

PICANet detection and management of potential outliers

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Document History

Version	Author	Date	Comments
1.0	Hannah Buckley	03/05/2019	Based on an amalgamation of earlier (un-versioned) policies from 2005 and 2015 created by Gareth Parry and Roger Parslow, taking into account HQIP guidance
2.0	Hannah Buckley	14/03/2022	<p>Expansion of management of potential positive and negative outliers section to add clarity and ensure is in line with minimal national standards.</p> <p>Numerous updates, and minor corrections / clarifications to phrasing / typography.</p> <p>Removal of some extraneous detail (such as on case ascertainment) either entirely or to Appendices.</p> <p>‘Alert’ status updated to be based on SMR and funnel plot analysis for most recent single year of data.</p> <p>Notification that RSPRT plots may be presented in the Annual Report from 2022.</p> <p>Updating of PICU metric targets in Appendix A Table 1 to be based on 2021/2022 PICU Metric Definitions and/or PCCS Standard 2021 as appropriate.</p>
2.1	Chris Leahy	27/09/2022	Management of SMR positive potential outliers brought in line with process established in v2.0 for managing negative outliers. Updated management process for UK nations and ROI and key metrics.

This policy is reviewed and updated biennially as a minimum; it is recommended that the policy be reviewed on an annual basis prior to the analysis for the PICANet Annual Report.

Next review date	Reviewed by	Date
Oct 2021	HB	14/10/2021
Sep 2022	CL	27/09/2022
Sep 2023		

1 Introduction

PICANet is part of the National Clinical Audit and Patient Outcomes Programme (NCAPOP), for England, established to monitor and review outcomes of treatment episodes, amongst other objectives. As part of this monitoring and review process we identify healthcare providers whose performance falls outside defined limits, referred to as outliers, which may reflect poorer or better performance. In this document, the term healthcare provider is used to refer to designated level 3 paediatric intensive care units (PICUs), or, where the metric relates to transport, centralised transport services (CTS) / Specialist Paediatric Transport Services (SPTS). This policy details the identification and management of potential outliers for healthcare providers who submit data to PICANet.

Outlier detection should be based on a valid performance indicator which has a clear relationship between the indicator and quality of care, and relates to events that occur frequently enough to give statistical power (1). Choice of expected performance level (or target) needs careful consideration. Furthermore, it is possible to base targets on external sources such as the Paediatric Critical Care Society (PCCS) Standards¹ (2) or the NHS England Specialised Services PICU Quality Dashboard 2021/2022 (6), or to base them on internal data, such as average performance of all healthcare providers.

This document considers which performance indicators could be used to identify healthcare providers that are performing outside of an expected range and documents the process to be followed after a potential outlier has been identified.

¹ Please note that the Paediatric Critical Care Society use to be called Paediatric Intensive Care Society (PICS).

2 Choice of performance indicator

PICANet currently reports annually on the following key metrics in relation to healthcare provider performance:

- Case ascertainment and timeliness of data completeness
- Critical care emergency transport mobilisation times
- Unplanned extubations in PICU
- Emergency readmission within 48 hours
- Risk-adjusted in-PICU mortality

Whilst all the measures considered are useful in terms of the wider audit, on consideration of the information documented, it is felt at present that risk-adjusted mortality is the only suitable performance indicator for outlier detection. Appendix A Table 1 shows details of how this decision was reached based on the PICANet team's current assessment of relative merits of detecting potential outliers based on each of the above outcomes.

3 Statistical methods for outlier detection

3.1 Data cleaning prior to outlier exploration

PICANet undertake detailed data cleaning prior to any analysis. Additionally regular validation emails are circulated to PICUs which include identification of data quality issues on a more real time basis. In brief, this includes examining relevant fields (such as PIM data and mortality information), for: completion rates; values being within range; and outstanding database validations. Where appropriate, queries are sent to the data provider to confirm or amend their data. For transparency, PICANet publish data completeness and case ascertainment in the Annual Report.

If a provider has more than 5% of its admission events (within a reporting period) with missing or unknown status at discharge (rather than alive or dead), then the relevant PICANet lead for the provider will be given written notification that their data completeness on this field requires improvement. The provider should review their data and correct any inaccuracies or provide further information where possible. If, following this, a provider continues to have missing or unknown status at discharge for more than 5% of its admission events, it will be considered for exclusion from the outlier analysis on the basis of poor data quality. Such status will be reported to the provider Clinical Lead and to the Care Quality Commission (CQC) as part of the National Clinical Audit Benchmarking (NCAB) Programme submission, and will be publically available through documentation in the PICANet Annual Report.

3.2 Methods for monitoring mortality

PICANet uses two main methods for monitoring mortality:

- 1) Risk-adjusted resetting probability ratio test (RSPRT) plots providing monitoring on a 'real-time' basis;
- 2) Risk-adjusted standardised mortality ratios (SMRs) calculated annually.

3.2.1 RSPRT plots and interpretation

In addition providers are able to access PICU specific risk-adjusted mortality data in real time via risk-adjusted resetting probability ratio test (RSPRT) plots (3). RSPRT plots present PIM3-adjusted mortality data on a cumulative basis allowing trends in mortality to be seen. Unlike SMRs which provide a comparison between observed and expected mortality, RSPRT plots are based on the cumulative log-odds of mortality; summation of the log-odds begins in 2016 (when PIM3 was routinely collected in all participating units) and continues until the plot resets, at which point the cumulative log-odds are reset to zero and summation restarts.

The RSPRT plot is presented in two halves: the cumulative log-likelihood of the odds of mortality doubling is plotted on the top half of the graph (indicating that odds of mortality in a given unit are higher than expected) and the cumulative log-likelihood of the odds of mortality halving is plotted on the bottom half of the graph (indicating that odds of mortality are lower than expected). Two sets of control limits are used, indicated by two pairs of lines with less stringent threshold limits displayed as an orange line and more stringent limits as red lines. If either half of the graph crosses a red threshold line then further investigation is required. Providers are prompted to review their RSPRT plot on a quarterly basis. The interpretation and action required by PICUs are based on three possible scenarios which are detailed in PICANet's RSPRT guidance for units document.

RSPRT plots provide an indication that a provider may be heading towards becoming an outlier (positive or negative), but do not mean that a provider will necessarily be identified as a potential outlier in the formal outlier analysis which is based on standardised mortality ratios. From 2022, RSPRT plots may be published in the PICANet Annual Report in specific cases; providers will be notified prior to publication via email if this is the case.

3.2.2 Standardised Mortality Ratios (SMRs)

Risk-adjusted standardised mortality ratios (SMRs) are estimated for each PICU on an annual basis; risk-adjustment is undertaken via a recalibrated Paediatric Index of Mortality Version 3 (PIM3) (4).

Risk-adjusted SMRs compare the number of observed deaths in PICU with the number of deaths expected based on the specific case-mix for that unit. An SMR of one indicates that the number of observed deaths were equal to the number of expected deaths; an SMR of greater than one indicates more deaths were observed than expected; and, an SMR of less than one indicates fewer deaths were observed than expected.

The SMRs are presented graphically via funnel plots (5), which, in brief, plot the risk-adjusted SMRs on the y-axis against the number of admissions on the x-axis. Control limit lines show the range of expected values for each unit's SMR assuming mortality is within the expected range and taking into account the inherent variability in mortality and the precision of each SMR estimate. Points falling outside of the control limits indicate either unusual excess mortality (for those falling above the upper limit), or unusual low mortality (for those falling below the lower limit). Control limits of 99.9% are set around the target performance (an SMR of one) for each provider on the associated funnel plot; these take into the account the number of admissions each unit has and the increased uncertainty a small number of admissions brings inherently into the calculations. PICANet do not present 95% control limits due to the impact of multiplicity on false identification rate (see Appendix B for further detail).

3.3 Formal outlier analysis

Detection and management of potential outliers is undertaken for all PICUs providing data to PICANet (i.e. NHS and private PICUs in England and Wales, and PICUs in Scotland, Northern Ireland, and the Republic of Ireland) following the process outlined in this policy and is based on risk-adjusted standardised mortality ratios and associated funnel plots.

The formal outlier analysis includes admissions to participating PICUs for children aged 0-15 years within the three-year reporting period unless otherwise stated; patients aged 16+ or of unknown age are excluded from this analysis as PIM3 (4) was devised and validated on this 0-15 year old population.

3.3.1 Identification of a potential positive or negative outlier – 'alarm' status

Any provider which falls below the lower control limit or above the upper control limit would be considered a potential outlier and would trigger an 'alarm' status requiring further investigation through our outlier management plan (see Section 4).

3.3.2 'Alert' status

The outlier analysis will be repeated including admissions to participating PICUs for children aged 0-15 years within the most recent year of the reporting period only. Any provider which falls outside the upper or lower control limit in this analysis would have an 'alert' status raised and would be informed of this. The provider will be advised to review the completeness and quality of their PIM and discharge status data and will be advised to closely review and monitor mortality within their unit. This analysis is likely to include smaller numbers of admissions (given only one year's worth of data is considered) and hence lower precision will be seen in SMR estimates, therefore confidence intervals should be considered in conjunction with control limits.

4 Management of potential outliers

If a provider is identified as a potential positive or negative outlier in the formal outlier analysis (see Section 3.3.1), then appropriate management is required to confirm this status.

Whilst the identification of negative outliers is of utmost immediate importance, it is also necessary to identify positive potential outliers in order to acknowledge excellent performance where appropriate. Bodies like the CQC can use positive outliers as examples of good practice and to inform inspections.

Table 1 shows actions, responsibilities and timelines upon detection of a potential outlier and is adapted from HQIP guidance (1). This process must be followed for all providers identified as a potential outlier (whether positive or negative).

Table 1: Potential outlier management details

Stage	What action?	Who?	Timelines
1	<p>PICANet internal checks</p> <p>Providers with a performance indicator 'alarm' (i.e. identified as a potential outlier) require careful scrutiny of the data handling and analyses performed by PICANet. Internal checks should include, but are not limited to:</p> <ul style="list-style-type: none"> • Validation of statistical programs to check for bugs and/or programming errors • Review of provider data quality and completeness for relevant fields (including PIM variables and unit discharge status) • Review of data to identify any potential drivers for the potential outlier status, errors and/or potential data collection periods of interest, for example, where there changes over the reporting period in: <ul style="list-style-type: none"> ○ case-mix of patients; ○ observed deaths; ○ expected deaths; 	PICANet	Within 10 working days

Stage	What action?	Who?	Timelines
	<ul style="list-style-type: none"> ○ SMR; ○ data quality; ○ missing data; ○ primary reason for PICU admission; or, ○ age distribution of patients. <p>Checks should be made for errors, suitability of risk-adjustment, systematic data collection issues.</p> <p><u>Outlier status not maintained</u> - potential outlier status is not confirmed, data and results are updated and details formally recorded.</p> <p><u>Outlier status maintained</u> – potential outlier status remains. Proceed to Stage 2.</p>		
2	<p>Provider notified of potential outlier status</p> <p>The Lead Clinician at the provider organisation should be informed by phone of the potential outlier status. This must be followed up by a letter formally notifying the provider.</p> <p>The formal letter will include a request for a written response (Stage 3) to:</p> <ul style="list-style-type: none"> • Confirm the accuracy and completeness of data submitted to PICANet • Provide any justifiable explanation(s) for the potential outlier status. <p>All relevant data and analyses will be made available to the Lead Clinician to assist with this.</p> <p>A copy of the letter should be sent to the provider organisation CEO and Medical Director (after the Lead Clinician has been informed).</p>	PICANet Co-PIs & Senior Statistician	Within 5 working days

Stage	What action?	Who?	Timelines
3	<p>Provider response to notification</p> <p>Lead Clinician to respond to the notification correspondence. The response should include:</p> <ul style="list-style-type: none"> • Details of data checks undertaken, whether inaccuracies or missing data were found and any action taken to address data issues. • Confirm that data submitted was complete, accurate and validated (specifically in relation the PIM variable and discharge status). • Any justifiable explanations for the potential outlier status • Any other information deemed relevant or pertinent <p>A copy of the response should be sent to the provider organisation CEO and Medical Director by the Lead Clinician.</p>	Provider Lead Clinician	Within 25 working days
4	<p>PICANet review of response</p> <p>PICANet to undertake review of Lead Clinician's response to determine:</p> <p><u>Outlier status not maintained</u> - original data confirmed as containing inaccuracies and re-analysis no longer indicates outlier status. In this case, data and results are updated and details formally recorded by PICANet and the Lead Clinician is notified in writing, copying in provider organisation CEO and Medical Director. Lead Clinician is asked to respond with reasons why the original data was inaccurate and what processes have been put in place to mitigate the risk of this occurring again in the future.</p>	PICANet	Within 20 working days

Stage	What action?	Who?	Timelines
	<p><u>Outlier status maintained</u> – Confirmation of statistical outlier status</p> <p>Original data confirmed as containing inaccuracies but re-analysis still indicates outlier status <u>OR</u> original data confirmed as accurate confirming the initial designation of outlier status. Proceed to Stage 5.</p>		
5	<p>Provider notified of confirmed statistical outlier status</p> <p>Lead Clinician contacted by telephone and notified of confirmed statistical outlier status. This must be followed up by a letter formally notifying the provider CEO of the status (copied to the Lead Clinician and Medical Director).</p> <p>The formal notification will contain:</p> <ul style="list-style-type: none"> • Confirmation of statistical positive/negative outlier status • All relevant data and statistical analyses, including previous response from the Lead Clinician • Advance notice for the CEO that PICANet will be publishing information of comparative performance that will identify providers • Notice that PICANet will be contacting relevant bodies (as detailed below based on location of provider) • Advice on which relevant bodies the CEO needs to inform (as detailed below based on location of provider) • Advice that the Medical Director and Lead Clinician should initiate a review • A request for acknowledgement of receipt of the letter and confirmation that a review will be undertaken <p>The provider can share the confirmed statistical outlier status in confidence with individuals within their regional network but not</p>	PICANet Co-PIs	Within 5 working days

Stage	What action?	Who?	Timelines
	<p>with other colleagues outside of the network until the PICANet Report is published.</p> <p>Relevant bodies informed (based on where PICU is located):</p> <p><u>England:</u></p> <ul style="list-style-type: none"> • PICANet to inform CQC and HQIP* • PICANet advise provider CEO to inform commissioners, NHS Improvement and Royal College of Paediatrics and Child Health. <p>N.B. For non-NHS PICUs, PICANet would not inform HQIP</p> <p><u>Wales</u></p> <ul style="list-style-type: none"> • PICANet to inform the Welsh Government, the Welsh Health Specialised Services Committee and Healthcare Inspectorate Wales. • PICANet advise provider CEO to inform commissioners, Improvement Cymru and Royal College of Paediatrics and Child Health. <p><u>Scotland</u></p> <ul style="list-style-type: none"> • PICANet to inform National Specialist and Screening Directorate (NSD), NHS National Services Scotland and Healthcare Improvement Scotland. • PICANet advise provider CEO to inform commissioners, and Royal College of Paediatrics and Child Health. <p><u>Northern Ireland</u></p> <ul style="list-style-type: none"> • PICANet to inform Health and Social Care (HSC) Strategic Planning and Performance Group of the Department of Health (SPPG) and The Regulation and Quality Improvement Authority (RQIA). 		

Stage	What action?	Who?	Timelines
	<ul style="list-style-type: none"> PICANet advise provider CEO to inform commissioners, Health and Social Care Quality Improvement (HSCQI) and Royal College of Paediatrics and Child Health. <p><u>ROI</u></p> <ul style="list-style-type: none"> PICANet to inform National Office of Clinical Audit (NOCA). PICANet advise provider CEO to inform commissioners and relevant Royal Colleges. 		
6	<p>Provider CEO to provide acknowledgement of receipt</p> <p>Acknowledgement of receipt sent from provider CEO to PICANet.</p> <p>The acknowledgement should confirm that:</p> <ul style="list-style-type: none"> Relevant bodies will be informed as required based on location of provider An investigation will be undertaken <p>As a minimum, the investigation should be local with independent assurance of the validity of this exercise; it is strongly recommended that a member of the PICANet Clinical Advisory Group (CAG) is consulted. Ideally, the investigation would be independent of the provider and undertaken by an expert panel of clinicians. It is desirable that the investigation is concluded prior to publication of the next annual report; therefore the investigation should be commissioned within three months of being confirmed a statistical outlier, and completed within six months of commissioning.</p> <p>It is the responsibility of the organisation involved to obtain and fund this review and to ensure that the information governance surrounding the exercise is in place. The provider should</p>	Provider CEO**	Within 10 working days

Stage	What action?	Who?	Timelines
	<p>share the findings of the review with PICANet and may also share it with Commissioners, relevant regulators and Quality Improvement bodies based on location of provider.</p> <p>Proceed to Stage 8</p> <p>If <u>no acknowledgement of receipt</u> provided to PICANet within 10 working days proceed to Stage 7.</p>		
7	<p>Reminder letter sent to CEO (if required)</p> <p>If no acknowledgement is received within 10 working days, a reminder letter should be sent to the CEO copying in the national organisations that PICANet notified in Stage 5 based on location of provider.</p> <p>If no response is received within 5 working days of the reminder letter, then notification of non-compliance should be reported by PICANet to the national organisations in Stage 5 based on location of provider.</p>	PICANet	Within 5 working days
8	<p>Publication</p> <p>Public disclosure of comparative information that identifies providers (e.g. PICANet annual report, data publication online).</p>	PICANet	N/A

* Inform HQIP via email prior to, or at the same time as, notifying CQC.

** It is accepted that acknowledgement of receipt of letter may come from an appropriate representative of the CEO such as clinical governance lead or another nominee.

See Table 2 on the next page for the contacts for notifying of confirmed statistical outlier status and / or notification of non-compliance.

Table 2: Contacts for confirmed statistical outlier status and / or notification of non-compliance²

Location of participating organisation	Organisations and their contact details <i>Personnel and email address should be checked before use</i>
England (NHS)	<p>HQIP: Notify the HQIP project manager and associate director. HQIP contact details can be found at: www.hqip.org.uk/about-us/our-team/).</p> <p>CQC: clinicalaudits@cqc.org.uk</p> <p>NHS Improvement: nhsi.medicaldirector@nhs.net</p>
England (non-NHS)	CQC: clinicalaudits@cqc.org.uk
Wales	<p>Welsh government: wgclinicalaudit@gov.wales</p> <p>Welsh Health Specialised Services Committee: kimberley.meringolo@wales.nhs.uk and Holly.Williams12@gov.wales</p> <p>Healthcare Inspectorate Wales: hiw@gov.wales</p> <p>Improvement Cymru: (029) 2022 7744 or Dr. John Boulton, Director of NHS Quality Improvement and Patient Safety / Director, Improvement Cymru John.Boulton2@wales.nhs.uk</p>
Scotland	<p>National Specialist and Screening Directorate (NSD), NHS National Services Scotland: Amy Connor, Programme Manager nss.specialistservices@nhs.scot</p> <p>Healthcare Improvement Scotland: Standards and indicators, his.standardsandindicators@nhs.scot</p>
Northern Ireland	<p>Health and Social Care (HSC) Strategic Planning and Performance Group of the Department of Health (SPPG): SPPGcommunications@hscni.net</p> <p>The Regulation and Quality Improvement Authority (RQIA) RQIA, Belfast: 028 9536 1111 or info@rqia.org.uk</p> <p>Health and Social Care Quality Improvement (HSCQI): ihub@hscni.net</p>
Republic of Ireland	NOCA contacted via Paediatric Programme Assistant Audit Manager (Karina Hamilton karinahamilton@noca.ie) and Head of Data Analytics and Research (Fionnola Kelly fionnolakelly@noca.ie)

² This list will be updated by PICANet on an ongoing basis as Governance and staffing change

5 Publication of outlier analysis results

Identifiable results from outlier analysis are published each year in the PICANet Annual Report which is freely available online. If any providers had insufficient data quality for inclusion in the formal outlier analysis then the provider will also be identified in the PICANet Annual Report. For providers in England, results from the outlier analysis will also be published as part of the NCAB programme.

As stated in Section 3.2.1, from 2022, RSPRT plots may be published in the PICANet Annual Report; providers will be notified prior to publication via email if this is the case.

6 References

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11. PICANet. *Paediatric Intensive Care Audit Network: Annual Report 2018*. [Online]. 2018. [Accessed 03/09/2021]. Available from: <https://www.picanet.org.uk/annual-reporting-and-publications/annual-report-archive/>

7 Related documents

1. PICANet RSPRT Guidance for units

8 Appendix A – Performance indicator consideration

Appendix A Table 1: Assessment of key metrics as performance indicators for outlier detection

Metric	Target (expected performance)	Benefits	Drawbacks	Conclusions
Risk adjusted in PICU mortality	Observed mortality = expected mortality (i.e. SMR=1)	<ul style="list-style-type: none"> • Risk adjustment model available (Paediatric Index of Mortality (4)) • Unadjusted mortality is an objective, robust outcome measure which can be externally verified if required. • It is widely acknowledged that there is a clear relationship between mortality and quality of care once case-mix has been accounted for through appropriate risk adjustment 	<ul style="list-style-type: none"> • There are limitations to the current risk adjustment model which may mean that case-mix is not fully adjusted for (e.g. PIM3 does not take into account certain life-limiting syndromes or co-morbidities which now form a significant proportion of PIC admissions). • Recalibration of the risk adjustment model to take into account changing patient case mix and improvements in survival can be sensitive to changes in the data. 	Despite the limitations in relation to current tools available for risk adjustment, this metric is considered suitable for outlier analysis as clear relationship between indicator and quality of care (although interpretation must be mindful of the limitations noted).
Case ascertainment	100%	<ul style="list-style-type: none"> • Clear target 	<ul style="list-style-type: none"> • Measure not based on quality of care but on quality of reporting 	Considered unsuitable for outlier analysis as does not meet the criteria in terms of

Metric	Target (expected performance)	Benefits	Drawbacks	Conclusions
			<ul style="list-style-type: none"> Estimated value across whole of audit based on a subsample of PICUs each year 	<p>clear relationship between indicator and quality of care.</p>
Timeliness of data completeness	<p>Within 2 months of discharge from PICU</p>	<ul style="list-style-type: none"> Standard exists (within England): NHS England Specialised Services PICU Quality Dashboard 2021/2022 target 100% (PIC010a) (6) 	<ul style="list-style-type: none"> Measure not based on quality of care but on quality of reporting Can be skewed by technical issues out of PICU staff's control 	<p>Considered unsuitable for outlier analysis as does not meet the criteria in terms of clear relationship between indicator and quality of care.</p>
Critical care emergency transport mobilisation time	<p>Starting journey within 30 minutes of clinical decision that PIC transport is required*</p> <p>*Please note prior to April 2016 the target was 1 hour</p>	<ul style="list-style-type: none"> Standard exists (within England): NHS England Specialised Services PICU Quality Dashboard 2021/2022 target for 95% of cases achieving the standard (PIC14i) (6) 	<ul style="list-style-type: none"> On occasion transport may be strategically delayed due to appropriate risk-based triaging which would mean the mobilisation target is missed but the team are providing good quality care Measure of system capacity more than quality of care Impact of timeliness of access to paediatric intensive care on clinical outcomes is not yet established 	<p>Considered unsuitable for outlier analysis as does not meet the criteria in terms of clear relationship between indicator and quality of care. Additionally, whilst there is currently a standard available, it is recognised that this is aspirational at present (7). To reassess suitability of this or a similar measure in future</p>

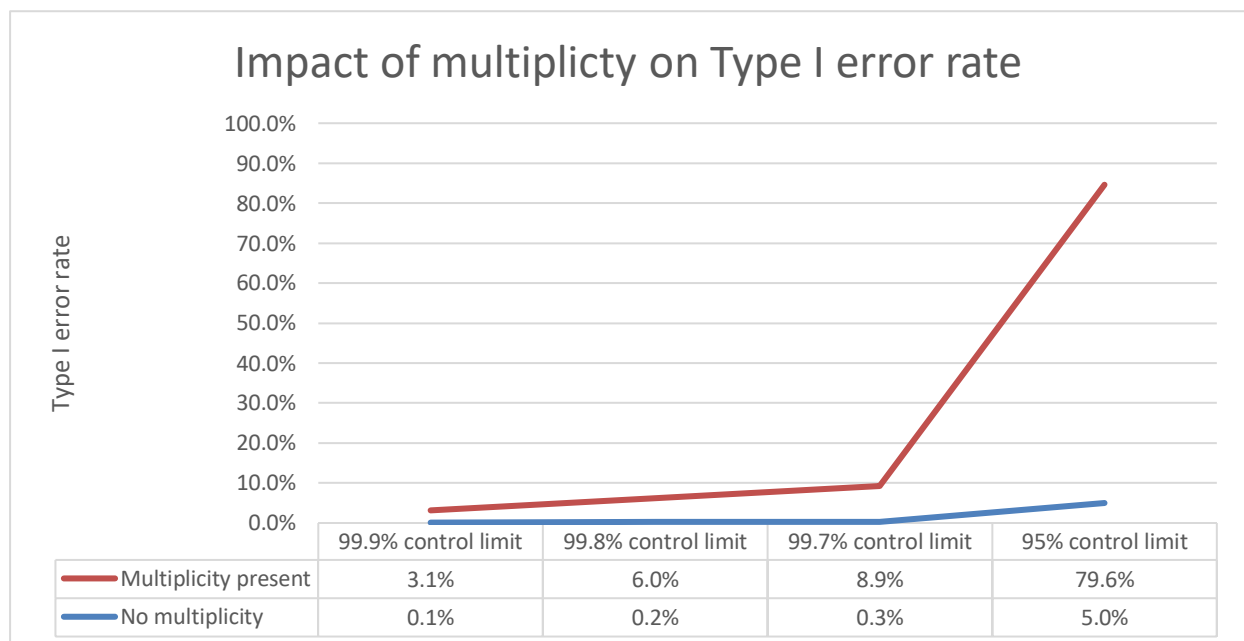
Metric	Target (expected performance)	Benefits	Drawbacks	Conclusions
			<p>(being assessed as part of the DEPICT study)</p> <ul style="list-style-type: none"> • Risk adjustment not accounted for in standards • Starting the journey is only one part of timely access 	<p>following full consideration of the results from the DEPICT study.</p>
<p>Emergency readmission within 48 hours (to same PICU)</p>	<p><2%</p>	<ul style="list-style-type: none"> • Emergency readmissions are an established metric both for PICU and other specialities across the NHS • Standard exists (within England): NHS England Specialised Services PICU Quality Dashboard 2021/2022 target <2% emergency readmissions to PICU (PIC04) (6) 	<ul style="list-style-type: none"> • Approximately 93% of patients discharged from PICU are discharged to another ward within the same hospital or to another hospital (10). This means that the metric is highly dependent on the designation of the funded beds within the PICU (e.g. whether it has designated Level 2 beds) and its supporting local care facilities rather than necessarily being a reflection of the quality of care provided by a PICU. • Rare event (affects 1.6% of all admissions (11)) so may not occur frequently enough to give statistical power • Ongoing research work at Birmingham is investigating the impact of the 	<p>Considered unsuitable for outlier analysis as does not meet the criteria in terms of clear relationship between indicator and quality of care.</p>

Metric	Target (expected performance)	Benefits	Drawbacks	Conclusions
			various contributory factors on emergency readmissions	
Unplanned extubations in PICU	Target tbc in 2023 and implemented in PICANet's 2023 state of the nation report	<ul style="list-style-type: none"> • Within unit measure which is not impacted by wider organisational influence • Interest within the clinical community as most commonly occurring adverse event • NHS England Specialised Services PICU Quality Dashboard 2021/2022 target <5 per 1,000 ventilated days (PIC08a) (6) 	<ul style="list-style-type: none"> • Relatively new data item and interpretation of the definition incorporates an element of subjectivity so data quality may not yet be to up to the required standards • Rare event (0.4 unplanned extubations per 100 intubated days (11)) so may not occur frequently enough to give statistical power • May be linked to the sedation policy of the PICU. 	Considered unsuitable for outlier analysis as data quality not yet sufficiently robust and is a rare event. PICANet to take steps to address clarity of definition and quality of reporting and reassess suitability in future updates of this policy.

9 Appendix B – Multiplicity

An important statistical consideration when looking at multiple PICUs is the impact of multiplicity on the number of providers identified as potential negative outliers due to chance alone (i.e. a false detection). Multiplicity (also called multiple testing or the multiple comparison problem) occurs when a number of statistical tests are performed simultaneously, as is the case when many providers are compared in the PICANet outlier analysis. The impact of multiplicity is an inflation of the Type I error rate (meaning our risk of falsely identifying a provider as a potential outlier is higher); specifically the larger the number of tests performed, the larger the Type I error. This must be taken into account when setting control limits and considering the false positive rate (see Figure 1).

Figure 1: Graph showing impact of multiplicity on Type I error rate



Footnote: Calculated using $\alpha_{FWER} = 1 - (1 - \alpha)^m$, where α_{FWER} is the family-wise error rate (or overall Type I error rate), α is the Type I error rate for an individual provider and m is the number of providers examined (in this case 31).

For PICANet (with 31 providers), the Type I error rate associated with the plotted 99.9% control limits inflates from 0.1% to 3.1% (meaning our control limits are actually equivalent to 96.9% control limits). This is the lowest Type I error rate we can achieve with the current number of providers included in analysis. This rate means that there could be one provider per analysis which is falsely detected as a potential negative outlier and has ‘alarm’ status raised,

consequently we may be over-identifying potential outliers. Additionally, when detecting potential outliers, we would rather make a false detections than find a falsely reassuring result (i.e. missing identification of a true outlier), and so our approach is conservative.

Multiplicity is the reason that PICANet do not employ an 'alert' status based control limits set to two standard deviations. Were we to additionally plot 95% confidence limits, these would actually equate to 20.4% control limits and the associated Type I error rate would rise from 5% to 80.6% meaning that around 25 providers could have a false 'alert' per analysis. This is clearly is clearly impractical and uninformative.