Explanation document for the Graphical Display for the Outlier process

Outlier methodology
A random effects methodology is used to infer the outlier status of each hospital or surgeon. Further technical details are reported in a separate section. The results are displayed graphically using a forest plot.

Forest plot (see figure)
Vertical axis: Hospital or surgeon (GMC) identifier and in parentheses: number of patients treated and completeness rate of life status tracking percentage (i.e. the percentage of patients for whom survival data are available).

Horizontal axis: Percentage In-hospital Survival (Overall for UK, and Observed, Predicted, model-based Risk-Adjusted per hospital or surgeon).

More specifically, the following quantities are presented:

1. **Overall In-hospital Survival [dashed vertical line]**: the overall proportion of patients who survive across all hospitals in the UK. In the attached graph it is around 98%.

2. **Observed Survival per hospital or surgeon [square]**: The proportion of patients who survive in hospital after Cardiac Surgery for each hospital or surgeon.

3. **Predicted Survival per hospital or surgeon [cross]**: The Predicted Survival, using the adjusted EuroSCORE model [1-4] to account for case-mix. A high predicted survival (relative to overall UK survival) suggests that the hospital or surgeon performs Cardiac Surgery on relatively low-risk patients.

4. **Survival probability (RE model) for outlier detection [full circle]**: Survival for each hospital or surgeon, derived from a random effects model after accounting for case-mix. This estimate and the corresponding horizontal bar provide an indication of whether the hospital or surgeon is an ‘outlier’ after taking into account observed and predicted survival.

Quantities 1) and 2) do not require any statistical modelling. Calculation of the quantities 3) and 4) require the application of the adjusted EuroSCORE model [1-4] to predict the outcome and of a random effects model for the detection of outliers.

Display of outliers
Hospitals (or surgeons) with outcomes within limits of acceptable variability are assumed to demonstrate ‘usual’ or ‘normal performance’, or performance ‘within expected limits’. A hospital is said to be an outlier when its performance deviates from usual, normal performance.

**Black full circles** indicate hospitals/surgeons with normal performance.
**Purple/Blue full circles** indicate hospitals/surgeons with worse/better performance than normal at the 2 Standard Deviation (SD) level. A hospital/surgeon with lower risk-adjusted survival than usual at the 2SD level is called an ‘Alert’.

**Red/Green full circles** indicate hospitals/surgeons with worse/better performance than normal at the 3SD level. A hospital/surgeon with lower risk-adjusted survival than usual at the 3SD level is called an ‘Alarm’. For the purposes of public reporting only 3SD outliers are displayed on the published forest plots. (2SD outliers are notified by SCTS and NICOR, but their results are not displayed).

**The confidence intervals for the Survival probability (RE model) for outlier detection (solid horizontal bars)** indicate whether a hospital or surgeon is a potential outlier at a given significance level (typically either 2 or 3 standard deviations (SD). For the 3SD significance level:

- If the confidence interval for a hospital or surgeon crosses the vertical Overall Survival dashed line, then the performance of that hospital or surgeon does not deviate from normal performance.
- If the confidence interval fails to cross the vertical Overall Survival dashed line, then the hospital or surgeon is either performing significantly better (Green), or significantly worse (Red) than normal. Such hospitals or surgeons are potential outliers at the 3 SD level.

The length of each confidence interval relates to the estimate of the Survival probability (RE model) for each hospital or surgeon, after accounting for case-mix, relative to the variation in survival across all hospitals. The confidence intervals are not symmetric due to the inverse log-odds transformation. The length of the confidence interval shortens as survival approaches 100%.

**Note:** The validity of the outlier process relies on having an adequate number of patients per hospital or surgeon. Although there is no exact guideline for this figure, simulation studies suggest that for the settings considered (outcome prevalence of 2%) the minimum number of patients to ensure the validity of the tests is 200. Thus, hospitals with fewer than 200 patients will not have confidence intervals placed around their survival estimate and will not be assigned an outlier status. For individual surgeons the minimum case number used is 100 cases (otherwise a large proportion of surgeons would be excluded from the outlier process). The simulation studies still show that this gives a valid result, however the certainty of the outcome may be reduced. This needs to be taken into account for any surgeon assigned as an Alert or Alarm outlier.

**References**


Example Forest Plot

Outlier Status
- Alarm
- Alert
- Normal
- Higher than expected
- Significantly higher than expected

Survival
- Observed
- Predicted
- Risk - Adjusted (model)

Overall Risk Adjusted Survival
Random effects model (with some technical details)

A random effects model is an extension of a standard regression model, which additionally allows for the fact patients come from different hospitals (are 'clustered' within hospitals).

We use a (logistic) regression model that relates observed mortality to predicted mortality. Differences between these quantities (for each hospital) are captured by 'random intercepts'. Some degree of variation in these random intercepts is expected (e.g. due to natural variability and unmeasured hospital-level characteristics). Our statistical testing aims to identify those random intercepts that are abnormally large or small. For presentation purposes these random intercepts are transformed to the probability scale.