Technical Appendix

Case ascertainment

Background

Case ascertainment is estimated, both nationally and for individual NHS organisations, by comparing the number of cases submitted to NELA with the number of cases found in the national administrative hospital datasets for the same time period. The source of this national hospital data for England is the Hospital Episode Statistics (HES) dataset; for Welsh patients, it is the Patient Episode Dataset for Wales (PEDW).

The following paragraphs describe how potential NELA cases are found in HES and PEDW. It is written for participating sites so that they can understand how NELA calculates the number of cases it expects to be submitted by the NHS organisation.

What are the HES and PEDW datasets?

When patients are admitted to an English or Welsh NHS hospital, some basic information about their stay in hospital is extracted from their medical notes.

- For English NHS hospitals, this is collated as part of the Commissioning Data Set (CDS) and is returned to the organisations as the Secondary Uses Service (SUS) dataset; an equivalent dataset (HES) is available for other organisations for research/planning purposes. For further details see https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics
- For Welsh NHS hospitals, the information is collated into the PEDW dataset. This is aligned with HES data to allow comparison. For further details see http://www.infoandstats.wales.nhs.uk/page.cfm?orgid=869&pid=40977

Both datasets contain similar information about admitted patients. This includes:

- Their age and sex
- The NHS organisation, dates of admission and discharge, the speciality managing the patient's care, and whether the admission was as an emergency or elective patient (known as mode of admission)
- Diagnosis fields (entered using International Classification of Diseases [ICD]-10 codes) that describe the conditions suffered by the patient, including the principal reason for admission as well as comorbid conditions
- Procedure fields (entered using Office of Population Censuses and Surveys [OPCS-4] codes) that describe what operative procedures were performed and on what date these occurred.

Finding cases in HES

The NELA team developed an algorithm to identify patients in HES/PEDW data who meet the NELA inclusion criteria. In summary, the criteria state NHS organisations should submit data to NELA on patients who are:

- Aged 18 years or more AND
- Either
    - underwent a major emergency abdominal procedure on the gastro-intestinal (GI) tract, or
    - returned to theatre for an emergency laparotomy after an elective GI procedure
- Some specific types of procedures / conditions are excluded (the precise criteria available from https://www.nela.org.uk/NELADocs).

As there is no single procedure code for an emergency laparotomy or laparoscopic procedure, the NELA team request extracts of HES and PEDW data for patients whose data suggest they might have had an eligible emergency laparotomy based on OPCS codes that correspond to the various types of procedures covered within NELA.

The extracts contain information about all admissions for the relevant patients within the requested time period:

- Each HES record represents a single episode of patient care under one speciality and English NHS hospitals can enter data on up to 24 procedures and 20 diagnoses in each HES record. Therefore, a single admission may consist of multiple records.
- Each PEDW record represents a single hospital admission and Welsh NHS hospitals can enter data on up to 12 procedures and 14 diagnoses in each PEDW record.

The algorithm to identify NELA patients in HES/PEDW uses various pieces of information including: mode of admission, ICD-10 diagnosis codes and the type (via OPCS codes) and date of procedures. The algorithm itself processes the basic HES/PEDW extract by following a number of steps:

1. An admission is excluded if the procedure fields do not contain any OPCS procedure codes that corresponded to a potentially valid emergency laparotomy. Admissions may not contain relevant OPCS codes as they are unrelated to NELA or may not contain any OPCS codes.
2. It flags admissions which contain eligible surgical procedure(s). The ICD-10 diagnosis codes listed as the primary diagnosis are used to distinguish between admissions that meet the inclusion criteria and those that are to be excluded. NB: A patient may have more than one emergency laparotomy (EL) over the time period included in the HES extract, and so this step produces only a provisional set of patients.
3. Within these admissions flagged as potential NELA patients, the algorithm identifies the various types of EL procedures that a person had, and uses the date fields to distinguish between the earliest eligible procedure from possible subsequent procedures.

As the time of operation is not captured in HES/PEDW, it is assumed that all procedures that occurred on the same date were performed during the same theatre visit.

Determining which procedures are valid:
It is possible for patients to have a combination of procedures during an emergency

laparotomy. To differentiate between the different types of procedure, and determine if the admission meets the NELA inclusion criteria, a procedure is labelled as one of four categories (tiers A, B, C and D):

- A: procedures involving excision of all/part of an organ (stomach/ bowel) or repair of a perforation
- B: procedures involving some form of bowel incision
- C: any other procedure in the EL OPCS code list, e.g. drainage, washout
- D: procedure codes consistent with an EL but which occur with a procedure that is outside the scope of NELA, e.g. repair of an abdominal aortic aneurysm.

Given the combination of OPCS codes in the HES/PEDW records, an admission is assigned the most major EL category listed above. For example, records that contained OPCS codes for tier A and tiers B and/or C on the same date would be allocated according to their tier A procedure; tiers B and C on the same date would be allocated to their tier B procedure.

The algorithm uses the recorded mode of admission to classify the initial procedure as elective or emergency. The earliest procedure in an emergency admission was classified as an emergency laparotomy if it met the above OPCS procedure criteria. For elective procedures, only eligible procedures on dates after the original procedure would be flagged as potentially within NELA.

Details of the potentially valid OPCS codes and ineligible ICD-10 diagnosis codes are available from the NELA website https://www.nela.org.uk/Audit-info-Documents#pt

Things to consider if the estimated case ascertainment looks odd

1. Limitations of HES/PEDW data:

Due to the nature of HES/PEDW data, the algorithm requires the following assumptions:

- Elective/emergency admissions are coded appropriately[1]
- The initial procedure during an emergency admission was performed as an emergency procedure[2]
- Subsequent procedures during an admission (either elective/emergency) are emergency procedures and not planned follow-up procedures[3]
- Multiple procedures listed on the same date occur during the same visit to theatre[4]
- Where multiple procedures with an equivalent tier group (see above) are listed on the same date, the one with the lowest operation number (most resource intensive) is defined as the most important procedure[5]
- The first ICD-10 diagnosis code listed in the diagnosis fields in the record containing an eligible procedure is an accurate description of the reason for the patient undergoing an emergency laparotomy[6]
- NELA is based on clinical diagnoses which may not be fully captured by OPCS/ICD10 coding

1, 2, 3: the method used to find procedures varies between elective and emergency

admissions
4: means that a return to theatre on the same date as an initial operation cannot be found
5, 6: different procedures or diagnoses are allocated in different ways therefore this may affect whether a procedure is considered an emergency laparotomy by the algorithm.

NB. All procedures with appendicitis in any diagnosis code field are excluded. This includes those with peritonitis as their first ICD-10 diagnosis code.

2. At hospital level:

Audit data submission:
- Are all eligible cases being entered onto the NELA database and locked prior to data deadline?

3. HES/PEDW submission:
- Is the admission method coded appropriately in your local hospital systems?
    - Are the same number of fields/clicks needed to admit elective and emergency patients onto the system? If not, the quicker method may be used inappropriately.
- Are OPCS procedure codes and their date, and ICD-10 diagnosis codes:
    - Accurately recorded in patient notes?
    - Accurately coded at hospital/trust level so that accurate information is included in HES?

It's not unusual for patient admissions in HES/PEDW to have no procedures recorded or invalid dates for procedures.

Case ascertainment for each hospital are shown in the RAG table. Hospitals with a low case ascertainment may not have provided enough information on enough patients for audit results to accurately reflect the quality of their patient care.

Data quality

The RAG table includes a 'data completeness' indicator in the hospital level reports to help local teams assess the quality of their own data. Clinical teams need to have confidence in the quality of their audit data; it needs to be accurate, complete, reliable, timely and ultimately fit for purpose if they are to be able to use it to support changing practice or processes of care.

How to improve data completeness:
- Teams can regularly check the real time data on the NELA webtool for how many, and which cases are 'locked' and submitted
- Using the webtool, teams should perform regular benchmarking exercises against local, AHSN and national level data
- Teams can find further details in the NELA quarterly and BPT reports for case ascertainment.

How we calculate adjusted mortality rates for hospitals

Hospital-level adjusted mortality rates were calculated in three steps:

(1) Establishing the number of deaths within 30-days, and calculating the unadjusted 30-day mortality rate nationally and for each hospital
(2) Estimation of preoperative risk of 30-day mortality for each patient and calculation of the average estimated risk in each hospital
(3) Calculating the adjusted mortality rate from the results of steps (1) and (2)

We will describe each of these steps in turn.

1. Unadjusted mortality rates

An essential outcome that NELA monitors for quality assurance is 30-day mortality: whether a patient is alive or dead 30 days after their emergency laparotomy. To measure this variable, we take account of two sources of information:

- NELA data contain information about procedure dates, in-hospital deaths, and dates of death.
- Death registration data, supplied by the Office for National Statistics (ONS) via NHS Digital, give information on deaths both in and out of hospital, as well as dates of death.

In most cases, the two sources agree regarding whether a patient is alive or dead 30 days after their procedure. However, patients can opt out of having their death registration data stored in national data sets, and so we don't receive death registration information on all patients. Moreover, some deaths are registered with a delay, and sometimes we don't learn about registered deaths until after the NELA annual report is published. We therefore take the following general approach:

- If, according to hospital data submitted to NELA, a patient died within 30 days of their emergency laparotomy, this was counted as 'dead at 30 days', except when the ONS data suggested a date of death later than 30 days after the operation.
- If a patient is alive at 30 days according to hospital data, or was discharged sooner than 30 days post-operation, and their death registration suggests a date of death within 30 days of their operation, this was counted as 'dead at 30 days'.
- In all other cases, the patient was considered 'alive at 30 days'.

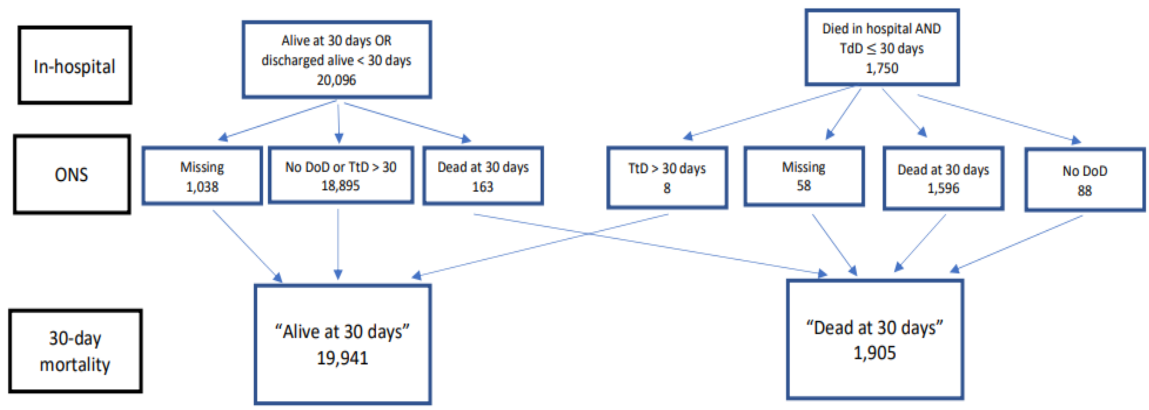
Figure 1 illustrates this approach, and shows its implementation for the data from NELA Year 7.

The national 30-day mortality rate after emergency laparotomy is calculated as the percentage of deaths. Taking the numbers from Figure 1, this gives:

$$National\ 30day\ mortality\ rate\ = \frac{1905}{19941 + 1905} = 0.0872 = \ 8.72\ \%$$

Each hospital's unadjusted 30-day mortality rate is calculated in the same way. For example, if Hospital X submitted records on 200 patients, and 16 of these patients died within 30 days of their surgery, then Hospital X's unadjusted mortality rate is 16/200 = 8%.

Figure 1. Calculating 30-day mortality



Notes: DoD: date of death; TtD: time to death in days from date of surgery. In-hospital: information from NELA data submitted by hospitals. ONS: Information from death registrations collated by the ONS. 30-day mortality: measure used in the analyses in this report.

2. Estimating preoperative patient risk

All patients' preoperative risk of 30-day mortality was estimated via logistic regression on all records from NELA Years 6 and 7 (after data cleaning, n = 47,060). Data from two audit years were used to make the estimation of risk more precise. An indicator variable for NELA year was included in the model to account for any change in the mortality rate between Year 6 and Year 7. Missing values in risk prediction variables were imputed using multiple imputation with chained equations (5 imputed data sets). Results are obtained from each of the 5 imputed data sets and then pooled using Rubin's rules (Carpenter & Kenward 2012). Risk predictors were all the variables and interactions contained in the NELA risk prediction model (Eugene et al 2018, see also: https://data.nela.org.uk/Support/NELA-Risk-Adjustment-Model.aspx?viewmode=0). In contrast to previous years, positive SARS-Cov-2 infection status was added to the NELA risk prediction model as an additional risk factor. No distinction was made between patients with known negative and unknown SARS-Cov-2 status, since there was little evidence that this distinction improved the prediction. The estimated coefficients from this risk prediction model are reported in Table 1.

Adjusting for individual patients' SARS-Cov-2 infection status does not in itself take into account all of the pressures that hospitals have faced in the COVID-19 pandemic. It was not possible to statistically account for such pressures in these analyses.

The risk prediction model (see Table 1) allows estimation of each individual patient's preoperative risk of 30-day mortality. For example, the first five patients in our example Hospital X might have predicted risks of 4.1%, 0.7%, 7.9%, 38.2%, and 2.6%. Based on these data, we can calculate an average predicted mortality risk for each hospital.

For example, the average risk of the first five patients in Hospital X would be:

$$Average\ mortality\ risk = \frac{(4.1\ +\ 0.7\ +\ 7.9 +\ 38.2 +\ 2.6)\%}{5} = \frac{53.5\ \%}{5} = 10.7\ \%$$

Given the average mortality risk in a hospital, we can calculate the statistically expected number of patient deaths in that hospital. "Statistically expected" here means the number of deaths we would be most likely to observe in that hospital if our risk prediction succeeds in precisely predicting each patient's real preoperative risk of 30-day mortality after emergency laparotomy.

For example, if the average mortality risk among all of the 200 patients at Hospital X is 10.7%, then the expected number of deaths is: 200 patients X 10.7% average risk = 21.4 expected deaths.

Table 1: Pooled coefficient estimates from a logistic regression of 30-day mortality on NELA risk model predictors and SARS-Cov-2 infection status (NELA Audit Years 6-7)

	Estimate	Std. Error
(Intercept)	-4.3148843	0.1121783
ASA3	0.9527064	0.0871760
ASA4	1.8212617	0.0909411
ASA5	2.6677245	0.1723157
Age_centred	0.0488918	0.0033770
Age_squared	0.0004813	0.0001607
Resp_preopmild COAD	0.5799901	0.1222721

Resp_preopDyspnoea: limiting or at rest	1.3166680	0.2077432
Sexfemale	0.0703091	0.0383618
Glasgow_cat3-8	0.6669217	0.0998047
Glasgow_cat9-12	0.7412319	0.1582264
Cardiac_preopCat 2	0.0902144	0.0437201
Cardiac_preopCat 4	0.2687196	0.0682833
Cardiac_preopCat 8	0.4713679	0.1210470
peritoneal_soilingSerous fluid	0.1452782	0.0486279
peritoneal_soilingLocalized pus	-0.1254716	0.0811418
peritoneal_soilingBowel content, pus, blood	0.4430220	0.0512301
pred_bloodloss101-500	0.0680091	0.0395378
pred_bloodloss501-999	0.1938820	0.0983679
pred_bloodloss≥1000	0.0479253	0.1183397
malignancyPrimary	0.1148833	0.0634536
malignancyNodal metastases	0.3982679	0.0877274
malignancyDistant metastases	0.9878043	0.0628898
op_severityMajor+	0.1495775	0.0393418
Numop_preopTwo	-0.2638588	0.0639843
Numop_preopThree +	-0.1095579	0.1997845
ECG_preopAF rate 60-90	0.3538834	0.0693984

ECG_preopAF rate >90 or other	0.1543539	0.0465541
urgency6-18 hrs	-0.0738275	0.0651201
urgency2-6hrs	0.0961799	0.0642183
urgency<2hrs	0.3998614	0.0755116
log_creat_wins	-0.1757347	0.0845003
log_creat_sq_wins	0.1627101	0.0503908
log_urea_wins	0.4146946	0.0466341
log_urea_sq_wins	-0.0134447	0.0375389
WBC_wins	-0.0071650	0.0031982
WBC_sq_wins	0.0012026	0.0001921
pulse_wins	0.0135672	0.0012445
pulse_sq_wins	-0.0001157	0.0000368
sysbp_wins	-0.0095176	0.0007658
sysbp_sq_wins	0.0001297	0.0000214
potassium_wins	-0.0754464	0.0333950
potassium_sq_wins	0.1951120	0.0311461
sodium_cubed_wins	-0.0008176	0.0001035
log_sodium_timescu_wins	0.0002616	0.0000327

(cont'd overleaf)

(Table 1 continued)

	Estimate	Std. Error
ASA3:Age_centred	-0.0157229	0.0042325
ASA4:Age_centred	-0.0236192	0.0039898
ASA5:Age_centred	-0.0219236	0.0072091
ASA3:Age_squared	-0.0005295	0.0002059
ASA4:Age_squared	-0.0004023	0.0001933
ASA5:Age_squared	-0.0002617	0.0003421
ASA3:Resp_preopmild COAD	-0.2707337	0.1384416
ASA4:Resp_preopmild COAD	-0.3997088	0.1410632
ASA5:Resp_preopmild COAD	-0.6568158	0.2704752
ASA3:Resp_preopDyspnoea: limiting or at rest	-0.6711253	0.2213940
ASA4:Resp_preopDyspnoea: limiting or at rest	-1.0010999	0.2187835
ASA5:Resp_preopDyspnoea: limiting or at rest	-1.0890044	0.2909945
nela_yearAudit Year 6	0.0100885	0.0373202
Covid positive Status	0.4396390	0.0970046

N = 47,060

3. Calculation of adjusted mortality rates

A hospital's adjusted mortality rate (AMR) is calculated as follows:

$$AMR = \frac{actual\ deaths}{expected\ deaths} \times National\ mortality\ rate$$

For example, if 16 patients died in Hospital X, the expected number of deaths was 21.4, and the national mortality rate was 8.72%, then the AMR for Hospital X is:

$$AMR = \frac{16}{21.4} \times 8.72 = 6.52$$

In this example, Hospital X has an AMR below the national average, because fewer patients died than statistically expected, given the average predicted patient risk. If more patients treated in a hospital die than statistically expected, then that hospital's AMR will be above the national average.

Outlier identification

Statistical outliers are identified by comparing hospitals' adjusted mortality rates with the national average. Some statistical (random) variation around the national average mortality is expected, so not every deviation from the national average is a cause for concern. Outlier identification is therefore based on the funnel plot methodology (Spiegelhalter 2005).

Hospitals are identified as 'alarms' if their adjusted mortality rate falls above the upper 99.8% control limit. This identifies hospitals whose adjusted mortality rate would be expected to be observed by chance in 1 out of 1,000 hospitals per year. The upper 99.8% control limit is approximately equivalent to being 3 standard deviations above the national average.

Hospitals are identified as 'alerts' if their adjusted mortality rate is above the upper 95% control limit, but below the 99.8% limit. This identifies hospitals whose adjusted mortality rate would be expected to be observed by chance in 1 out of 40 hospitals per year. The upper 95% control limit is approximately equivalent to being 2 standard deviations above the national average.

Hospitals are identified as 'positive outliers' if their adjusted mortality rate is below the lower 95% control limit.

Carpenter, James, and Michael Kenward. *Multiple imputation and its application*. John Wiley & Sons, 2012.

Spiegelhalter, David J. "Funnel plots for comparing institutional performance." *Statistics in medicine* 24.8 (2005): 1185-1202.