

NELA parsimonious risk score for adult patients undergoing laparotomy after an emergency admission (Parsimonious Risk Score (PRS))

This document describes the construction of the NELA parsimonious risk score. This parsimonious risk score was implemented within the NELA database from 1st April 2023 and will be used to assess patient risk and hospital risk adjustment from this date. The previous NELA risk model should not be used after 1st April 2023. It was designed to predict 30-day postoperative mortality for adults who have a laparotomy after an emergency admission. It was developed and validated using data submitted to the National Emergency Laparotomy Audit (NELA) by NHS hospitals in England and Wales that covered emergency laparotomies between 1 December 2016 and 30 November 2019. Its performance was evaluated to ensure it produced accurate predictions for the heterogeneous mix of conditions (such as perforation, ischaemia, sepsis, bleeding or obstruction) that patients in this cohort might have. A full description of the development work is currently under peer review prior to journal publication.

The model was developed using information on 22 patient risk factors. The process employed to select the risk factors for the model balanced the need for accurate predictions and the desire for a limited burden of data collection. The model was designed to support decision making prior to surgery, and was therefore developed using the anticipated values for the intraoperative risk factors. In the final model, two intraoperative risk factors were included - (1) peritoneal soiling and (2) extent of malignancy – and users will need to enter anticipated values for these variables.

Some of the risk factors are transformed before being used in the model:

- Respiratory history, ASA physical status, and GCS score are re-categorised to deal with small numbers (see Table 1 for groups).
- The indications for surgery were categorised into five groups. The mapping of these is described in Table 2.
- Peritoneal soiling was re-categorised to whether or not a patient had “free bowel content, pus or blood”. This improved the agreement between the anticipated values (measured pre-operatively) and the actual intraoperative values.
- The values for urea, white blood cell count and creatinine are log-transformed because these risk factors are highly skewed.
- All physiological risk factors are Winsorised at the 1st and 99th percentile to deal with extreme values at one or both ends of their distribution. See Table 3 for Winsorisation limits

All continuous variables were modelled using a linear term or a linear and squared term.

Table 1: Categories used by the model for the three transformed categorical risk factors

| Patient risk factor | Categories |
|--------------------------------|---|
| Glasgow Coma Score | < 14 14 15 |
| ASA Physical Status | 1 or 2 3 4 5 |
| Respiratory history / Dyspnoea | None On exertion or CXR: mild COAD Limits exertion or at rest or CXR: moderate COAD/ fibrosis/ consolidation |

Table 2: Definition of clinical indication categories

| Clinical indication group | Indication for surgery (drawn from NELA database) |
|---------------------------|---|
| 1. Haemorrhage | Haemorrhage |
| 2. Obstruction | Small bowel obstruction, Large bowel obstruction Intestinal obstruction, Volvulus Incarcerated hernia, Internal hernia Obstructing incision hernia, Intussusception Pseudo obstruction, Foreign body |
| 3. Sepsis | Phlegmon, Pneumoperitoneum, Iatrogenic injury, Anastomotic leak Perforation, Peritonitis. Abdominal abscess, Intestinal fistula Other sepsis |
| 4. Ischaemia | Necrosis, Ischaemia, Acidosis, Colitis |
| Other | Wound dehiscence, Abdominal compartment syndrome Planned relook, Other |

The NELA dataset allows for multiple “Indication for surgery” values to be entered. If the indications lead to a patient being allocated to multiple indication groups, they should be allocated to the group with the highest number. For example,

- If indications fall into “2. Obstruction” and “3. Sepsis” groups, allocate the patient to “3. Sepsis”
- If indications fall into “4. Ischaemia” and “1. Haemorrhage” groups, allocate the patient to “4. Ischaemia”

Patients with an indication in the “other” subgroup should be treated as equivalent to the “obstruction” subgroup.

Table 3: Distribution of continuous physiological variables and the Winsorisation limits based on the 1st and 99th percentiles

| Variable | Median (Interquartile Range) in the 2018-19 patient cohort | Winsorised range (1 st and 99 th percentiles) |
|--|--|---|
| Albumin (g/l) | 35 (29 to 41) | 10 to 55 |
| Urea (mmol/l) | 6.2 (4.3 to 9.4) | 0.5 to 3.7 (log scale) |
| White blood cell count (x10 ⁹ /l) | 11.0 (7.8 to 15.2) | 0.8 to 3.6 (log scale) |
| Systolic blood pressure (mmHg) | 126 (110 to 140) | 70 to 190 |
| Pulse (beats per minute) | 89 (78 to 100) | 55 to 145 |

Model equation for predicting 30 day postoperative mortality

The model requires the data on 13 risk factors, all of which are routinely collected in clinical practice during the pre-operative period. The risk factors are:

| | |
|-------------------------|------------------------|
| Age | Anticipated malignancy |
| ASA grade | Dyspnoea |
| Albumin | Urgency |
| White Blood Cell count | Glasgow Coma Score |
| Urea | Indication for surgery |
| Heart rate | Anticipated soiling |
| Systolic blood pressure | |

We highlight several characteristics of the model:

- Five of the continuous variables are entered into the model after being centred (see table 4). For Urea and White Blood Cell count, this is done after the raw values has been transformed onto the log natural scale.
- The coefficients have been reported at the level of 5 decimal places. Using fewer decimal places will produce slightly different predictions.
- There is one interaction term that combines age and ASA grade.

When evaluated, the model demonstrated high levels of accuracy and retained its performance during an assessment of temporal validation, using data on patients undergoing emergency laparotomy in the UK between during December 2018 and November 2019. Although the cohort of UK patients is likely to be similar to emergency laparotomy patients in other countries, we recommend an assessment of the model's

calibration in other population-based cohorts before being used in other health care systems. The NELA team will assess the model's performance periodically to monitor whether re-calibration is required.

Table 4: Definition of centred continuous risk factors

| Centred variables | | | |
|--------------------------|---------------------|--------------|-----------------|
| Age_cent | = Age - 64 | LN Urea_cent | = LN Urea - 1.9 |
| Pulse_cent | = Pulse - 91 | LN WBC_cent | = LN WBC - 2.4 |
| SystolicBP_cent | = Systolic BP - 127 | | |

Category definitions

Respiratory[2] = Dyspnoea on exertion or chest x-ray: mild COAD

Respiratory[3] = Dyspnoea limits exertion or at rest, or chest x-ray: moderate COAD / fibrosis / consolidation

CALCULATE the following equation for all patients

$$\begin{aligned}
 \text{Logit (predicted risk)} &= -3.04678 \\
 &+ 0.06660 \times \text{Age_cent} \\
 &+ 1.13007 \times \text{ASA}[3] + 1.76293 \times \text{ASA}[4] + 2.55345 \times \text{ASA}[5] \\
 &- 0.03021 \times \text{ASA}[3] \times \text{Age_cent} \\
 &- 0.03356 \times \text{ASA}[4] \times \text{Age_cent} \\
 &- 0.04676 \times \text{ASA}[5] \times \text{Age_cent} \\
 &- 0.04323 \times \text{Albumin} \\
 &+ 0.01265 \times \text{Pulse_cent} - 0.00012 \times \text{Pulse_cent}^2 \\
 &- 0.00683 \times \text{SystolicBP_cent} + 0.00011 \times \text{SystolicBP_cent}^2 \\
 &+ 0.38002 \times \text{LN_Urea_cent} \\
 &+ 0.02041 \times \text{LN_WBC_cent} + 0.24153 \times \text{LN_WBC_cent}^2 \\
 &+ 0.41557 \times \text{GlasgowComaScore}[14] + 0.64480 \times \text{GlasgowComaScore}[3-13] \\
 &+ 0.19201 \times \text{Malignancy}[\text{Primary}] + 0.50610 \times \text{Malignancy}[\text{Nodal metastases}] \\
 &+ 0.94309 \times \text{Malignancy}[\text{Distant metastases}] \\
 &+ 0.35378 \times \text{Respiratory}[2] + 0.60700 \times \text{Respiratory}[3] \\
 &+ 0.03782 \times \text{Urgency}[6-18\text{hrs}] + 0.14779 \times \text{Urgency}[2-6\text{hrs}] \\
 &+ 0.57310 \times \text{Urgency}[\text{<2hrs}] \\
 &+ 0.02812 \times \text{Indication}[\text{Sepsis}] \\
 &+ 0.56948 \times \text{Indication}[\text{Ischaemia}] \\
 &- 0.40615 \times \text{Indication}[\text{Bleeding}] \\
 &+ 0.29453 \times \text{Soiling}[\text{Free bowel content, pus or blood}]
 \end{aligned}$$