

ORIGINAL RESEARCH

# Social Deprivation and Post-TAVR Outcomes in Ontario, Canada: A Population-Based Study

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**BACKGROUND:** Transcatheter aortic valve replacement (TAVR)/intervention has become the standard of care for treatment of severe aortic stenosis across the spectrum of risk. There are socioeconomic disparities in access to TAVR. The impact of these disparities on postprocedural outcomes remains unknown. Our objective was to examine the association between neighborhood-level social deprivation and post-TAVR mortality and hospital readmission.

**METHODS AND RESULTS:** We conducted a population-based retrospective cohort study of all 4145 patients in Ontario, Canada, who received TAVR from April 1, 2017, to March 31, 2020. Our co-primary outcomes were 1-year postprocedure mortality and 1-year postprocedure readmission. Using Cox proportional hazards models for mortality and cause-specific competing risk hazard models for readmission, we evaluated the relationship between neighborhood-level measures of residential instability, material deprivation, and concentration of racial and ethnic groups with post-TAVR outcomes. After multivariable adjustment, we found a statistically significant relationship between residential instability and postprocedural 1-year mortality, ranging from a hazard ratio of 1.64 to a hazard ratio of 2.05. There was a significant association between the highest degree of residential instability and 1-year readmission (hazard ratio, 1.23 [95% CI, 1.01–1.49]). There was no association between material deprivation and concentration of racial and ethnic groups with post-TAVR outcomes.

**CONCLUSIONS:** Residential instability was associated with increased risk for post-TAVR mortality, and the highest quintile of residential instability was associated with increased post-TAVR readmission. To reduce health disparities and promote an equitable health care system, further research and policy interventions will be required to identify and support economically and socially minoritized patients undergoing TAVR.

**Key Words:** aortic stenosis ■ mortality ■ racial and ethnic groups ■ readmission ■ social deprivation ■ transcatheter aortic valve intervention ■ TAVR

**T**ranscatheter aortic valve replacement (TAVR)/intervention has become the standard of care or a feasible alternative for surgical aortic valve replacement for treatment of severe aortic stenosis across a wide spectrum of risk profiles.<sup>1–3</sup> This has resulted in an exponential growth in the demand for TAVR.

The association between social deprivation and increased cardiovascular disease, inadequate access

to treatment, and poor outcomes following cardiac intervention is well established.<sup>4–6</sup> In Ontario, Canada, TAVR is intended to be available to all eligible patients regardless of socioeconomic status under a publicly funded health care system. Despite this, income-, race-, and ethnicity-based disparities to TAVR access have been reported.<sup>7–9</sup> However, there is a paucity of data on the impact of these disparities on

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## CLINICAL PERSPECTIVE

### What Is New?

- Residential instability is associated with increased risk for 1-year post-transcatheter aortic valve replacement mortality and readmission.
- There is no association between either material deprivation or residing in an area with a high concentration of racial and ethnic groups with poor post-transcatheter aortic valve replacement outcomes.

### What Are the Clinical Implications?

- Economically and socially marginalized patients undergoing transcatheter aortic valve replacement may be at increased risk for poor postprocedure outcomes.
- Further investigation is needed to inform policy intervention aimed at identifying and supporting these patients as they undergo transcatheter aortic valve replacement, as well as dismantling structural racism, which underpins health disparities.

## Nonstandard Abbreviations and Acronyms

<b>ICES</b>	formerly known as the Institute for Clinical Evaluate Sciences
<b>ON-MARG</b>	Ontario Marginalization Index
<b>TAVR</b>	transcatheter aortic valve replacement

postprocedure outcomes; the available literature is both limited in scope and is not reflective of contemporary TAVR practice.<sup>9,10</sup>

Accordingly, to address this gap in knowledge, we sought to examine the association between neighborhood-level social deprivation and post-TAVR mortality and hospital readmission among patients residing in Ontario, Canada. The study of social deprivation and post-TAVR outcomes is of significant interest, as reducing social disparities in health care outcomes has become a global priority.<sup>11,12</sup> Identifying economically and socially marginalized patients at risk of poor postprocedure outcomes is a foundational first step to then develop care pathways to support these individuals.

## METHODS

The data underlying this article cannot be shared as they are based on administrative data and governed by the privacy regulations in Ontario, Canada.

## Study Design and Setting

We conducted a population-based, retrospective cohort study using administrative data held at ICES, Ontario (previously known as the Institute for Clinical Evaluative Sciences). The use of ICES data in this retrospective cohort study was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board. The use of anonymized administrative data without patient consent at ICES is allowed in Ontario on the basis of provincial privacy legislation. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology statement for reporting of observational studies.<sup>13</sup>

## Context

This study was conducted in Ontario, Canada, the largest Canadian province, with a population of 14.8 million.<sup>14</sup> In Ontario, all residents have universal health care coverage through a third-party payer, the Ontario Ministry of Health. TAVR was first introduced in Ontario in 2007 and received public funding in 2012. Presently, TAVR is approved for use in inoperable, high-risk, intermediate-risk, and low-risk patients with aortic stenosis.<sup>2,3</sup> TAVR is available at all 11 Ontario hospitals that provide cardiac surgery.

## Data Sources

The primary source of information was the CorHealth Ontario TAVR Registry. This database collects demographic, comorbidity, and procedural data that has been validated through chart review and core laboratory analyses.<sup>15</sup>

Neighborhood-level data (from the 20 160 dissemination areas in Ontario) on social deprivation was gathered from the Ontario Marginalization Index (ON-MARG). The ON-MARG categorizes various demographic factors into 4 distinct marginalization dimensions: residential instability (types and density of residential accommodations, family structure characteristics, and multiple household moves from their primary residence to another residence at a high frequency or in a short period of time),<sup>16</sup> material deprivation (composite measure of inability of individuals and communities to access basic material needs), racial and ethnic concentration (areas with high concentration of recent immigrants or people belonging to underrepresented groups), and dependency (concentrations of individuals having no income including seniors, children, and adults whose work is not compensated). These dimensions were derived from factor analysis of 42 sociodemographic variables previously identified to be related to inequality in Canada.<sup>17</sup>

Each ON-MARG dimension is subdivided into 5 quintiles with quintile 1 representing those least deprived and quintile 5 representing those most deprived. We used residential instability, material deprivation, and racial and ethnic concentration in our analyses; based on our previous work, dependency is highly colinear with age, as the proportion of adults who are aged  $\geq 65$  years is one of the components of dependency in the ON-MARG.<sup>17</sup> In our previous work, increasing age has been shown to be a patient-level driver of postprocedural outcomes in TAVR.<sup>18</sup>

Baseline comorbidity, procedural data, and readmission outcomes were obtained from the Canadian Institute for Health Information Discharge Abstract database. Validated ICES-derived databases were used to identify diabetes,<sup>19,20</sup> congestive heart failure,<sup>21</sup> hypertension,<sup>22,23</sup> dementia,<sup>24</sup> and chronic obstructive pulmonary disease.<sup>25</sup> We used the hospital frailty risk score to define medical frailty.<sup>26</sup> Mortality was ascertained through the Registered Persons database. All databases were linked using unique encoded identifiers and analyzed at ICES.

## Study Population

All Ontario residents aged  $>18$  years who received TAVR from April 1, 2017, to March 31, 2020, were included in this study. The maximum follow-up date was March 3, 2021. If a patient had multiple TAVR procedures during the study period, only the first procedure

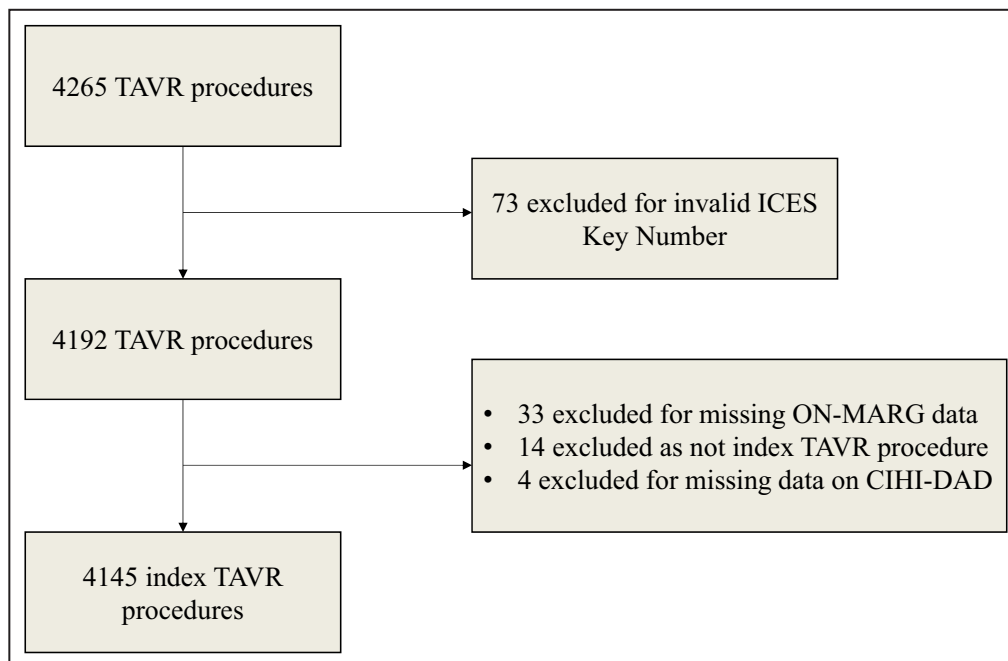
was included. Patients aged  $<18$  years or those with an invalid ICES key number were excluded.

## Outcome Measures

The co-primary outcomes were 1-year postprocedure mortality and 1-year postprocedure readmission. For mortality, outcomes were calculated 1-year from the date of procedure. For readmissions, we defined time 0 as date of discharge alive after the index TAVR hospitalization; as such, patients who died before discharge were excluded from this analysis.

## Statistical Analysis

We developed a Cox proportional-hazards model for postprocedure mortality. A cause-specific hazards model was created for postprocedure readmission where mortality before admission served as a competing risk. The primary covariates were the ON-MARG dimensions of residential instability, material deprivation, and racial and ethnic concentration. We created separate models for each dimension of the ON-MARG. All multivariable models were adjusted for demographic factors (age, sex, rural status, and neighborhood income), medical comorbidities (heart failure, ischemic heart disease, arrhythmia, peripheral vascular disease, cerebrovascular disease, diabetes, hypertension, dyslipidemia, chronic obstructive pulmonary disease, dementia, cancer, liver disease, interstitial lung disease, renal disease, and dialysis), Charlson score,



**Figure 1. Cohort selection flowchart.**

CIHI-DAD indicates Canadian Institute for Health Information–Discharge Abstract Database; ICES, formerly known as the Institute for Clinical Evaluate Sciences; ON-MARG, Ontario Marginalization Index; and TAVR, transcatheter aortic valve replacement.

**Table 1. Patients Who Underwent TAVR Between April 2017 and March 2020**

Characteristic	Total cohort (n=4145)
Age at index TAVR (mean±SD)	81.5±7.5
Male, n (%)	2371 (57.2)
Rural, n (%)	465 (11.2)
Medical comorbidities	
Charlson score (mean±SD)	1.7±1.8
Frailty low risk (<5), n (%)	3288 (79.3)
Heart failure, n (%)	2694 (65.0)
Ischemic heart disease, n (%)	2883 (69.6)
Atrial arrhythmia, n (%)	1047 (25.3)
Peripheral vascular disease, n (%)	147 (3.5)
Cerebrovascular disease, n (%)	174 (4.2)
Diabetes, n (%)	1816 (43.8)
Hypertension, n (%)	3865 (93.2)
Dyslipidemia, n (%)	2635 (63.6)
Chronic obstructive pulmonary disease, n (%)	1430 (34.5)
Interstitial lung disease, n (%)	54 (1.3)
Dementia, n (%)	262 (6.3)
Cancer, n (%)	318 (7.7)
Liver disease, n (%)	81 (2.0)
Renal disease, n (%)	135 (3.3)
Dialysis, n (%)	135 (3.3)
Prior cardiac procedures, n (%)	
Coronary artery bypass surgery	633 (15.3)
Percutaneous coronary intervention	1336 (32.2)
Valve surgery	440 (10.6)
In-hospital bleeding, n (%)	
Any	290 (7.0)
Major	136 (3.3)
Minor	154 (3.7)
No bleeding	3855 (93.0)
In-hospital dialysis	91 (2.2)
In hospital acute kidney injury, n (%)	64 (1.5)
In hospital acute kidney injury requiring dialysis, n (%)	10 (0.2)
Cardiac device, n (%)	
Cardiac resynchronization therapy-D or therapy-P at time of procedure hospitalization	45 (1)
Implantable cardioverter defibrillator at time of procedure hospitalization	15 (0.4)
Pacemaker at time of procedure hospitalization	402 (9.7)
Access site, n (%)	
Transfemoral	3950 (95.3)
Nontransfemoral	195 (4.7)
Procedure status	
Elective	3625 (87.5)
Urgent/emergent	520 (12.5)

(Continued)

**Table 1. Continued**

Characteristic	Total cohort (n=4145)
Fiscal year, n (%)	
2017	997 (24.1)
2018	1377 (33.2)
2019	1771 (42.7)

TAVR indicates transcatheter aortic valve replacement.

frailty score, prior cardiac procedures (coronary artery bypass surgery, percutaneous coronary intervention, and valve surgery), TAVR access site, fiscal year, and procedure status (elective versus urgent). To account for clustering at the level of the dissemination area, we made use of a robust variance estimator. The dissemination area was the level of clustering as opposed to the transcatheter aortic valve intervention hospitals because the ON-MARG variables of residential instability, deprivation, and ethnicity were dissemination area-level variables. SAS version 9.4 (SAS Institute, Cary, NC) was used for data analysis. Statistical significance was a 2-sided  $P < 0.05$ .

## RESULTS

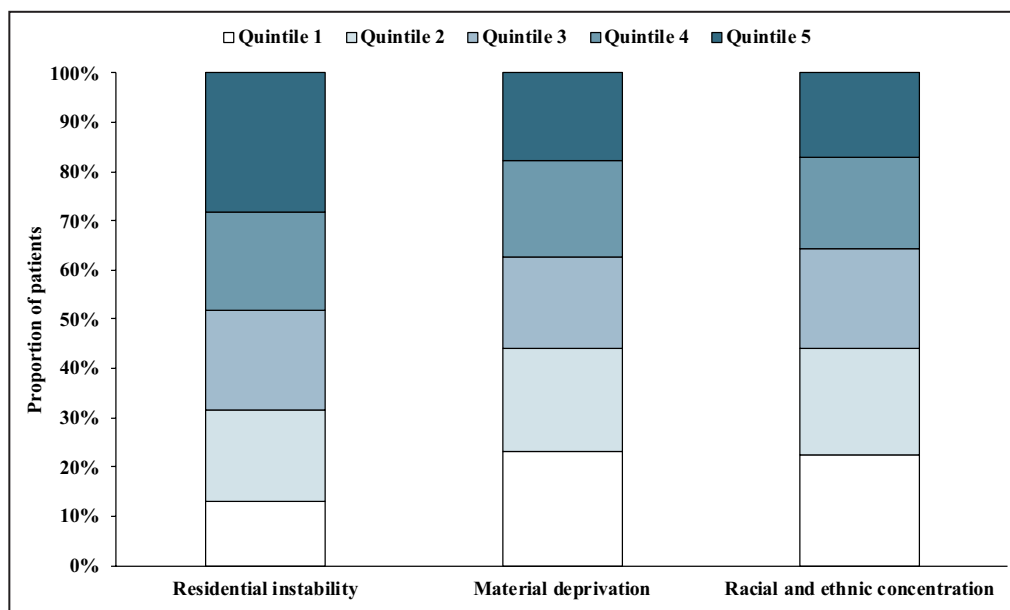
### Cohort

We identified 4265 TAVR procedures performed in Ontario from April 1, 2017, to March 31, 2020. After exclusions, our cohort consisted of 4145 unique patients undergoing TAVR (Figure 1).

Cohort details are presented in Table 1. The mean age of our cohort was 81.5 years, 57.2% of patients were men, and 11.2% of patients lived in a rural setting. The most frequent comorbidities were hypertension (93.2%), ischemic heart disease (69.6%), congestive heart failure (65.0%), and dyslipidemia (63.6%). The percentage of patients with prior percutaneous coronary intervention and coronary artery bypass surgery was 32.2% and 15.3%, respectively. The transfemoral approach was the most common approach (95.3%) and the majority of TAVR procedures were elective (87.5%). The number of TAVR procedures performed increased from 997 in 2017 to 1771 in 2019.

The proportion of patients in each quintile of the ON-MARG dimensions is shown in Figure 2. The proportion of patients across quintiles for material deprivation and those residing in areas with greater concentration of racial and ethnic groups was relatively balanced. In contrast, residential instability had a higher proportion of patients in the most deprived quintile compared with the least deprived.

Unadjusted outcomes are shown in Table 2 as well as Figure S1 (1-year mortality), and Figure S2 (1-year



**Figure 2. Proportion of patients per quintile by ON-MARG dimension.**  
ON-MARG indicates Ontario Marginalization Index.

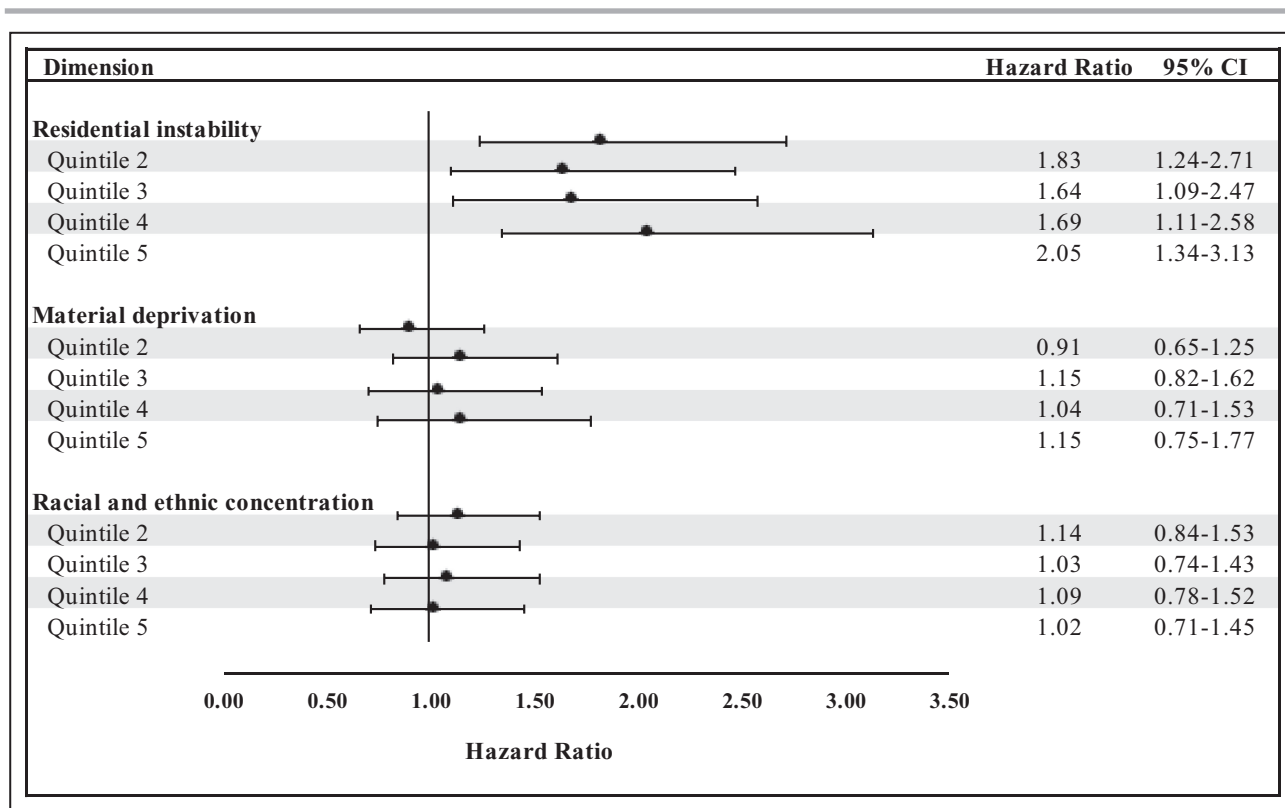
readmission). Residential instability was associated with increased risk for 30-day and 1-year postprocedure mortality but not postprocedure readmission.

There was no association between the primary outcomes and material deprivation or residing in an area with a greater concentration of racial and ethnic groups.

**Table 2. Crude Mortality and Readmission Outcomes by ON-MARG Domain**

Domain	No.	30-day mortality	1-year mortality	30-day readmission	1-year readmission
Residential instability, n (%)					
Quintile 1	536	*	35 (6.5)	61 (11.4)	191 (35.6)
Quintile 2	768	26 (3.4)	87 (11.3)	86 (11.2)	291 (37.9)
Quintile 3	848	20 (2.4)	87 (10.3)	105 (12.4)	312 (36.8)
Quintile 4	823	14 (1.7)	85 (10.3)	97 (11.8)	306 (37.2)
Quintile 5	1170	32 (2.7)	139 (11.9)	143 (12.2)	462 (39.5)
Total	4145	96 (2.3)	433 (10.4)	492 (11.9)	1562 (37.7)
P value		0.017	0.017	0.937	0.563
Material deprivation, n (%)					
Quintile 1	955	25 (2.6)	95 (9.9)	134 (14.0)	359 (37.6)
Quintile 2	867	14 (1.6)	78 (9.0)	85 (9.8)	310 (35.8)
Quintile 3	782	23 (2.9)	93 (11.9)	91 (11.6)	294 (37.6)
Quintile 4	801	21 (2.6)	82 (10.2)	105 (13.1)	303 (37.8)
Quintile 5	740	13 (1.8)	85 (11.5)	77 (10.4)	296 (40.0)
Total	4145	96 (2.3)	433 (10.4)	492 (11.9)	1562 (37.7)
P value		0.29	0.304	0.032	0.545
Racial and ethnic concentration, n (%)					
Quintile 1	932	22 (2.4)	93 (10.0)	109 (11.7)	349 (37.4)
Quintile 2	894	22 (2.5)	103 (11.5)	106 (11.9)	349 (39.0)
Quintile 3	843	19 (2.3)	81 (9.6)	100 (11.9)	325 (38.6)
Quintile 4	763	16 (2.1)	83 (10.9)	91 (11.9)	278 (36.4)
Quintile 5	717	17 (2.4)	73 (10.2)	86 (12.1)	261 (36.6)
Total	4145	96 (2.3)	433 (10.4)	492 (11.9)	1562 (37.7)
P value		0.991	0.71	1	0.763

ON-MARG indicates Ontario Marginalization Index. \*No value as  $n < 5$  for quintile 1.



**Figure 3. Cox model hazard ratios for 1-year mortality after TAVR by ON-MARG dimension.**

Model is adjusted for demographic factors, medical comorbidities, Charlson score, frailty score, prior cardiac procedures, TAVR access site, fiscal year, and procedure status. ON-MARG indicates Ontario Marginalization Index; and TAVR, transcatheter aortic valve replacement.

### Adjusted Mortality Outcomes

Figure 3 depicts 1-year postprocedure mortality outcomes by ON-MARG dimension after multivariable adjustment. For residential instability, compared with the least deprived quintile, each of quintiles 2 to 5 had significantly higher risk for mortality with hazard ratio ranging from 1.83 to 2.05. There was no statistically significant association between patients experiencing material deprivation or living in areas with a higher concentration of racial and ethnic groups with greater postprocedure mortality (Figure 3).

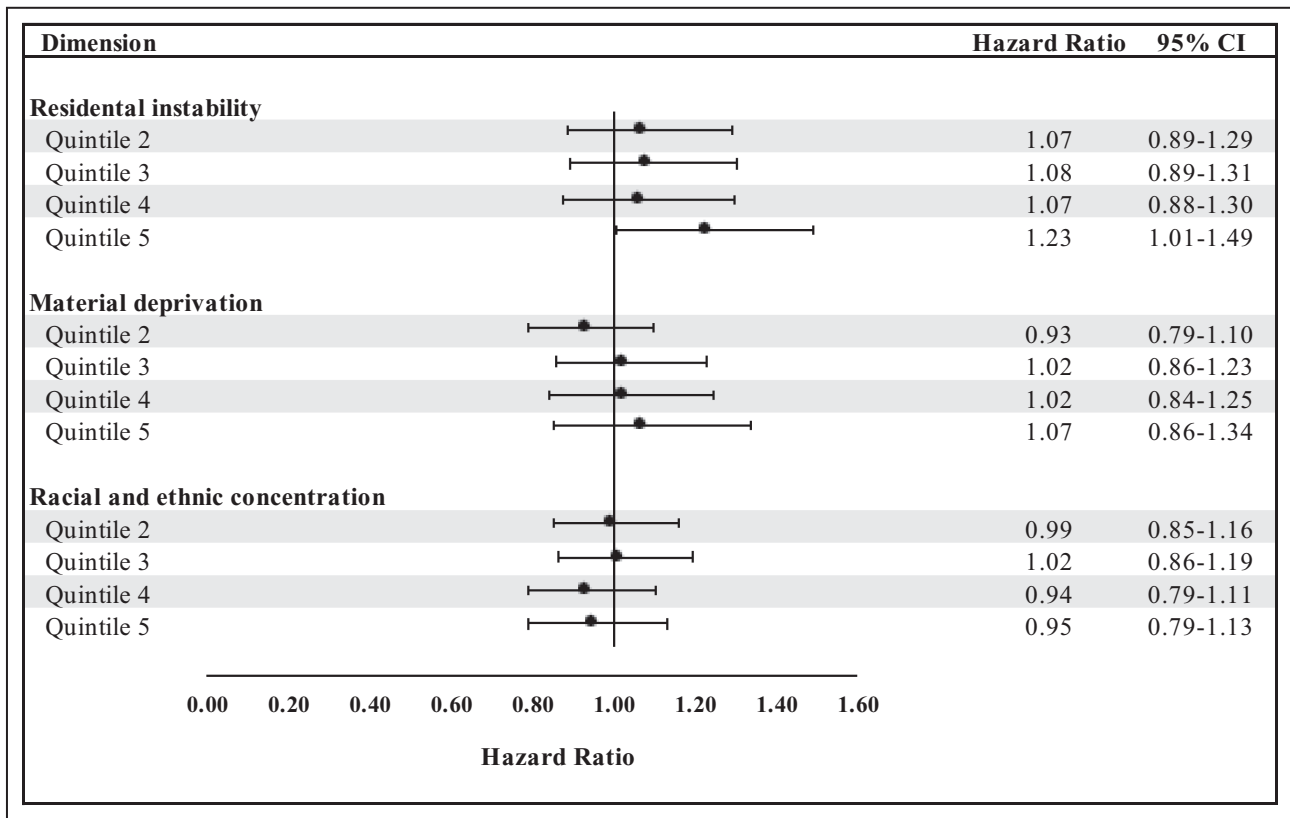
### Adjusted Readmission Outcomes

Figure 4 depicts 1-year postprocedure readmission outcomes by ON-MARG dimensions after multivariable adjustment. Only patients in the most severe quintile (ie, quintile 5) of residential instability were at increased risk for postprocedure readmission (hazard ratio, 1.23 [95% CI, 1.01–1.49]). There was no association between 1-year postprocedure readmission and material deprivation or increased neighborhood concentration of racial and ethnic groups (Figure 4).

## DISCUSSION

The objective of our study was to investigate the relationship between social deprivation and post-TAVR outcomes. We found that residential instability was associated with increased risk for postprocedure mortality and readmission. There was no association between material deprivation and residing in an area with a higher concentration of racial and ethnic groups with postprocedure outcomes.

The social disparities in access to TAVR have been previously documented.<sup>8</sup> However, evidence for the impact of these disparities on TAVR outcomes is sparse. In studies from Wales and the United States, low-income patients undergoing TAVR were not found to be at increased risk for postprocedure mortality.<sup>9,10</sup> However, these studies were either limited in sample size or were not relevant to current practice as they were from an early era of TAVR. They also used income as the sole indicator for social deprivation. This contrasts with our work, which includes all TAVR procedures performed in Ontario, Canada, in a contemporary period from 2017 to 2020, and evaluated



**Figure 4. Cause-Specific Cox Model Hazard ratios for 1-year readmission post-TAVR by ON-MARG dimension.** Model is adjusted for demographic factors, medical comorbidities, Charlson score, frailty score, prior cardiac procedures, TAVR access site, fiscal year, and procedure status. ON-MARG indicates Ontario Marginalization Index; and TAVR, transcatheter aortic valve replacement.

a multidimensional framework to categorize social deprivation. Using the ON-MARG, we were able to identify specific areas of social deprivation associated with post-TAVR outcomes in a rigorous and comprehensive manner. Furthermore, the granularity provided by analyzing each of the dimensions of the ON-MARG individually lends itself to the development of solutions at target social deprivation based on a patient’s unique characteristics.

Building on the work of these previous studies, we have found a novel relationship between residential instability and post-TAVR mortality. This is consistent with previous literature demonstrating an association between decreased social support and increased mortality risk in health care.<sup>27,28</sup> There may be multiple explanations for these findings. Compared with the other dimensions, residential instability uniquely reflects neighborhood cohesiveness. This involves the social capital and instrumental supports one gains from residing in their neighborhood, independent of income.<sup>29</sup> Patients with precarious access to housing are more likely to experience delays in accessing medical care and are more frequent users of the emergency department, suggesting a lack of

access to reliable primary or subspecialty care.<sup>30</sup> Additionally, while the Canadian health care services are provided with no additional cost to the patient, patients undergoing TAVR tend to be older adults who may be more dependent on local support for health maintenance needs such as transportation to medical appointments or the pharmacy for medication pickup. Moreover, these patients may have a higher burden of comorbidity, an independent risk factor for post-TAVR readmission and mortality.<sup>31,32</sup>

Consistent with previous studies, we found that material deprivation, which considers employment and income, is not a risk factor for poor post-TAVR outcomes. This may be because Canadian health care services, such as investigations to identify severe aortic stenosis, pre-TAVR workup, TAVR itself, and post-TAVR care, are provided with no additional cost to patients. Furthermore, residing in a neighborhood with predominantly minority racial and ethnic groups did not have a significant association with increased postprocedure readmission or mortality. One explanation may be the “healthy immigrant effect,” in which immigrants to Canada are found to have a survival advantage compared with the native population, perhaps attributable

to an immigration process that favors healthy individuals with greater capital.<sup>33</sup>

Our findings must be taken in the context of structural racism, as it underpins all measures of economic and social marginalization evaluated in our study. Structural racism has been identified to be the primary driver of persistent health disparities.<sup>34</sup> By elucidating a link between social deprivation and post-TAVR mortality, our work further supports the detrimental impact of structural racism on cardiovascular disease outcomes. Therefore, future research or policy measures must focus not only on identifying and supporting individuals experiencing social deprivation, but also work at a systems level to dismantle structural racism. This is a focus of further work in our group, by investigating the relationship between social deprivation and pre-TAVR wait times and the impact of this on subsequent morbidity and mortality. If so, a potential intervention could be satellite valve clinics closer to the homes of such patients, as travel to tertiary centers may be a contributing factor; remote monitoring after the procedure may also be of value. Further interventions to limit residential instability may need to come from municipal or provincial governments. Such interventions may include increased low-income housing, rent control or rent assistance programs, and provision of legal services to prevent evictions.<sup>35</sup>

There are several limitations to our study that merit discussion. First, we conducted a retrospective, observational study that is limited by confounding bias. We attempted to mitigate this effect by controlling for multiple predictors of post-TAVR mortality and readmission in our models; that said, we cannot discount the potential of residual unmeasured confounders. Second, the ON-MARG values for marginalization are a composite measure of a given geographic area and do not measure individual data, which would have given a more precise estimate of social deprivation. To mitigate this limitation, we used dissemination areas, the smallest area unit available in the ON-MARG database. In addition, the ON-MARG dimensions consist of multiple constructs, it is uncertain if one construct has a greater effect than others within the dimension. Third, we were unable to conduct a sensitivity analysis for cardiovascular mortality as these data are provided by Statistics Canada and are not promptly available. Fourth, our follow-up period coincided with the COVID-19 pandemic, which may have introduced unforeseen and unmeasured confounders affecting our co-primary outcomes. Patients may not have been able to receive typical post-TAVR care because of a lack of in-person follow-up appointments or investigations. Fifth, our data set does not include the percentage of patients in each quintile of economic and social marginalization who attended postprocedure follow-up appointments and at what intervals. This represents an important area of study for future work given the

potential implications of different rates of follow-up between patients with lower versus higher levels of economic and social marginalization. Finally, our study by its nature is hypothesis generating and not conclusive.

In conclusion, residential instability is associated with increased risk for post-TAVR mortality and readmission. To reduce health disparities and promote an equitable health care system, further research and policy interventions will be required to not only identify and support economically and socially marginalized patients undergoing TAVR but also address structural racism on a larger scale.

## ARTICLE INFORMATION

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The corresponding author affirms that he has listed everyone who contributed significantly to the work. The authors had access to all the study data, take responsibility for the accuracy of the analysis, and had authority over manuscript preparation and the decision to submit the manuscript for publication. The corresponding author confirms that all authors read and approved the manuscript.

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### Disclosures

None.

### Supplemental Material

Figure S1–S2

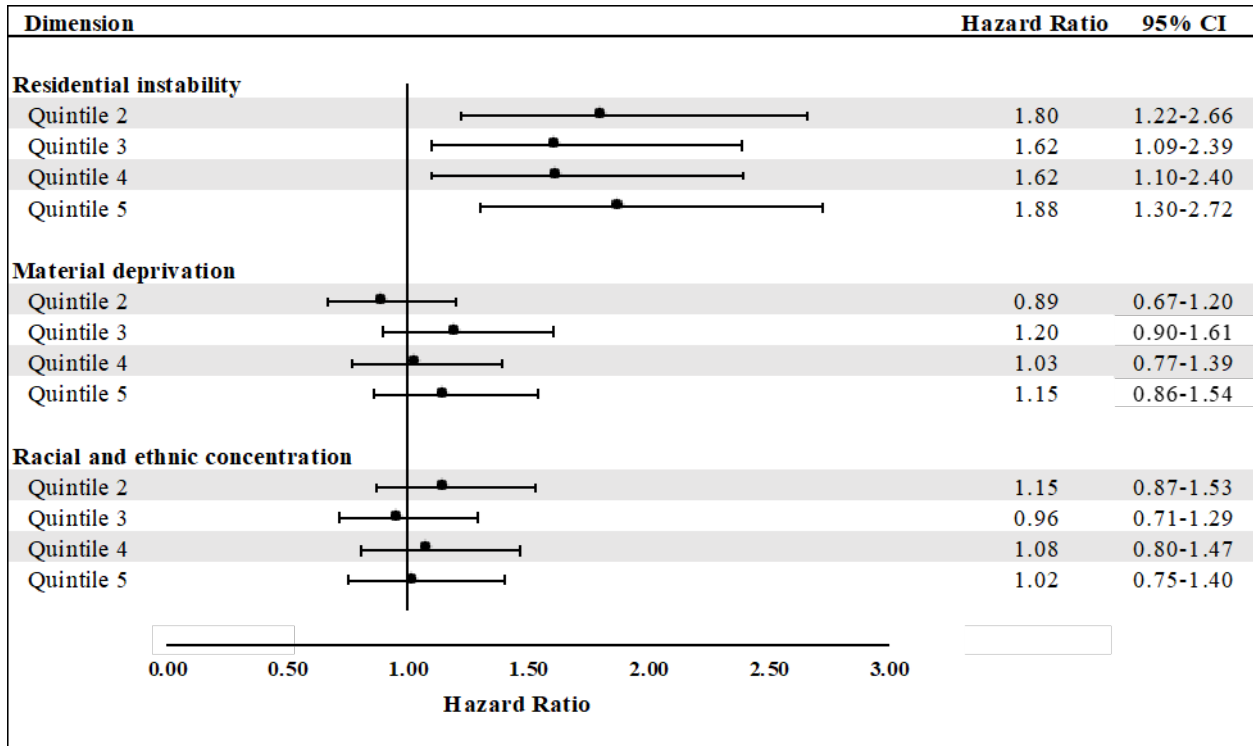


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## **SUPPLEMENTAL MATERIAL**

**Figure S1. Main effect model for 1-year mortality post-TAVR by ON-MARG dimension**



**Figure S2. Main effect model for 1-year readmission post-TAVR by ON-MARG dimension**

