for each census metropolitan area (CMA) in Ontario, Canada, as computed by geographically weighted Poisson regression. The cochlear implant center in this study is indicated by a red star. Light blue colors indicate smaller coefficients (increased likelihood of receiving a cochlear implant), and darker blue colors indicate greater coefficients (decreased likelihood of receiving a cochlear implant).

or surgery. This is of particular importance because a higher prevalence of hearing loss among Canadian adults with lower household income has been reported, and thus a greater demand for CIs among adults from lower socioeconomic status (27). Our results further indicate that adults with higher income levels were not being prioritized for implantation and suggest that there were no income-based inequities in the access and utilization of CIs in Ontario during the study period. However, given our small sample size, the generalizability of our results is limited, and analysis of larger data sets spanning several years is essential to understand the spatially varying relation between adult CIs and income level.

A survey of all Canadian CI centers from 2007 has reported that education attainment is not a barrier to CI service provision in Canada (28). The results of our Poisson regression yielded similar results to this Canadian study; however, our GWPR deconstructed this relationship further and revealed that there are spatial variations between the

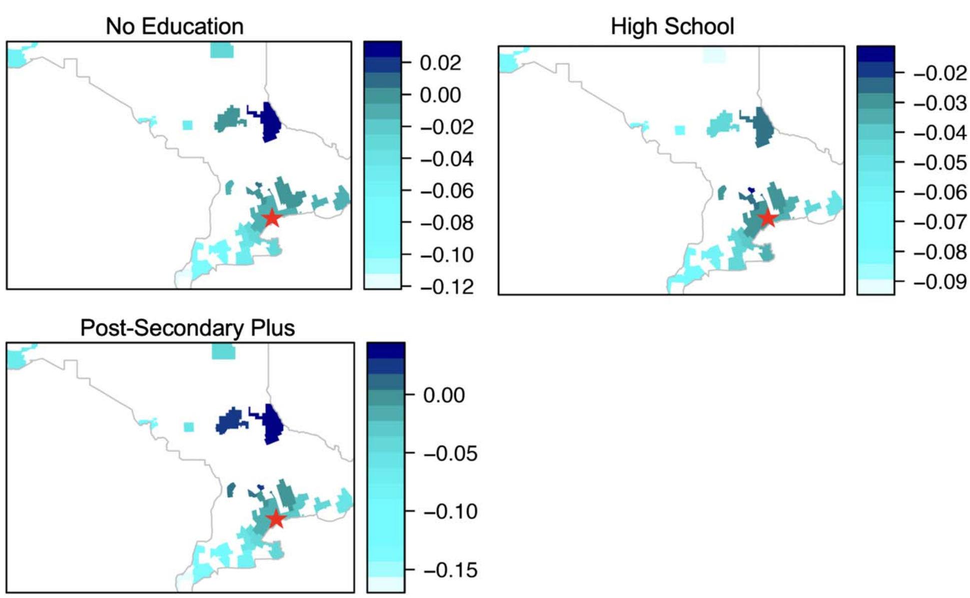

FIG. 3. Spatial distribution of cochlear implants by education attainment for each census metropolitan area (CMA) in Ontario, Canada, as computed by geographically weighted Poisson regression. The cochlear implant center in this study is indicated by a red star. Light blue colors indicate smaller coefficients (increased likelihood of receiving a cochlear implant), and darker blue colors indicate greater coefficients (decreased likelihood of receiving a cochlear implant).

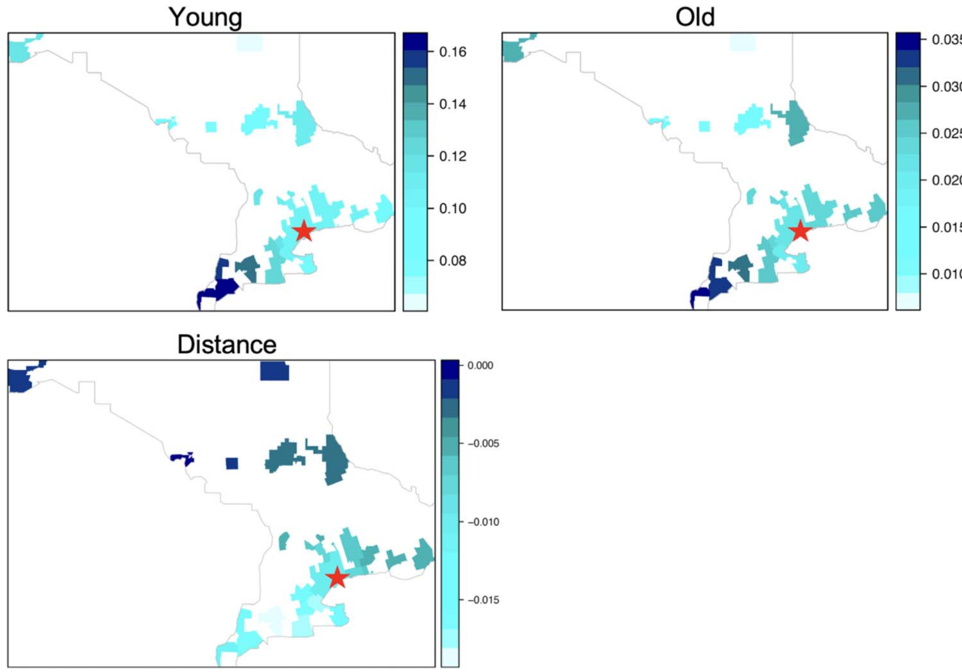

FIG. 4. Spatial distribution of cochlear implants (CIs) by age at implantation and distance to CI center for each census metropolitan area (CMA) in Ontario, Canada, as computed by geographically weighted Poisson regression. The CI center in this study is indicated by a red star. Light blue colors indicate smaller coefficients (increased likelihood of receiving a CI) and darker blue colors indicate greater coefficients (decreased likelihood).

CMAs in Ontario affecting this finding (Fig. 3). There was a negative association between adults who had a "high school diploma" education level and implantation rates across all CMAs. For adults with "no education" or "postsecondary plus" attainment, the estimated local coefficients ranged from negative to positive over the province, which did not emerge with traditional Poisson regression. These findings highlight the importance of the GWPR specification and its ability to capture the local spacing associations between a health outcome and explanatory variables. The CMAs surrounding the CI center in South Central and North Central Ontario had positive coefficients, indicating that these adults were more likely to undergo implantation (Fig. 3). A possible explanation for this phenomenon is that South Central and North Central CMAs have the most robust economies in Ontario, which are driven by higher education attainment (29,30). In the most recent Census, Toronto (a South Central CMA with the largest economy in Canada) had the greatest proportion of individuals with a postsecondary degree or higher, and our results showed higher implantation rates in this CMA (31,32). Education attainment is directly related to health literacy, and those with greater health literacy are more likely to access and use healthcare services, including cochlear implantation (33–35). Of note, our results show that adults living in CMAs in Southwestern Ontario were less likely to receive a CI when considering education attainment. This is likely explained by the fact that there is a second CI center in Southwestern Ontario that is more accessible and services this population. Further investigation is required for a deeper understanding of the spatial variations between education attainment and implantation, and future studies should include all three provincial CI centers to effectively capture the geographic distribution of CIs.

According to the Poisson and GWPR models, adults younger than 65 years old were more likely to receive a CI than those greater than this age (Fig. 4). Our findings are again supported by a survey of all CI centers in Canada, which showed that a majority of CI operations were performed in adults younger than 60 years (28). It is likely that younger adults experience fewer difficulties accessing CIs due to greater health literacy, increased willingness to undergo surgery, and fewer comorbidities that may affect rehabilitative outcomes (36). Clinicians are often reluctant to consider implantation in the elderly, as the rehabilitative outcome is often inadequate because of cognitive deterioration with aging (37). Another possibility for this finding is that the study period spanned the COVID-19 pandemic, so many elderly patients may have intentionally delayed their operations to avoid potential exposure risk at the CI center, given the high infection rates in this CMA (38–40). Moreover, our GWPR model demonstrated considerable spatial heterogeneity between CMAs as indicated by the large coefficient range, which indicates that it is important to use GWPR to identify regions that are being underserviced (Table 2). Moreover, our GWPR model also suggested a positive relationship between implantation and adults older than 65 years, but to a lesser extent than those younger than this age. Over the past several years, Canadian adults older than 80 years have been receiving CIs at rapidly rising rates due to higher prevalences of presbycusis (28). There has also been a growing body of evidence that cochlear implantation in the elderly population is safe, well tolerated, and results in significant improvements in hearing outcomes and quality of life (41). There have been focused efforts to improve CI access among the elderly population, as untreated hearing loss has been recently identified as the number one modifiable risk factor contributing to dementia (42).

Further geographic distance from the CI center resulted in lower implantation rates as seen in both Poisson and GWPR models. Interestingly, the GWPR shows that CMAs with farther distances from the center yielded greater coefficients, indicating that these adults were more likely to receive a CI than adults from CMAs closer to the center (Fig. 4). These findings are unexpected, as closer geographic proximity to healthcare services has been shown to result in increased utilization of those services (4). Previous research has described travel time and distance, lost earnings, and accommodation costs as barriers to access care for rural patients in the United States (43). However, it is possible that, given Ontario's publicly funded healthcare system, there is a concerted effort to improve CI access for those in typically underserviced in rural locations. Hearing healthcare campaigns and audiological clinics targeting rural populations have emerged in Ontario to reduce the geographic inequities in accessing CIs and other hearing-related services. Despite this, the overall association between distance to CI center and implantation remains negative and distance continues to be a sociodemographic barrier to implantation within Canada's single-payer system.

Our findings should be interpreted in the context of limitations. First, because of the retrospective nature of this study, we could not control the data collection process and we could not account for other contributing sociodemographic factors, such as severity of hearing loss by geographic region, race, and occupation. Second, because data were analyzed at the communal level, relationships found between the variables and CI incidence cannot be inferred to an individual level. Third, our sample was biased because we focused on one of three CI centers in Ontario, which limits the validity of our conclusions on CI service delivery across Canada's public healthcare system. The greatest number of patients with implants in our study included patients in close geographic proximity to the CI center. Thus, given that there are three CI centers in the province, further study assessing all CI centers is needed to confirm the validity of our results. Compounding this, our study used postal codes as a proxy for sociodemographic factors, which further reduced the sample size of our study because of invalid postal codes and limits the generalizability of our findings. Furthermore, our study divided age at implantation into two groups based on availability of Census data, which limits our ability to determine the effects of mobility limitations and comorbidities in the medical decision-making process of older adults. Lastly, the design of this GWPR study limits the ability to prove causality. Further investigation with larger sample sizes spanning longer periods is needed to explore the underlying causes of these variations, which may be attributed to severity of hearing loss, race, and occupation by geographic region. More factors should also be considered to explore their impact on implantation, such as studying patient satisfaction and postsurgical complications to weigh the benefits and risks of this procedure. Based on our pilot study's findings, the powerful utility of GWPR in describing geographical distribution of CIs is clear, and our research group has plans to reproduce this study with a larger data set spanning 5 years to define long-term trends and further demonstrate the power of GWPR analysis in analyzing CI distribution.

CONCLUSIONS

To the best of our knowledge, this is the first study to assess the spatial variations affecting the associations between adult CI incidence and sociodemographic factors using GWPR. In this pilot study, we provide evidence that the rates of implantation varied spatially across Ontario, which uses a publicly funded healthcare system. Adults living in CMAs with lower income levels, younger age proportions, and closer distances to the CI center were most likely to receive a CI as indicated by traditional Poisson regression. However, when taking into account local variations between CMAs, several other relationships emerged with education attainment and older age. Ignoring these spatial variations could lead to inefficient resource usage. In this pilot study, we present the utility value of GWPR analysis with a smaller sample size and suggest that GWPR should be applied across multiple institutions to effectively capture the distribution of CIs in Canada's public healthcare system. GWPR is an emerging method to analyze data in healthcare, and our study has shown if it can be effectively used to quantify the sociodemographic inequities in the use of CIs at the local level of care policy. A follow-up study spanning 5 years replicating this study's methods will further demonstrate the utility of GWPR and establish long-term trends of CI distribution in Canada. Clear themes emerged despite our small sample size, and we suggest that the GWPR method would be effective at evaluating the access and utilization of CIs at a national level in both privately and publicly funded healthcare systems.

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