

NELA risk adjustment model: recalibration of predictor coefficients, August 2020

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The NELA risk adjustment model for 30-day mortality after emergency laparotomy was developed to facilitate casemix-adjusted comparison of mortality rates between hospitals. The rationale for the model and its development are documented in Eugene et al (2018). The original development used data from NELA Audit Years 1 and 2.

This document reports on the re-estimation of the NELA risk adjustment model coefficients, using records from NELA Audit Years 4-6. This re-calibration was performed in July 2020 and had two purposes:

- (1) To calibrate the risk calculation to the lower mortality rate observed in NELA audit years 4-6, compared to the first two audit years, whose data were used for the original risk model development;
- (2) To re-estimate the coefficients of the risk predictors using recent data, which were deemed likely to be of higher quality than the data used for the original risk model development.

This document first gives a brief technical summary of the recalibration process. This is followed by detailed information on how to calculate predicted pre-operative risk for an emergency laparotomy from information contained in the NELA data set, using the recalibrated coefficients of the NELA risk adjustment model.

Technical Summary

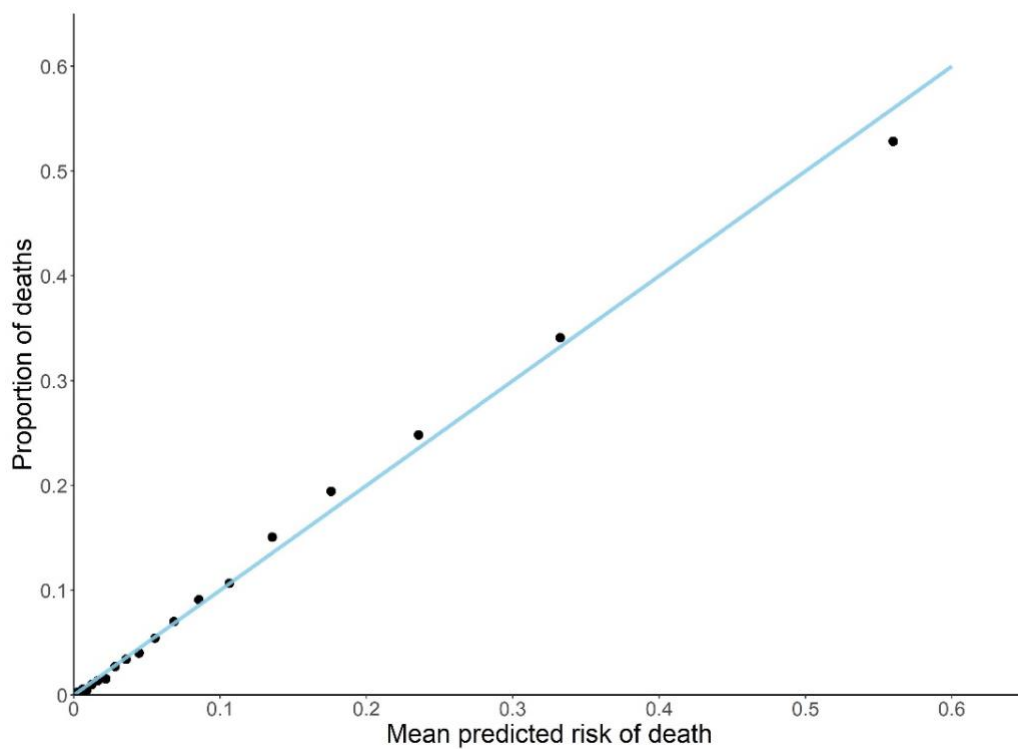
This analysis included data from 73,924 emergency laparotomies conducted between 1 December 2016 and 30 November 2019. Data were cleaned before analysis. All locked records from the time period were considered for inclusion. Updated information about death registrations received from the Office for National Statistics were used. Therefore the data set used here is not identical to the combined data sets used for the NELA audit reports from the relevant years, but rather represents an updated version of these data sets.

The overall mortality rate in this data set was 9.7 %. Although the observed mortality rate differed slightly between the three audit years, there was little statistical evidence for a difference in the mortality rate between the three years, after adjustment for predicted preoperative risk.

Missing values were imputed using multiple imputation with chained equations (five imputed data sets). Results are obtained from each of the five imputed data sets and then pooled using Rubin's rules. No changes to the set of predictors, the winsorization, or the transformation of predictors were considered.

Table 1 shows the coefficients and their standard errors from the re-estimation of the model on NELA data from Audit Years 4, 5, and 6. The model has excellent discrimination, with a C-statistic of 0.863 (pooled statistic from five imputed data sets). Using the pooled risk from five imputed data sets, the model is adequately calibrated (see Figure 1). These results are very similar to those obtained by Eugene et al (2018) in the development of the original risk adjustment model.

Figure 1: Model calibration plot



Notes: $N = 73,924$. Each dot shows 5 % of cases, ordered by predicted risk of death.

Table 1: Pooled risk adjustment model coefficients (NELA Audit Years 4-6)

| | Estimate | Std. Error |
|---|------------|------------|
| (Intercept) | -4.3488269 | 0.0919561 |
| ASA3 | 1.0573609 | 0.0723812 |
| ASA4 | 1.8546010 | 0.0747371 |
| ASA5 | 2.6489194 | 0.1272511 |
| Age_centred | 0.0572932 | 0.0032013 |
| Age_squared | 0.0001274 | 0.0001589 |
| Resp_preopmild COAD | 0.5395227 | 0.1054766 |
| Resp_preopDyspnoea: limiting or at rest | 1.2601628 | 0.1806783 |
| Sexfemale | 0.0280548 | 0.0298116 |
| Glasgow_cat3-8 | 0.7842625 | 0.0774343 |
| Glasgow_cat9-12 | 0.6355512 | 0.1150081 |
| Cardiac_preopCat[2] | 0.1054722 | 0.0341498 |
| Cardiac_preopCat[3] | 0.2655433 | 0.0522570 |
| Cardiac_preopCat[4] | 0.3017798 | 0.0960544 |
| peritoneal_soilingSerous fluid | 0.1727508 | 0.0380228 |
| peritoneal_soilingLocalized pus | -0.0837140 | 0.0620996 |
| peritoneal_soilingBowel content, pus, blood | 0.4387634 | 0.0392618 |
| pred_bloodloss101-500 | 0.0563362 | 0.0309755 |
| pred_bloodloss501-999 | 0.3148512 | 0.0681174 |
| pred_bloodloss>=1000 | -0.0278452 | 0.0886633 |
| malignancyPrimary | 0.0332072 | 0.0499288 |
| malignancyNodal metastases | 0.3666088 | 0.0701890 |
| malignancyDistant metastases | 0.9988459 | 0.0486032 |
| op_severityMajor+ | 0.2043578 | 0.0305716 |
| Numop_preopTwo | -0.2888454 | 0.0481143 |
| Numop_preopThree + | -0.1316191 | 0.1489059 |
| ECG_preopAF rate 60-90 | 0.3375291 | 0.0550434 |
| ECG_preopAF rate >90 or other | 0.1411111 | 0.0357890 |
| urgency6-18 hrs | -0.0617987 | 0.0510557 |
| urgency2-6hrs | 0.0787992 | 0.0502621 |
| urgency<2hrs | 0.4708663 | 0.0579594 |
| log_creat_wins | -0.3093507 | 0.0662349 |
| log_creat_sq_wins | 0.2428102 | 0.0392945 |
| log_urea_wins | 0.4227387 | 0.0369368 |
| log_urea_sq_wins | -0.0542346 | 0.0297218 |
| WBC_wins | -0.0072917 | 0.0024633 |
| WBC_sq_wins | 0.0013263 | 0.0001454 |
| pulse_wins | 0.0132113 | 0.0009678 |
| pulse_sq_wins | -0.0001264 | 0.0000285 |
| sysbp_wins | -0.0090343 | 0.0005978 |
| sysbp_sq_wins | 0.0001137 | 0.0000167 |
| potassium_wins | -0.0994759 | 0.0259147 |
| potassium_sq_wins | 0.1699467 | 0.0239506 |
| sodium_cubed_wins | -0.0007271 | 0.0000811 |
| log_sodium_timescu_wins | 0.0002304 | 0.0000256 |

(cont'd overleaf)

(Table 5 continued)

| | Estimate | Std. Error |
|--|------------|------------|
| nela_yearAudit Year 4 | 0.0282586 | 0.0347390 |
| nela_yearAudit Year 5 | 0.0199663 | 0.0346941 |
| ASA3:Age_centred | -0.0235901 | 0.0037685 |
| ASA4:Age_centred | -0.0276586 | 0.0036107 |
| ASA5:Age_centred | -0.0337041 | 0.0054304 |
| ASA3:Age_squared | -0.0001441 | 0.0001874 |
| ASA4:Age_squared | 0.0000669 | 0.0001787 |
| ASA5:Age_squared | 0.0002500 | 0.0002602 |
| ASA3:Resp_preopmild COAD | -0.1807609 | 0.1172194 |
| ASA4:Resp_preopmild COAD | -0.3157025 | 0.1184620 |
| ASA5:Resp_preopmild COAD | -0.3012922 | 0.1955989 |
| ASA3:Resp_preopDyspnoea: limiting or at rest | -0.5437609 | 0.1900075 |
| ASA4:Resp_preopDyspnoea: limiting or at rest | -0.8688040 | 0.1879180 |
| ASA5:Resp_preopDyspnoea: limiting or at rest | -0.9052032 | 0.2314529 |

Note: N = 73,924. For variable definitions and calculation of predicted risk see Table 5.

References:

Eugene N, Oliver CM, Bassett MG, *et al.* Development and internal validation of a novel risk adjustment model for adult patients undergoing emergency laparotomy surgery: the National Emergency Laparotomy Audit risk model. *Br J Anaesth* 2018;**121**:739–48. doi:10.1016/j.bja.2018.06.026

How to calculate NELA pre-operative predicted risk using the recalibrated coefficients – mathematical specification

Data preparation involves winsorisation and centering of continuous predictors as shown in Tables 2 and 3. Categorical variables are defined as in Table 4. The calculation of predicted risk of 30-day mortality is shown overleaf.

Table 2: Winsorised ranges of continuous predictor variables

| Physiological Risk factor | Median | Interquartile Range | Winsorised Range |
|--|--------|---------------------|-----------------------|
| Potassium (mmol/l) | 4.1 | 3.8 - 4.5 | 2.8 - 5.9 |
| Urea (mmol/l) | 6.3 | 4.4 - 9.7 | 0.0 - 3.7 (log scale) |
| White Blood Cell (x10 ⁹ /l) | 11.1 | 7.8 - 15.5 | 1.0 - 42.7 |
| Creatinine (umol/l) | 77 | 60 - 103 | 3.3 - 6.0 (log scale) |
| Sodium (mmol/l) | 137 | 134 - 139 | 124 - 148 |
| Pulse (bpm) | 90 | 79 - 103 | 55 - 145 |
| Systolic BP (mmHg) | 125 | 110 - 140 | 70 - 190 |

Table 3: Centering of continuous predictor variables

| | | | |
|-----------------|---------------------|-----------------|------------------|
| Age_cent | = Age - 64 | Creatinine_cent | = Creatinine - 4 |
| Pulse_cent | = Pulse - 91 | Urea_cent | = Urea - 1.9 |
| SystolicBP_cent | = Systolic BP - 127 | Potassium_cent | = Potassium - 4 |
| Sodium_cent | = Sodium - 123 | WBC_cent | = WBC - 13 |

Table 4: Category definitions for categorical variables

| | |
|----------------|---|
| Respiratory[2] | = Dyspnoea on exertion or CXR |
| Respiratory[3] | = Dyspnoea limiting exertion & at rest |
| Cardiac[2] | = Diuretic, digoxin, antihypertensive therapy |
| Cardiac[3] | = Peripheral oedema, warfarin therapy or CXR |
| Cardiac[4] | = Raised jugular venous pressure or CXR |

Table 5: NELA risk adjustment model recalibrated coefficients (July 2020)

Calculate for all patients

$$\begin{aligned}
 \text{PartA} = & 0.0280548 \times \text{Female} \\
 & + 0.1054722 \times \text{Cardiac}[2] + 0.2655433 \times \text{Cardiac}[3] + 0.3017798 \times \text{Cardiac}[4] \\
 & - 0.0617987 \times \text{Urgency}[6-18\text{hrs}] + 0.0787992 \times \text{Urgency}[2-6\text{hrs}] + 0.4708663 \times \text{Urgency}[<2\text{hrs}] \\
 & + 0.3375291 \times \text{AF rate}[60-90] + 0.1411111 \times \text{AF rate}[>90 / \text{abnormal rhythm}] \\
 & - 0.2888454 \times \text{Operations}[n=2] - 0.1316191 \times \text{Operations}[n>2] \\
 & + 0.2043578 \times \text{Operative severity}[Major+] + 0.0563362 \times \text{Blood loss}[101-500\text{ml}] \\
 & + 0.3148512 \times \text{Blood loss}[501-999\text{ml}] - 0.0278452 \times \text{Blood loss}[\geq 1000\text{ml}] \\
 & + 0.1727508 \times \text{Soiling}[Serous fluid] - 0.0837140 \times \text{Soiling}[Localised pus] \\
 & + 0.4387634 \times \text{Soiling}[Free bowel content, pus or blood] \\
 & + 0.0332072 \times \text{Malignancy}[Primary only] + 0.3666088 \times \text{Malignancy}[Nodal metastases] \\
 & + 0.9988459 \times \text{Malignancy}[Distant metastases] \\
 & + 0.6355512 \times \text{Glasgow coma score}[9-12] + 0.7842625 \times \text{Glasgow coma score}[3-8] \\
 & + 0.0132113 \times \text{Pulse_cent} - 0.0001264 \times \text{Pulse_cent}^2 \\
 & - 0.0090343 \times \text{SystolicBP_cent} + 0.0001137 \times \text{SystolicBP_cent}^2 \\
 & - 0.3093507 \times \text{Creatinine_cent} + 0.2428102 \times \text{Creatinine_cent}^2 \\
 & - 0.0994759 \times \text{Potassium_cent} + 0.1699467 \times \text{Potassium_cent}^2 \\
 & + 0.4227387 \times \text{Urea_cent} - 0.0542346 \times \text{Urea_cent}^2 \\
 & - 0.0072917 \times \text{WBC_cent} + 0.0013263 \times \text{WBC_cent}^2 \\
 & - 0.0007271 \times \text{Sodium_cent}^3 + 0.0002304 \times \text{Sodium_cent}^3 \times \log(\text{Sodium_cent})
 \end{aligned}$$

| For patients with ASA | Calculate Log odds of 30 day mortality as: |
|-----------------------|--|
| 1-2 | $ \begin{aligned} \text{Log (odds)} = & \text{PartA} - 4.3488269 \\ & + 0.0572932 \times \text{Age_cent} \\ & + 0.0001274 \times \text{Age_cent}^2 \\ & + 0.5395227 \times \text{Respiratory}[2] \\ & + 1.2601628 \times \text{Respiratory}[3] \end{aligned} $ |
| 3 | $ \begin{aligned} \text{Log (odds)} = & \text{PartA} - 4.3488269 + 1.0573609 \\ & + (0.0572932 - 0.0235901) \times \text{Age_cent} \\ & + (0.0001274 - 0.0001441) \times \text{Age_cent}^2 \\ & + (0.5395227 - 0.1807609) \times \text{Respiratory}[2] \\ & + (1.2601628 - 0.5437609) \times \text{Respiratory}[3] \end{aligned} $ |
| 4 | $ \begin{aligned} \text{Log (odds)} = & \text{PartA} - 4.3488269 + 1.8546010 \\ & + (0.0572932 - 0.0276586) \times \text{Age_cent} \\ & + (0.0001274 + 0.0000669) \times \text{Age_cent}^2 \\ & + (0.5395227 - 0.3157025) \times \text{Respiratory}[2] \\ & + (1.2601628 - 0.8688040) \times \text{Respiratory}[3] \end{aligned} $ |
| 5 | $ \begin{aligned} \text{Log (odds)} = & \text{PartA} - 4.3488269 + 2.6489194 \\ & + (0.0572932 - 0.0337041) \times \text{Age_cent} \\ & + (0.0001274 + 0.0002500) \times \text{Age_cent}^2 \\ & + (0.5395227 - 0.3012922) \times \text{Respiratory}[2] \\ & + (1.2601628 - 0.9052032) \times \text{Respiratory}[3] \end{aligned} $ |

Note: All coefficients are given to seven decimal digits.