Public Health England

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Analysis Methods and Caveats for Quarterly Reports

For all data from October 2018 onwards

Contents

Rationale

Data for Q11-12 were the first to be entered into the new ICU DCS, which has slightly different question flows and validation rules. As a result, we have had to process denominator data in a different way compared to previous reports.

As these methods differ to the previous reports, we have applied the same processing steps to all quarters included in this report, so that you have a time series which has been processed in the same way. This may explain why your rates for the quarters in both this report and previous reports may be different.

De-duplication of positive blood culture episodes

Patient-episodes are defined as a 7-day period. If an episode with all of the same organisms within a single patient is entered ±6 days of an existing episode from the same patient, then the second episode is considered a duplicate. Patients are identified using NHS number, date of birth and intensive care unit. Episodes are then created based on patient and all organisms entered within an individual record. If more than one record is found within an episode, then the following steps are followed to identify which record to retain:

i. If specimen dates for the multiple within-patient-episode records were the same, the record with the fullest information is retained. If there was the same level of data entered for all records, then the record entered earliest (lowest ICU DCS ID number) will have been retained.
ii. For multiple within-patient-episode records where the specimen date is not the same (but is ±6 days of the earliest specimen date entered for that episode), the earliest record within the episode (lowest ICU DCS ID number) was retained.

Polymicrobial Infections

A polymicrobial infection is defined as multiple organisms grown from blood cultures taken on the same day. These could have been reported as multiple organisms grown in the same blood culture within the same ICU DCS record or from multiple blood cultures taken on the same date and reported as multiple ICU DCS IDs. In order to calculate the number of polymicrobial episodes within a unit-month, both types of record were used. As such, if a patient within Unit X had multiple organisms grow from the same blood culture, then this individual positive blood culture within a single ICU DCS ID will count as a single polymicrobial episode (n=1). However, if a patient within Unit X has three ICU DCS IDs with the same specimen date (but not the same organisms reported – as these were removed as part of our de-duplication algorithm, see above), all of these three positive blood cultures will be defined as a single polymicrobial episode (n=1).

Validation of denominator data

On the old ICU DCS, all denominator metrics had to be completed for the data to be saved. As such, it was possible to include in-built validation rules on the old system. These validation rules prevented the saving of illogical data. However, this also meant that a unit could only save data if it had all of the denominator data entered in one go.

Based on feedback received from stakeholders, we relaxed these data entry rules for both the daily and monthly ICU denominators as part of the new ICU DCS launch. In order to save a denominator record, ICU Data Entry users can enter any of the five denominator metrics and save the record.

As the new system can have any of the five metrics entered and the record saved, the validation rules that had previously been applied had to be removed from the new system. Only a warning could be provided if any of the data would have breached the set validation rules. This means that validation rules had to be manually applied to extracted data during analysis.

Below are the validation rules applied to both daily and monthly denominator data collections

1. Number of occupied patient bed-days in the unit cannot be less than the number of occupied patient bed-days in the unit when restricted to only include patients in the unit for >2 nights (i.e. ICU patient bed-days)
2. Number of occupied patient bed-days in the unit cannot be less than the number of occupied patient bed-days in the unit when restricted to only include patients with at least 1 CVC in place (i.e. CVC-days)
3. Number of occupied patient-days in the unit cannot be less than the number of occupied patient-days in the unit when restricted to patients in the unit for >2 nights with at least 1 CVC in place (i.e. ICU-CVC-days)
4. Number of occupied patient bed-days in the unit restricted to patients with at least 1 CVC in place (i.e. CVC-days) cannot be less than the number of occupied patient bed-days in the unit when restricted to only include patients in the unit for >2 nights with at least 1 CVC in place (i.e. ICU-CVC-days)
5. Number of occupied patient bed-days in the unit restricted to patients in the unit for >2 nights (i.e. ICU patient bed-days) cannot be less than the number of occupied patient bed-days in the unit when restricted to only include patients in the unit for >2 nights with at least 1 CVC in place (i.e. ICU-CVC-days)

Initially, these validation rules were applied separately to the daily and monthly census datasets. If a pair of values failed a validation rule (for example, if the number of occupied patient bed-days for patients in the ICU >2 nights exceeded the number of occupied patient bed-days for all patients), both values were dropped to be imputed in the next step.

The daily and monthly denominators were then merged to create an overall denominator dataset (see details below). Validation rules were again applied to this dataset. Missing denominator data were then imputed and validation rules were applied for a final time to the imputed data. However, if a validation rule was broken within the imputed dataset, then instead of dropping both data points, the following were applied

i. When two metrics breached the validation rules post-imputation, if one of these two metrics had been user-entered and the other imputed, then the user-entered data point was used to cap the imputed data point
ii. If; however, both data points were imputed, then the value which should have been the greater of the two was used to cap the other metric. For example, if the number of total occupied patient bed-days for Unit X was imputed to be 20 but the number of total CVC-days for Unit X for the same time period was imputed to be 25, then both metrics were capped at 20.

A final validation rule was applied, if the total number of blood culture sets entered for a unit and month was provided as zero; however, positive blood cultures were reported by the same unit and time period, the zero-value was deleted and imputed, as it would not be possible to have reported positive blood cultures if no blood culture sets had been taken for the same time period.

Merging of Daily and Monthly Census data collections

In order to calculate rates of positive blood cultures/blood stream infections (BSI)/CVC-BSI etc, we require both numerator data and denominator data. We require denominator data for each unit on a monthly basis; however, we are aware that units may not be able to calculate this easily from admission and discharge data and so units are able to provide these data on a daily or monthly basis. The new ICU DCS calculates a monthly value from any daily data entered, as follows:

Monthly value = (sum of daily values of metric/total number of days denominator data has been entered) x number of days in the month

However, currently, if a unit has entered blood culture sets taken on 20 days of a 30-day month but has entered occupied patient bed-days for all 30 days of the 30-day month, then the system-calculated value for blood culture sets will be an underestimate, as the average value for the month will be divided by 30 and multiplied by 30, as there are 30 denominator day entries for the unit. As such, we have manually re-calculated data where this has occurred so that the correct values can be used within this report. If only monthly totals have been provided by a unit, then these data have been used. However, if the monthly total was created via the Daily Unit Census, then the following rules have been applied to the data.

1. Daily census data were recalculated based on the number of days each denominator metric were entered, rather than the number of days for which any of the five denominator metrics were entered onto the system
2. Monthly Census values were used in rate calculations unless the following occurred
    a. A unit had informed us in writing that the Daily Census data should be used instead
    b. The monthly data were calculated by the ICU DCS based upon the daily collection and the total number of days denominator data had been entered for a specific metric was not the same as the total number of days that the ICU DCS had used to calculate the denominator data for that metric.

Imputation

Participating ICUs provide both positive blood culture data on a patient-level per month (numerator) and various denominator values at a unit-level either by a daily or monthly unit census. When the numerator and denominator datasets are brought together, there can be a mismatch in which time periods have been completed for which data collection.

When denominator data have been entered but no positive blood cultures, it is assumed that there were no positive blood cultures for that unit-month (i.e. there was a “nil-return”). Numerator data are never imputed.

However, when positive blood cultures have been reported by a unit but denominator data are missing for the same time period, we impute the denominator data from other denominator data entered for the same unit. In addition, where data have been deleted based on breached validation rules, or we have been informed of an error in a designated time period, we also impute data for these affected time periods.

We impute each denominator metric individually. For any missing denominator metric-month, the algorithm searches for data to use for imputation in a three-step hierarchy. If the algorithm cannot find data to use for a particular step in the hierarchy, it moves to the next step.

1. If data for a denominator metric was provided by the unit for the same month that is missing but for the previous year, then this data point is used to impute the missing denominator metric-month.;
2. If data for a denominator-metric was provided by the unit for a previous month, then the data from the most recent previous month is used to impute the missing denominator metric-month;
3. If data for a denominator-metric was provided by the unit for a "future" month, then the data from the from the most recent future month is used to impute the missing denominator metric-month.

The algorithm does not use any values that have already been imputed to further impute other missing denominator metric-months down the line.

One the initial imputation has been completed, the data are assessed for unusually high or low values for a given metric-month. Any metric-month that exceeds a 100% change (in either direction) from the previous month is flagged, along with the previous month. The flagged values are then assessed in the context of all provided data for that metric by the unit and the value(s) dropped if they do not fit in with the rest of the time series. The imputation is then run again using the baseline data so that the months with excluded values for a given metric can have these values imputed. The post-imputation data check is performed again to confirm that the newly imputed data doesn't have any unusual values in it. In some cases, it was the initial imputation that caused the unusual values as an older value was used, as per the hierarchical selection of provided data for imputation, which may not reflect a capacity/activity change within the unit. As such, one of the later data selection steps (i.e. most recent "future" month) is selected for base data for such imputation.

Units who have not supplied any denominator data for a particular denominator metric, cannot have this metric imputed for them. As such, rates which require this denominator metric cannot be calculated. Furthermore, these units have their numerator data excluded when calculating unit type (adult, paediatric and neonatal) values (counts and rates) in order to not overestimate these data. **NB.** Some units will have provided some but not all denominator metrics, this means that there will be different numbers of units that contribute to the unit-type overall totals and rates.

Definitions applied to the numerator data

Blood stream infections (BSIs)

Table A1: Criteria for case definitions for bloodstream infections in adults and paediatrics

Adults (≥13 years)	Paediatrics (<13yrs)
Meets one of the following criteria:	***Meets one of the following criteria:***
a) A recognised pathogen from at least one blood culture	a) A recognised pathogen from at least one blood culture
OR	**OR**
b) A common skin microorganism* from 2 blood cultures drawn on separate occasions and taken within a 48hr period **AND** The patient has at least ONE symptom of fever >38°C, chills or hypotension	**b)** A common skin microorganism* from 2 blood cultures drawn on separate occasions and taken within a 48hr period **AND** The patient has at least TWO symptoms of paediatric SIRS[1]: tachycardia, bradycardia (<1yr), temperature >38.5°C <36°C, elevated respiratory rate, leukocytes (elevated/depressed for age), leukocyte count (if leukocyte is selected)

* include diphtheroids (*Corynebacterium* spp.), *Bacillus* (not *B. anthracis*) spp., *Propionibacterium* spp., coagulase negative *staphylococci* (including *S. epidermidis*), viridans group *streptococci*, *Aerococcus* spp. and *Micrococcus* spp.

[1]The presence of at least TWO of the following four criteria (one of which must be abnormal temperature or leukocyte count):

- Tachycardia defined as a mean heart rate >2SD above normal for age in the absence of external stimulus, chronotropic drugs or painful stimuli
- For children <1 year old bradycardia defined as a mean heart rate <10th percentile for age in the absence of external vagal stimuli, beta blocker drugs or congenital heart disease
- Core temperature of >38.5 or <36 degrees Celsius
- Mean respiratory rate >2SD above normal for age or mechanical ventilation for an acute process not related to underlying neuromuscular disease or receipt of general anaesthesia
- Leukocyte count elevated or depressed for age (not secondary to chemotherapy induced leukopenia) or >10% immature neutrophils

Table A2: Criteria for case definitions for bloodstream infections in neonates

Neonates (<28 days)
Meets one of the following criteria:
a) A recognised pathogen from at least one blood culture **OR** b) A common skin microorganism* is cultured from blood AND Patient has ONE of: C-reactive protein >2.0 mg/dL immature/total neutrophil ratio (I/T ratio) >0.2 leukocytes <5/nL platelets <100/nL
AND
At least TWO of: temperature >38°C or <36.5°C or temperature instability tachycardia or bradycardia apnoea extended recapillarisation time metabolic acidosis hyperglycaemia other sign of BSI such as apathy

Table A3: Criteria for Neonatal Data Analysis Unit Definition

Neonates (<28 days): Neonatal Data Analysis Unit Definition[2]
Meets one of the following criteria:
a) A single recognised pathogen from at least one blood culture
OR
b) Growth of mixed organisms or skin commensals* **AND** Three or more predefined clinical signs: • Increase in apnoea or bradycardia • Temperature instability • Impaired peripheral perfusion (CRT > 3s pallor/mottling/core-peripheral temp gap >2°C) • Metabolic acidosis/base deficit < -10mmol/L • Lethargy/irritability/poor handling • Increased oxygen requirement or ventilator support • Ileus/onset of feed intolerance • Fall in urine output • Hypotension • Glucose intolerance

* include diphtheroids (*Corynebacterium* spp.), *Bacillus* (not *B. anthracis*) spp., *Propionibacterium* spp., coagulase negative *staphylococci* (including *S. epidermidis*), viridans group *streptococci*, *Aerococcus* spp. and *Micrococcus* spp.

Lower values for heart rate, leukocyte count and systolic BP = 5th percentile; upper values for heart & respiratory rate, leukocyte count = 95th percentile

†NDAU Definitions for catheter association BSI accessed 15th April 2016: https://www1.imperial.ac.uk/resources/99F3B656-C321-4881-8E24-EA1F4355B276/definitionforcabsiv3.pdf

[2] NDAU Definitions for catheter association BSI accessed 15th April 2016: https://www1.imperial.ac.uk/resources/99F3B656-C321-4881-8E24-EA1F4355B276/definitionforcabsiv3.pdf

ICU-associated bacteraemia

Date of positive blood culture > 2 days (or >48 hours, if ICU admission time and ICU specimen time provided) after date of ICU admission (where the date of ICU admission is day 1).

Central venous catheter-bloodstream infection

I. Catheter-associated BSI (CABSI)

Table A4: Criteria for defining catheter-associated BSI (CABSI)

Meets ALL of the following criteria:
a) One of the criteria for bloodstream infection
AND
b) The presence of at least one central venous catheters at the time of the positive blood culture, or CVC removed within 48 hrs before positive blood cultures
AND
c) The signs and symptoms, and the positive laboratory results, including pathogen cultured from the blood, are not primarily related to an infection at another site

II. Catheter-related BSI (CRBSI)

Table A5: Criteria for defining catheter-related BSI (CRBSI)

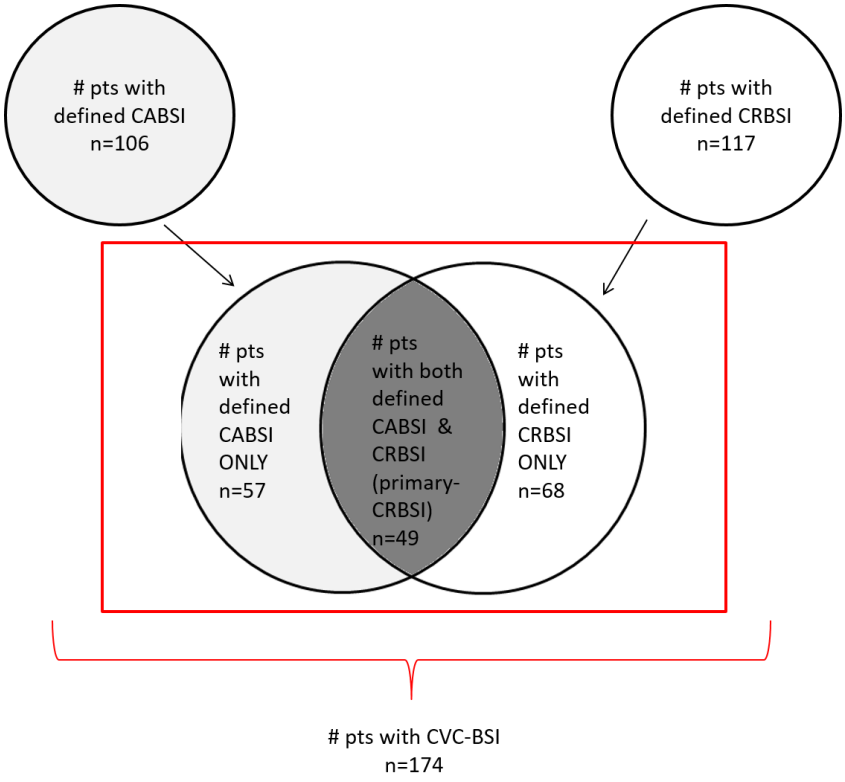
Meets ALL of the following criteria:
a) One of the criteria for bloodstream infection
AND
b) The presence of at least one central venous catheters at the time of the positive blood culture **or** CVC removed within 48 hrs before positive blood cultures
AND
c) At least <u>one</u> of the following where the same culture was identified: i. quantitative CVC culture ≥10^3 CFU/ml or semi-quantitative CVC culture >15 CFU ii. quantitative blood culture ratio CVC blood sample/peripheral blood sample >5 iii. differential delay of positivity of blood cultures: CVC blood sample culture positive 2 hours or more before peripheral blood culture (blood samples drawn at the same time) iv. positive culture with the same micro-organism from pus from insertion site v. symptoms improve within 48hr of removal of CVC

III. CVC-BSI

CABSI and CRBSI definitions share (a) and (b) (Tables A4 and A5), it is only (c) in which they differ. Once parts (a) and (b) are met, to then meet the CRBSI definition one of multiple microbiological corroborating factors must be met or the removal of the CVC results in improvement of symptoms. However, to meet the CABSI definition no other potential source of the BSI must be present. These definitions are not mutually exclusive but are dependent on the data that are available for each

patient. As such, a BSI episode could be defined as both CABSI and CRBSI, CABSI but not CRBSI or CRBSI but not CABSI.

Therefore, a collective term of CVC-BSI is also used, which is a collective term for CABSI and/or CRBSI. As CABSI and CRBSI are not mutually exclusive, CVC-BSI are not simply the sum total of CABSI and CRBSI. For example:



Rate Calculations

Counts of the various numerator definitions and denominator data were aggregated to totals per quarter for each unit. In addition, values were aggregated by unit type (i.e. adult, paediatric and neonatal) for each quarter, to provide a benchmark for your unit. Units missing all denominator data required for a particular rate calculation were excluded from the unit type numerator aggregation, so not to overestimate the unit type counts and rates. For example, Unit X is an adult unit and provided some data for the total number occupied patient bed-days; however, they did not provide any data for the total number of ICU patient bed-days. As such they have rates calculated for total positive blood cultures per 1,000 patient bed-days and blood stream infections per 1,000 bed days, but not for total number of ICU-associated blood stream infections per 1,000 ICU-bed-days. Therefore, their total number of positive blood cultures and blood stream infections have been included in the overall adult total positive blood cultures and blood stream infections; however, their total ICU-associated blood stream infection count was removed from the calculation of total ICU-associated blood stream infections as their unit-denominator data for ICU-bed-days was missing and could not be included in the adult ICU-bed-days aggregation.

Rates for individual units, and unit types, were calculated using the following formula:

Rate = (numerator / denominator) x scalar value of 1,000