Quality-of-Care Comparisons between Hospitals: a method comparison between Inverse Probability Weighting and the Fine & Gray Model

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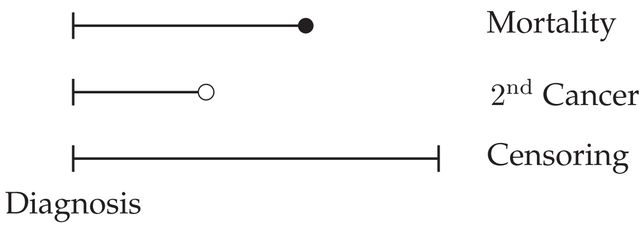
Background

- Quality-of-care outcomes are measures of a particular healthcare process that reflect an institution's level of quality-of-care (surgery mortality) [1].
- **Quality-of-care comparisons** have been a growing interest for stakeholders to identify specific areas of improvement among hospitals and facilitate decision making in resource allocation and target intervention [1].
- Hospital comparisons have rarely been addressed in a causal inference framework, particularly for **competing risk time-to-event outcomes** (T).



- Inverse probability weighting using the propensity score (**IPW-PS**) [2] and direct standardization (DS) with the Fine & Gray model (**F&G**) [3] are two methods to unbiasedly estimate the t-year potential **cumulative incidence** (CI).
- **Objectives**:
  1. We present a causal inference based framework for hospital comparisons in the context of competing risk quality-of-care outcomes.
  2. Through a simulation study, we compare the performance of IPW-PS and F&G in estimating the t-year potential CI.
  3. Using Ontario Cancer Registry (OCR) breast cancer data, we assess hospital performance by comparing each hospital's 5-year second cancer CI after initial breast cancer diagnosis.

Methods

Potential Cumulative Incidence Function

The potential CI function for a patient in hospital z for the competing risk event, k, at time t is defined as,

$$F_k^{(z)}(t) = P(T^{(z)} \leq t, \epsilon^{(z)} = k) \quad (1)$$

Z	Diagnosis at Hospital z (**Exposure**)
$T^{(z)}$	Time-to-Event Potential Outcomes
$\epsilon^{(z)}$	Potential Competing Risk Event
$\mathbf{X}$	Patient Information (Confounders)

Hospital

Patient ID	1	2	3	4	5
1	?	0.19	?	?	?
2	?	?	?	0.05	?
3	0.25	?	?	?	?
⋮	⋮	⋮	⋮	⋮	⋮
n	?	?	?	?	0.12

Potential Cumulative Incidence $(F_k^{(z)}(t))$

Employing a causal inference framework [4] and assuming positivity, consistency and conditional exchangeability, we estimate,

$$F_k^{(z)}(t) = E_{\mathbf{X}}[F_k(t|Z=z, \mathbf{X})] = F_k(t|Z=z) \quad (2)$$

References

[1] Mainz, J. *Defining and classifying clinical indicators for quality improvement*, International Journal for Quality in Health Care 15. (2003). pp.523–530.

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[4] Varewyck, M., Goetghebeur, E., Eriksson, M., Vansteelandt, S. *On shrinkage and model extrapolation in the evaluation of clinical center performance*. Biostatistics 15. (2014). pp. 651–664.

Methods

Inverse Probability Weighting via Propensity Score

- Balance patient case-mix information in each hospital by weighting a patient based on the inverse of their propensity score.
- The IPW cumulative incidence estimator is defined as [2],

$$F_{k,\text{IPW}}(t|\mathbf{X}, Z=z) = \sum_{j:t_j \leq t} \hat{S}^W(t_{j-1})\hat{\lambda}_k^W(t_j) \quad (3)$$

Direct Standardization using Fine & Gray Model

- In DS, all observed patients are assumed to have received diagnosis at the same hospital regardless of where they actually received their diagnosis.
- Through the Fine & Gray model [3],

$$\lambda_k^*(t) = \lambda_{k,0}^*(t)\exp\{\beta_z Z + \boldsymbol{\beta}^{\boldsymbol{T}}\mathbf{X}\} \quad (4)$$

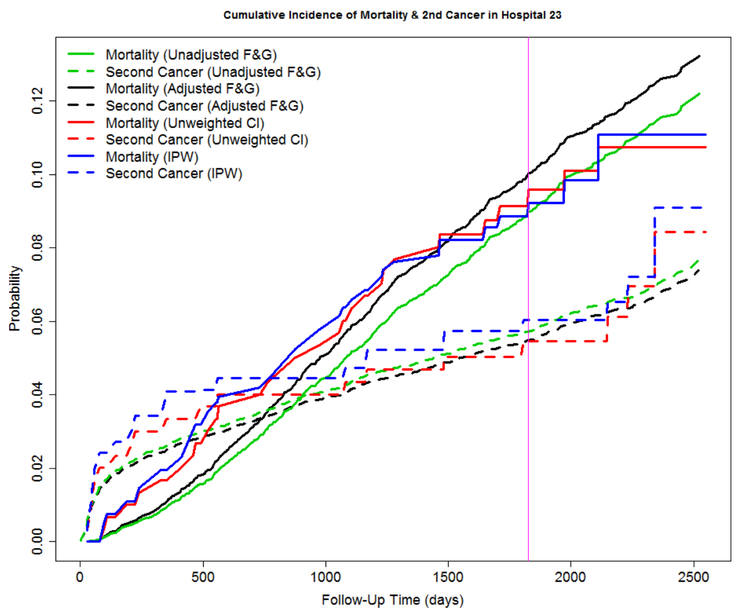
$$F_{k,\text{FG}}(t|\mathbf{X}, Z=z)) = 1 - \exp\left[-\int_0^t \lambda_k^*(u)du\right] \quad (5)$$

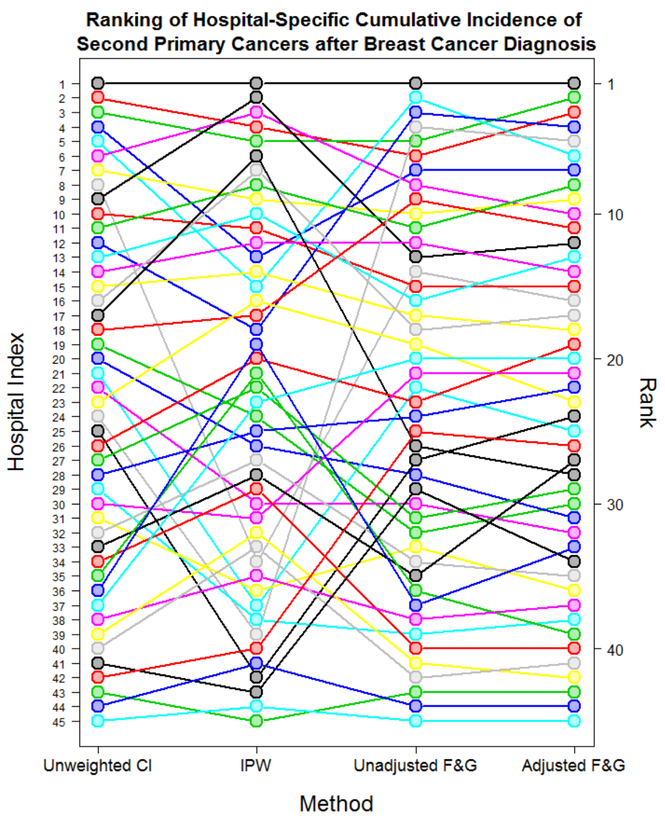
Data Analysis

Ontario Cancer Registry (OCR) Data

- In our analysis, 12 687 OCR breast cancer patients collected from an initial breast cancer diagnosis in 2010-2012 and followed up until the end of 2016.
- During follow-up, 810 patients had second cancers, 945 patients died, and 10 932 patients reached end of follow-up.
- Patient diagnostic information from 45 different hospitals include tumor size, number of positive lymph nodes, laterality, histology, etc.

Cumulative Incidence Estimation & Ranking

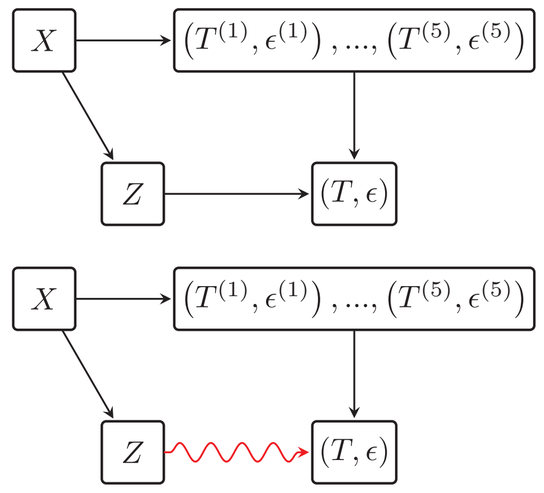




- **Interpretation**: The probability of being diagnosed with a 2nd cancer at hospital 23 within 5 years of first BC diagnosis is roughly **5.5%**.
- With a rank correlation of **0.7** between IPW & Adjusted F&G, both methods estimate and rank hospitals in a similar fashion.

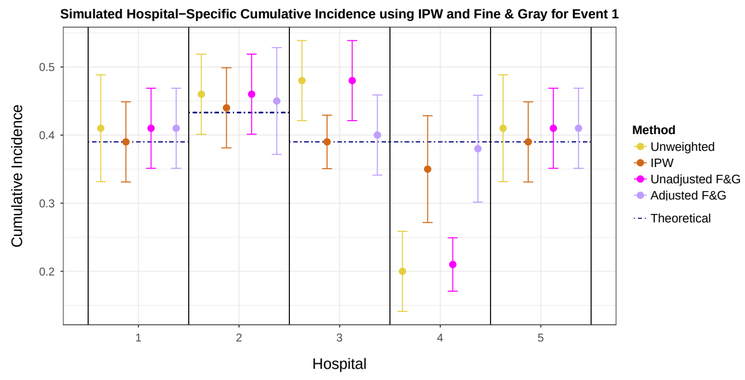
Simulation Study

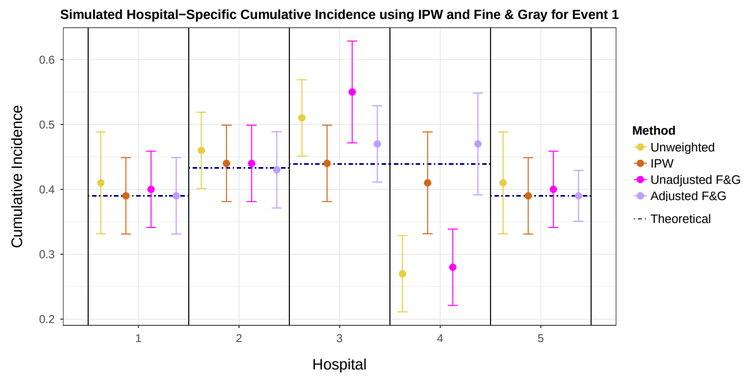
Data-Generating Process



- Patient covariates (X), the assignment mechanism to 5 hospitals (Z) and competing risk potential outcomes (F) generated from proportional cause-specific hazards were simulated.
- Performance of each method was assessed by comparing bias under correct specification and misspecification of hospital & covariate effects when generating **potential hazards**. Covariate effects on hospital assignment were only generated for Hospital 3 and 4.

Simulation Results





- IPW and F&G both reduce bias and correctly adjust for confounder effect under correct specification and misspecification scenarios.
- Lingering bias possibly explained by proportional subdistribution hazards assumption (F&G) and weight truncation at the 99th percentile (IPW).

Discussion

- Despite generating outcomes with cause-specific hazards, F&G, which assumes proportional subdistribution hazards, still reduces most of bias due to confounding, even when the model is misspecified.
- Performance of both methods (i.e. CI estimation, hospital ranking) is very limited by degree of violation in causal inference assumptions.
- Hospital comparisons framework can be generalized to any group-based comparison.

Conclusion:

- Direct standardization using the Fine & Gray model and inverse probability weighting via the propensity score both perform well in estimating hospital-specific cumulative incidence.
- Both methods provide a framework for comparing hospital quality-of-care for competing risk outcomes.