# GEOGRAPHIC DISPARITIES IN CARDIOVASCULAR MORTALITY AMONG LYMPHOMA SURVIVORS: A POPULATION-BASED COMPETING RISK ANALYSIS USING THE SEER DATABASE, 2000–2022

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## INTRODUCTION

Cardiovascular disease is the leading non-cancer cause of death among lymphoma survivors, driven by the cardiotoxic effects of anthracycline-based chemotherapy and mediastinal radiation.

Whether rural residence independently predicts excess cardiovascular mortality — beyond socioeconomic and demographic confounding — has not been examined in a population-based competing risk framework.

## OBJECTIVE

To determine whether rural residence independently predicts excess cardiovascular mortality among lymphoma survivors, using a population-based competing risk framework that accounts for lymphoma-specific and other-cause death.

## METHODS

We identified 128,940 adults (aged ≥20 years) with Hodgkin lymphoma (HL) or diffuse large B-cell lymphoma (DLBCL) in the SEER database (2000–2022). Rurality was classified via Rural-Urban Continuum Code into metro (n=114,605), adjacent non-metro (n=8,449), and remote rural (n=5,886).

Cardiovascular cause-of-death was the primary outcome; lymphoma-specific and other-cause death were competing events. Cumulative incidence functions were estimated and compared using Gray's test.

Multivariable Fine-Gray regression adjusted for age, sex, race/ethnicity, histology, stage, treatment, marital status, county-level income, and diagnosis era. Sensitivity analyses and interaction terms were pre-specified.

## CONCLUSIONS

Rural lymphoma survivors bear a 34% higher crude cardiovascular mortality burden, explained by a concentration of older age, lower socioeconomic status, and adverse demographic profiles rather than geography per se.

Modern gains in cardiovascular survivorship have not been equitably realized rurally, implicating income inequality and gaps in cardio-oncology surveillance as primary intervention targets.

## RESULTS

Among **128,940** patients (**755,715 person-years**), **7,539** cardiovascular deaths occurred.

Crude cardiovascular mortality followed a rural gradient: **9.62, 11.83 and 12.88** per 1,000 person-years in metro, adjacent non-metro and remote rural patients — a **34% rural excess** (Gray's p<0.001).

At 10 years, cumulative cardiovascular mortality was **5.78%** (metro) vs **7.29%** (rural); among HL survivors the rural excess reached **44%** (3.07% vs 4.43%).

Metro rates declined substantially across eras (10.26→9.23 per 1,000 PY) while rural rates declined minimally (13.38→12.24), widening the absolute gap.

On multivariable Fine-Gray regression, rurality was **not an independent predictor** (rural SHR 0.953, 95% CI 0.852–1.065, p=0.39). Diagnosis in 2016–2022 conferred a **58% lower** cardiovascular hazard vs 2000–2009 (SHR 0.423) — a benefit not proportionally realized rurally. All sensitivity analyses were consistent.

### KEY FIGURES

**128,940**
lymphoma survivors, SEER 2000–2022

**7,539**
cardiovascular deaths observed

**+34%**
crude CV mortality excess, rural vs metro

**0.953**
adjusted rural SHR — not significant

| Independent predictor | Adjusted SHR |
|---|---|
| Older age (per year) | 1.056 |
| Male sex | 1.286 |
| Non-Hispanic Black race | 1.231 |
| Hodgkin lymphoma histology | 1.172 |
| Lower county-level income (per rank) | 0.978 |
| Diagnosis 2016–2022 vs 2000–2009 | 0.423 |
| Remote rural residence | 0.953 (p=0.39, NS) |

*Table 1. Multivariable Fine-Gray competing-risk regression: independent predictors of cardiovascular death among lymphoma survivors, SEER 2000–2022. Rural residence was not independently predictive (SHR 0.953, 95% CI 0.852–1.065, p=0.39). NS = not significant.*

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