Appendix: Reference Effect Measures (REM)

Contextual Effects

Contextual effects (also known as contextual factors) refer to the influence of group-level or setting-specific factors that modify a certain outcome. When the outcome of interest is a continuous variable, the influence of setting-specific factors can be easily determined (e.g. a student's school might account for 10% of their SAT score variance), so long as the data is collected using a hierarchical structure. However, most relevant outcomes in health care are binary outcomes (mortality, morbidity, use of a certain technique). For these outcomes, there is no simple way to quantify the role of contextual effects. This is because in a logistic regression model, unlike in a linear regression model, the variability of the outcome not explained by the predictors included in the model (measured variables) is absorbed in the model's likelihood and cannot be directly partitioned.

For a given binary outcome such as getting a SLNB, the outcomes of two given patients with identical individual characteristics (age, comorbidities, tumor size) may vary according to setting-specific variables such as facility type and procedural volume, in addition to other setting-specific factors that are unmeasured. These include factors such as institutional culture, provider beliefs, availability of multidisciplinary teams and geographic norms. Understanding the impact of these unmeasured contextual factors is critical to guiding effective strategies to decrease inappropriate variation in healthcare delivery.

Reference Effect Measures (REM)

REM was developed to estimate the contribution of contextual effects to variation in binary outcomes such as SLNB use. It does this by comparing outcomes across different percentiles of the contextual grouping—e.g., comparing a patient treated at a facility in the 90th percentile of SLNB use to a similar patient treated at a facility in the 10th percentile—while holding individual patient characteristics constant. In essence, REM measures the impact of **"where"** a patient is treated rather than **"who"** the patient is.

This approach estimates the difference in odds (expressed as odds ratios) attributable to unmeasured contextual factors and allows comparison to the effects of known contextual (e.g., facility type) and individual-level factors (e.g., comorbidities). While REM does not identify **which** contextual factors are responsible, it quantifies their **combined impact**.

In this study, REM provides insight into how much of the variation in SLNB use is driven by the care environment, rather than by patient-specific characteristics alone.

Why Use REM

Traditional models emphasize fixed effects—such as age or tumor characteristics. REM complements these models by highlighting how much of the observed practice variation is driven by context.

In our study, REM revealed that even after adjusting for all known variables, substantial variation in SLNB utilization persisted. This suggests that unmeasured, facility-level factors—such as institutional practices and local culture—play a major role in determining care patterns.

Limitations

- REM does not identify specific contextual factors; it estimates their **overall influence**.
- It assumes that random effects are normally distributed.
- Estimates may be sensitive to the number of clusters (e.g., facilities) and sample size.

For further methodological details, including a comparison between REM and other methods that estimate the contribution of contextual effects to variation in binary outcomes, readers are referred to: *Glorioso TJ, Grunwald GK, Ho PM, Maddox TM. Reference effect measures for quantifying, comparing and visualizing variation from random and fixed effects in non-normal multilevel models, with applications to site variation in medical procedure use and outcomes. BMC Med Res Methodol. 2018 Jul 6;18(1):74. doi: 10.1186/s12874-018-0517-7. PMID: 29980180; PMCID: PMC6035479.*