13. APPENDICES

Appendix A: Statistical Approach to Calculating Risk-Standardized Hospital Visit Rate

We fitted a hierarchical generalized linear model (HGLM), which accounts for the clustering of observations within hospitals. We assume the outcome is a known exponential family distribution and relates linearly to the covariates via a known link function, *h*. For our model, we assumed a binomial distribution and a logit link function. Further, we accounted for the clustering within hospital by estimating a hospital-specific effect, α_i which we assume follows a normal distribution with mean μ and variance τ^2, the between-hospital variance component. The following equations define the HGLM:

(1) $$h\left(\Pr(Y_{ij}=1|\boldsymbol{Z}_{ij,}\omega_i)\right)=\log\left(\frac{\Pr(Y_{ij}=1|\boldsymbol{Z}_{ij,}\omega_i)}{1-\Pr(Y_{ij}=1|\boldsymbol{Z}_{ij,}\omega_i)}\right)=\alpha_i+\boldsymbol{\beta Z}_{ij}$$

$$where\ \alpha_i=\mu+\omega_i;\ \omega_i\sim N(0\tau^2)$$

$$i=1...I;\ j=1...n_i$$

Where Y_{ij} denotes the outcome (equal to one if patient has one or more qualifying hospital visit within seven days of procedure, zero otherwise) for the *j-th* patient who had an procedures at the *i-th* facility; $\boldsymbol{Z}_{ij}=(Z_{1ij},Z_{2ij},\ldots Z_{pij})$ is a set of *p* patient-specific covariates derived from the data; and *I* denotes the total number of facilities and n_i is the number of procedures performed at facility *i*. The facility-specific intercept, or effect, of the *i-th* facility, α_i, defined above, comprises μ, the adjusted average intercept over all facilities in the sample, and ω_i, the facility-specific intercept deviation from μ. A point estimate of ω_i, greater or less than 0, determines whether facility performance is worse or better compared to the adjusted average outcome.

The HGLM is estimated using the SAS software system (GLIMMIX procedure).

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Using the HGLM defined by Equation (1), we estimate the parameters $\hat{\mu}$, $\left(\hat{a}_1,\hat{a}_{2,},...,\hat{a}_1\right)$, $\hat{\beta}$, and $\hat{\tau}^2$. We calculate a standardized outcome, s_i, for each facility by computing the ratio of the number of predicted hospital visits to the number of expected hospital visits, multiplied by the overall national rate of unplanned hospital visit, $\bar{y}$. Specifically, we calculate:

(2) Predicted Value: $\hat{Y}_{ij} = h^{-1}\left(\hat{\alpha}_i + \hat{\beta} Z_{ij}\right) = \frac{\exp\left(\hat{\alpha}_i + \hat{\beta} Z_{ij}\right)}{\exp\left(\hat{\alpha}_i + \hat{\beta} Z_{ij}\right) + 1}$

(3) Expected Value: $\hat{e}_{ij} = h^{-1}\left(\hat{\mu} + \hat{\boldsymbol{\beta}} \boldsymbol{Z}_{ij}\right) = \frac{\exp\left(\hat{\mu} + \hat{\boldsymbol{\beta}} \boldsymbol{Z}_{ij}\right)}{\exp\left(\hat{\mu} + \hat{\boldsymbol{\beta}} \boldsymbol{Z}_{ij}\right) + 1}$

(4) $s_i = \frac{\sum_{j=1}^{n_i} \hat{Y}_{ij}}{\sum_{j=1}^{n_i} \hat{e}_{ij}} \times \overline{y}$

If the “predicted” number of hospital visits is higher (lower) than the “expected” number of hospital visits, then that facility’s $\hat{s}_i$ will be higher (lower) than the overall national rate of unplanned hospital visit.