Defining competence in obstetric epidural anaesthesia for inexperienced trainees†

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Abstract

Background: Cumulative sum (CUSUM) analysis has been used for assessing competence of trainees learning new technical skills. One of its disadvantages is the required definition of acceptable and unacceptable success rates. We therefore monitored the development of competence amongst trainees new to obstetric epidural anaesthesia in a large public hospital.

Methods: Obstetric epidural data were collected prospectively between January 1996 and December 2011. Success rates for inexperienced trainees were calculated retrospectively for (1) the whole database, (2) for each consecutive attempt and (3) each trainee’s individual overall success rate. Acceptable and unacceptable success rates were defined and CUSUM graphs generated for each trainee. Competence was assessed for each trainee and the number of attempts to reach competence recorded.

Results: Mean (SD) success rate for all inexperienced trainees was 76.8 (0.1%), range 63–90%. Consecutive attempt success rate produced a learning curve with a mean success rate commencing at 58% on attempt 1. After attempt 10 the attempt number had no effect on subsequent success rates. From these results, the acceptable and unacceptable success rates were set at 65 and 55% respectively. CUSUM graphs demonstrated 76 out of 81 trainees competent after a mean of 46 (22) attempts.

Conclusions: CUSUM is useful for assessing trainee epidural competence. Trainees require approximately 50 attempts, as defined by CUSUM, to reach competence.

Key words: anesthesia regional; competence; epidural; learning curves; obstetric

Editor’s key points

• CUSUM analysis can be used to monitor performance in anaesthesia and surgery
• Monitoring the success of training in technical skills should be routine for trainees and supervisors alike
• CUSUM thresholds (benchmarks) will vary according to their purpose
• This study is consistent with others showing that most anaesthetic technical skills require at least 30–50 procedures to gain competency

In the NHS, training and the delivery of patient care are closely linked and the majority of training occurs in a service environment. Before Modernising Medical Careers and the introduction of the European Working Time Regulations, the majority of this learning was experiential and required long hours delivering service. The reduction in working hours has necessitated changes in medical education. There is now a need for competence-based training and robust methods to evaluate training.

Competence is the ability of an individual to do a job properly. The issue of acquiring competence in new procedures has troubled trainers for many yrs. After the loss of the apprenticeship

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method of training, Modernising Medical Careers introduced workplace-based assessments (WPBAs) to assess competence of trainees. There is currently no universally accepted and comprehensive way to assess competence in a procedural skill, and WPBAs have not been shown to improve performance, whereas cumulative sum (CUSUM) analysis is a statistical method that investigates the outcome rather than the process of performing a procedural skill. WPBAs are snapshots of the training episode and are not sensitive in the early recognition of the trainee who is struggling. CUSUM has been suggested to fill this role and allow early remediation of the trainee.

The CUSUM chart allows the observer to decide whether a production process is in control (i.e. production is within a defined quality boundary) or it has become out of control, at which point the process needs to be halted, as quality has decreased below acceptable limits. CUSUM graphs have been used for many anaesthetic procedural skills including regional anaesthesia, vascular cannulation and tracheal intubation. CUSUM analysis lends itself to the surveillance of performance in virtually all aspects of procedural health care, with the proviso that acceptable success and failure rates can be defined.

We therefore used a large departmental obstetric anaesthetic database to develop a definition of competence for obstetric epidural catheterization.

Methods

Since 1996, the anaesthetic department at Derriford Hospital, Plymouth, has rigorously collected data from all obstetric anaesthetic interventions including all neuraxial anaesthetic techniques. Data were entered on the database by one consultant anaesthetist, who, by using the birth register, ensured that no anaesthetic interventions were missed. Patient follow up data and an independent assessment of success of the epidural by the attending midwife were recorded.

Data from January 1996 to December 2011 from all obstetric epidurals by all trainees with no prior experience of obstetric anaesthesia were extracted. Success rates were calculated. Acceptable and unacceptable success rates were defined and used to construct CUSUM graphs to define competency.

Ethics and data protection

Application was made to Plymouth Hospital NHS Trust’s Research and Development Department. Full ethical approval was deemed not necessary and the project was registered as an Audit. Data handling was discussed with the Caldicott Guardian. All patient data were anonymized. Trainees were identified by numerical codes known only to the investigator. The database was encrypted, password protected and stored on a single computer with password access.

Database handling

The obstetric anaesthetic Microsoft Access database includes any anaesthetic intervention on delivery suite or in maternity operating theatres. Each record represents an attempt at anaesthesia or analgesia for a parturient. All mothers are followed up after delivery to ensure that they have no residual problems after anaesthetic intervention. Problems were recorded as free text. This field was further categorized to allow accurate data analysis.

Novices in obstetric anaesthesia were identified from the database where each trainee has an individual code prefixed with the stage of training. Hence all novices were identified from the designated ‘novice’ prefix. Novice data were then exported onto trainee-specific Microsoft Excel spreadsheets. To ensure that the data had been correctly extracted from the original database the results were then checked manually.

Exclusions

In order to explore the full transition from novice to competency, novice trainees with less than 91 neuraxial procedures were excluded from the study.

Definition of epidural success or failure

Information on the success or failure of each obstetric epidural was extracted from the anaesthetic database. Midwife assessment of the quality of analgesia by the obstetric epidural throughout both labour and delivery as anything but ‘good’ was regarded as a ‘failure’. If spinal or general anaesthesia was used for operative delivery (unless for obstetric reasons a very rapid delivery was required where it would be impossible to provide epidural anaesthesia in time), then the obstetric epidural was described as a ‘failure’. If there was any other additional analgesia (e.g. additional systemic opioid for labour or operative delivery), then the obstetric epidural was described as a ‘failure’. The database also included a field labelled ‘problems’. If data, (e.g. dural puncture, post-dural puncture headache, neuropaxia) were entered in any of the problem group categories then the obstetric epidural was regarded as a failure.

Statistical analysis

Success rate calculations

Mean success rates for obstetric epidurals were calculated from all obstetric epidural catheterizations attempted by novice trainees. Success rates for each consecutive attempt were calculated. To investigate whether there was any difference in success rates once the trainee has had a developmental period to reach competency, skill linear regression was applied to the first 100 attempts. Statistical modeling, using the statistical program R, was applied to the data collected. The model was refitted removing the initial attempts until the slope parameter was zero. This was the point at which the attempt number has no bearing on subsequent success rate.

Construction of CUSUM graphs

The overall trainee success rate was established and used to determine the acceptable and unacceptable success rates. CUSUM plots were generated with the acceptable success rate set at 65% and the unacceptable success rate set at 55%. As a comparison, CUSUM plots were also generated using the more rigorous acceptable success rate of 80% and unacceptable success rate of 70%. The number who reached competence and the number of attempts required to achieve this were determined. Competency was achieved when the graphical trend fell below two adjacent calculated boundary lines ($h_0$, $2h_0$, $3h_0$, $4h_0$, …) Competency was lost if the graph ascended and crossed two calculated boundary lines. (Fig. 1).

Results

Results from the database

During the period January 1996 to December 2011, there were 105 ‘novice’ trainees who attempted 13747 obstetric neuraxial
(epidural, continuous spinal epidural, and spinal) procedures, with an overall epidural success rate of 77%. Twenty-four of the 105 ‘novice’ trainees had between 1 and 90 records, median 46 (range 1–86) obstetric neuraxial procedures). None had completed an obstetric anaesthetic training block, typically because of changes in rotation. These 24 were excluded from the final analysis. This left 81 novice trainees who had performed more than 90 obstetric neuraxial procedures for final analysis (Fig. 2). All had completed an obstetric anaesthesia training module.

**Attempt data**

Novice trainees attempted a median 119 (range 46–395) obstetric epidural catheterizations during the study period.

**Epidural success rates**

**Success rates**

Figure 3 describes success rates for the first 100 obstetric epidural attempts (or all the attempts if trainees had less than 100 attempts.) Linear regression was applied to subsets of the data from attempt 1 to attempt 100. A zero slope parameter was found at attempt 10. Subsequent attempts have a constant success rate of 77%. Overall dural puncture rate was 0.67%; there were no neuropraxias reported.

**CUSUM plots**

Figure 1 displays sample CUSUM plots for two of the trainees – one who reaches competence and one who does not. Table 1...
displays the number of trainees reaching competence with two different failure rates. Use of the 80% acceptable success rate produces a smaller number of trainees (46/81) reaching competence than using the more generous 65% acceptable success rate (77/81). The mean number of attempts to competency is much lower in the 65% acceptable success rate group than the 80% acceptable success group (46 vs 77 attempts).

Do overall failure rates correlate with trainees who eventually reach competence?

Table 2 summarizes obstetric epidural data from the five trainees with the lowest overall success rates and one additional trainee with a lower success rate who did not achieve competence. For the five trainees with the lowest success rates, the success rates ranged between 63 and 66%. Of the whole cohort (n=81) studied, there were four non-competent trainees as defined by CUSUM analysis using an acceptable success rate of 65%. Three of the four non-competent trainees had the lowest overall success rates. The exception was trainee 6 who was also not competent. This trainee had the least obstetric epidural attempts (only 46) in the database. This trainee was included in the analysis because they had attempted more than 90 obstetric neuraxial procedures and had completed a training block. Their overall obstetric epidural success rate was 70%. This trainee had the 15th lowest overall success rate. Lack of obstetric epidural attempts is a factor in this trainee not reaching competency and with more attempts they might have achieved competency. The two trainees who were eventually described as competent took 114 attempts. It could be inferred from this that, if the overall success rate for a trainee is greater than 70%, then the trainee is likely to be competent as defined by CUSUM.

Discussion

This is the largest sequential series of anaesthesia trainees learning obstetric epidural insertion and management. Previously, the largest cohort for a study in obstetric epidural anaesthesia and CUSUM was 13. Our database included all novice trainees, giving valuable insight into a whole cohort with varying abilities. The success or failure assessment was made independently of the trainee inserting the obstetric epidural and is therefore less...
prone to reporting bias. A single performance of a procedure may be reliably assessed by training observers using checklists and rating scales. However such qualitative analysis does not address overall competence as the latter requires the demonstrated ability to successfully deliver a procedure on multiple occasions to a defined standard.

The results of this study have changed practice in our department. Novice trainee anaesthetists are not permitted to work alone until they have completed a minimum of 10 obstetric epidurals (where it can be anticipated that the average success rate for each subsequent attempt is more than 75%). Our consent process explains the identity of the operator as a medically qualified trainee. Risks are explained in general terms and we offer an overall complication rate rather than one that is trainee specific. There may be a case for changing this but we would also acknowledge that for a novice trainee the individual success rate is by definition, at that time, unknown. Quoting an average is arguably unhelpful as the individual trainee might be very dextrous (or particularly inept).

What acceptable success rate should be used in investigating trainee competence?

To decide the minimum acceptable success rate pragmatically, one could use the lowest trainee’s overall success rate (63%). This trainee was in fact assessed as clinically competent using current methods of trainer supervision. If the minimum acceptable success rate for novices was set at 65% and the unacceptable success rate as 55%, then 95% of all trainees are deemed competent by CUSUM.

The change in numbers of trainees reaching competency with different acceptable and unacceptable success rates has previously

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Table 1 Progression to competence by CUSUM for different minimum acceptable success rates in boundary

<table>
<thead>
<tr>
<th>Trainee</th>
<th>Overall success rate (percentage)</th>
<th>Total number of epidural attempts</th>
<th>Number of epidural attempts to reach competence by CUSUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>137</td>
<td>Not competent</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>80</td>
<td>Not competent</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
<td>120</td>
<td>114</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>115</td>
<td>114</td>
</tr>
<tr>
<td>5</td>
<td>66</td>
<td>93</td>
<td>Not competent</td>
</tr>
<tr>
<td>6</td>
<td>70</td>
<td>46</td>
<td>Not competent (only attempted 46 epidurals out of &gt;90 neuraxial procedures.)</td>
</tr>
</tbody>
</table>

Table 2 Obstetric epidural data from the trainees with the five lowest overall success rates and one other trainee who did not reach competence

<table>
<thead>
<tr>
<th>Trainee</th>
<th>Overall success rate (percentage)</th>
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</table>
be reported. If 80% was used as the minimum acceptable success rate when plotting the CUSUM graphs only 57% of all trainees would be defined as competent and a very large number of trainees would fail the obstetric module. It is unlikely that all these trainees are truly incompetent, and setting a lower minimum success rate allows a more realistic number of trainees to pass the assessment. It is unknown whether patient safety is affected by assessment criteria in training.1 2

Our acceptable success rate of 65% is more generous, though the definition of success is more rigorous than previously reported. Kestin recommended failure rate of 5–10%, others 20–40%.8 14 Our study used a lower acceptable success rate because data collection in this study is more robust and less prone to reporting bias. All the preceding studies have used data collected by the trainees themselves7 8 12 15 16 and they probably overestimate the success of the procedures they perform. In contrast, our assessment of success is made independently by the midwife and this method of data collection makes the study unique. Success of an obstetric epidural for this study was defined as good analgesia for labour and delivery, whilst earlier studies recommending lower acceptable success rates used less rigorous definitions of a successful obstetric epidural.17 18 The cohort of trainees in our study were novices in the skill and hence the boundaries set should be generous. Runcie and colleagues19 recommended tight acceptable success rates for trained experienced doctors and widening boundaries for trainees with less experience in the skill. However, the use of lower acceptable success rates for beginners may mean that some trainees are deemed competent when they actually require remediation or retraining, and detection of their difficulties may be delayed.

Risk adjusted CUSUM charts have been described in the medical literature.18 19 These avoid the need for the definition of the acceptable and unacceptable failure rates and take other confounders which are out of the trainees control into account. Thus should a trainee have a run of difficult epidurals not because of lack of skill but because of patient characteristics then the difficult characteristics are taken into account whilst plotting the CUSUM chart. This may be useful should CUSUM charts be used prospectively for training and represents an area for future research.

How many obstetric epidurals do trainees need to perform?
The mean (range) number of obstetric epidurals needed to reach competence was 46 (19–114). It can be concluded that from these results that trainees should expect to complete at least 50 obstetric epidurals to ensure that they are competent and often will need more. These numbers are consistent with previously published data.7 8 15

The average overall obstetric epidural success rate calculated from our database for novice trainees was 77%. Scott and colleagues20 reported a 79% success rate in novice epiduralists and Crawford and colleagues21 reported 79% albeit using different measures of success. Other studies include experienced epiduralists and hence their success rates are higher.22–25

In the cohort studied only 4 from 81 were not deemed competent if the minimum acceptable success rate was set at 65% (Table 1). Investigating the four trainees who did not reach competence, it could be concluded that having a low overall success rate correlates strongly with non-competence (Table 2). Prospective plotting of CUSUM graphs would pick up the outliers who need more practice to reach competence.

The study has overcome some of the problems reported in the literature, namely small trainee cohorts, self-reporting of success of obstetric epidural and definition of success-of-epidural, which enhances the validity of our analysis. The limitation of our study is its retrospective nature, although it would be difficult to achieve such a large cohort of trainees and such a complete set of data if the study had been attempted prospectively and would introduce reporting bias should the data be collected by trainees involved.17 18 Adverse events were reported as freehand text and may have been missed. Some of the trainees may have had a prior exposure to non-obstetric epidural anaesthesia in general theatres before their obstetric training. This may affect success rates and the rate at which competence is reached.

The use of CUSUM in learning obstetric epidural anaesthesia could provide benefits to patients, trainees and trainers alike. Our data and analysis succeeds in defining early success rates for obstetric epidurals and should lead to a similar series of analyses that begin to define early success rates for other practical procedures. Epidural anaesthesia is harder to learn than other procedures12 16 and procedure specific boundary conditions will be required.

Conclusions
We found CUSUM an effective tool in charting the development of competence for trainees in obstetric epidurals. Results of this study suggest that there is little improvement in epidural success rates after attempt 10 and to achieve competence a trainee needs to perform at least 50 epidurals.

Authors’ contributions
J.C. contributed to data collection and data entry to the database. E.D. contributed to the study design, data analysis and drafting the paper. J.S.R. contributed to the study design, drafting and revising of the paper.

Declaration of interest
E.D. and J.C. – none declared. J.R.S. – has just left the BJA board.

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Appendix: Construction of CUSUM graphs
To construct the CUSUM chart the variables required are the acceptable \( f_s \) and unacceptable \( f_u \) failure rates and reasonable probabilities of type I and II errors \( (\alpha \text{ and } \beta) \). The CUSUM graphical trend is calculated as follows:
\[
S_n = \sum X_n - f_0
\]
where
\[
X_n = \begin{cases} 1 & \text{success} \\ 0 & \text{failure} \end{cases}
\]
and the decision limits are calculated as:
\[
h_0 = \frac{b}{P + Q}
\]
\[
h_1 = \frac{a}{P + Q}
\]
Where
\[
P = \ln\left( \frac{f_1}{f_0} \right) \quad a = \frac{\ln(1-\beta)}{\alpha} \quad b = \frac{\ln(1-\alpha)}{\beta}
\]
The type I and II errors were set at 0.1. By setting type I and II errors equal, \( h_0 = h_1 \), and subsequent boundary lines are multiples of \( h_0 \). Type I error is the risk of declaring competence when it is not achieved and a type II error is the risk of not declaring competence when it is achieved.
The chart starts at zero and the plotted line will move upwards with a failure and downwards with a success. A negative trend line depicts success and a positive trend suggests failure. If the line crosses the upper decision limit \( (h_1) \) from below, then the failure rate is significantly greater than the acceptable failure rate. If a line crosses the lower decision limit \( (h_0) \) from above, then the true failure rate does not differ significantly from the acceptable failure rate. If the CUSUM remains between two boundary lines, the results are indeterminate and the null hypothesis cannot be accepted or rejected, and more observations are required. Competency is achieved when the graphical trend decreases below 2 adjacent calculated boundary lines \( (h_0, 2h_0, 3h_0, 4h_0, \ldots) \). Competency is lost if the graph ascends and crosses two calculated boundary lines. For clarity and consistency we have referred to success rates (i.e. 100% - failure rate) throughout our manuscript.

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