Aiming for zero: decreasing central line associated bacteraemia in the intensive care unit

Mary E Seddon, Catherine J Hocking, Pat Mead, Catherine Simpson

Abstract

Aim To eliminate Central Line Associated Bacteraemia (CLAB) in the Critical Care Complex (CCC)—Intensive Care Unit (ICU) and High Dependency Unit (HDU)—Middlemore Hospital

Method Multifaceted quality improvement programme that included: engagement with ICU leadership and education of ICU staff; the introduction of a CLAB prevention bundle of care through standardised checklists for central line insertion (December 2008) and line maintenance (July 2009); the development of a central line pack; and rapid, visual feedback of results.

Results Absolute numbers of CLAB in the CCC decreased from 14 in 2008, to 4 in 2009 and 1 in the first 6 months of 2010 (despite increase in bed census and a doubling of admissions). The CLAB rate per 1,000 line days decreased from 6.6 to 0.9. The days between CLAB increased from a median of 30 to >100 days, with zero CLAB for 5 of the last 6 months. Mortality for patients with CLAB was 37%, compared with mortality of 13% for all other ICU patients. The conservative cost savings were $200,000 in 2009 and $260,000 in 2010.

Conclusion Using an evidenced-based quality improvement approach, it is possible to significantly decrease Central Line Associated Bacteraemia in the Critical Care Complex. In doing so patient morbidity and mortality are reduced and money is saved for other healthcare needs.

Central venous lines are common in the Intensive Care Unit (ICU)—more than 50% of Middlemore Hospital ICU patients have a central line on any given day—and nationally there are approximately 19,000 ICU admissions each year. In these vulnerable patients, there is a serious risk of central line associated infection, and with it an estimated mortality of 10–50%.1–3

The cost of each Central Line Associated Bacteraemia (CLAB) has been estimated to be between $NZ 20,0004 and $54,000.5,6 This has become important in New Zealand as we strive to decrease waste spending in a recession. It is even more of an issue in the US where major funders of health care (Medicare and Medicaid) no longer fund hospitals when patients suffer such preventable complications,7 and there is good evidence that CLAB is a largely preventable complication.

Work by Pronovost and his team has shown that a zero rate could be attained, firstly in Johns Hopkins8 and then in most of the ICUs in Michigan state.9 Preventing CLAB was one of the six evidence-based programmes that made up the Institute for Healthcare Improvement (IHI) ‘Saving 100,000 Lives Campaign’.10
The IHI suggested that hospitals adopt evidence-based bundles of care for the top conditions that caused harm.\textsuperscript{11} The CLAB bundle had 5 components:\textsuperscript{12}

- Hand hygiene.
- Chlorhexidine skin antisepsis (chlorhexidine 2% in 70% alcohol).
- Maximum barrier precautions (hat, mask, sterile gloves, sterile gown and full patient drape).
- Optimal catheter site selection (subclavian vein as the preferred site).
- Daily review of the need for the line, with prompt removal of unnecessary lines.

Evidence exists that each of these components can decrease the rate of CLAB. Chlorhexidine skin antisepsis has proven to be better than providone-iodine solutions and other agents.\textsuperscript{13,14}

Two studies have shown that not using maximum barrier precautions increases the likelihood of a CLAB by 2.2 and 6.3 times.\textsuperscript{15,16} The evidence for hand hygiene in all sterile procedures goes back to Ignaz Semmelweis in the 1840s,\textsuperscript{17} the man who first demonstrated that washing hands prevented mortality from postpartum sepsis. The evidence for site selection is less convincing, at least when lines are inserted by experienced critical care doctors.\textsuperscript{18} However, in less controlled environments, or where the doctor inserts relatively few lines, the subclavian approach has been shown to be associated with fewer infections.\textsuperscript{19,20}

Our working hypothesis was that we could apply the IHI CLAB bundle of care and significantly reduce the rate of CLAB in the Critical Care Complex (CCC).

**Methods**

There was a good deal of discussion with senior ICU clinicians about the merits of the CLAB initiative generally and the individual components of the bundle. However, in December 2008 the Critical Care Complex Intensivists decided to adopt 4 out of the 5 components of the CLAB bundle (subclavian placement being the exception) and the CLAB initiative began.

The ICU staff, supported by the Quality Improvement Unit, decided to use the IHI CLAB prevention ‘how to guide’.\textsuperscript{12} The core concepts of the IHI approach are:

- Engage clinical staff with the CLAB bundle
- Ensure all elements of the bundle are used by standardising the insertion and maintenance of central lines using checklists
- Measure and display results for all staff

The definition of a CLAB came from the CDC (see Box 1).\textsuperscript{21}
Box 1. Definition of CLAB

| Patient must meet either criterion 1 or 2 and have a central line in situ to be classified as having a CLAB. |
| Criterion 1: Patient has a recognized pathogen cultured from one or more blood cultures and organism cultured from blood is not related to an infection at another site. |
| Criterion 2: Patient has at least one of the following signs or symptoms: fever (>38°C), chills, or hypotension and signs and symptoms and positive laboratory results are not related to an infection at another site and common skin contaminant (i.e., diphtheroids [Corynebacterium spp.], Bacillus [not B. anthracis] spp., Propionibacterium spp., coagulase-negative staphylococci [including S. epidermidis], viridans group streptococci, Aerococcus spp., Micrococcus) is cultured from two or more blood cultures drawn on separate occasions. |

Any positive blood cultures from the CCC were reviewed by the head of Infection Prevention and Control. If the patient had a central line in situ, the case was reviewed for evidence of secondary infection. In cases where it was unclear, it would then be discussed with a microbiologist and intensivists. Confirmed cases were reportedly directly to the quality facilitator in ICU.

If the CLAB developed within 48 hours of transfer out of ICU, the CLAB was still attributed to ICU (transfer rule). The number of line days was determined by the tally method. This method involves counting patients with central lines 5 days per week and using this sampling to estimate average number of lines per day and therefore the total central line days for the month. If the patient had several lines in, only one line per patient was counted.

The CLAB bundle was formatted into two checklists—one for insertion of the line, and the other for maintenance of that line. The IHI insertion checklist was modified by the ICU staff for local consumption (see Figure 1) and the nursing and medical staff were trained in its use. The nursing staff were encouraged to feedback immediately to the doctor inserting the line, if any of the components of the checklist were skipped. The 5th element of the checklist—to use the subclavian approach preferentially—was rejected by the intensivists as this approach had become uncommon (with only 2–5% of lines using the approach), due to concerns about the inability to compress the site in patient with coagulopathy and the concern about the risk of pneumothorax in patients with precarious ventilation.

The checklist did not mandate how the line was inserted (e.g. if it was inserted under ultrasound guidance) however, as lessons were learnt from the CLAB cases, antibiotic impregnated lines were recommended for high risk patients (patients with extensive burn injury or neutropenic patients) and it was recommended to consider a chlorhexidine impregnated dressing (biopatch). In most other cases antisepctic lines (chlorhexidine and silver sulfadiazine) were used. The CLAB maintenance bundle was adapted for the nursing shifts in the Critical Care Complex and introduced in July 09 (see Figure 2).
### Figure 1. Insertion checklist

#### CLAB Insertion Bundle Checklist

**Preventing Central Line infections in CMDHB**

<table>
<thead>
<tr>
<th>Central Line Definition:</th>
<th>Patient Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any catheter whose tip terminates in a great vessel</td>
<td>NHI Number</td>
</tr>
<tr>
<td><strong>Use patient Label</strong></td>
<td></td>
</tr>
</tbody>
</table>

**PLEASE COMPLETE FOR ALL CENTRAL LINE INSERTIONS ON ALL PATIENTS**

<table>
<thead>
<tr>
<th>Where was the line inserted?</th>
<th>Insertion site:</th>
<th>Catheter Type:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU</td>
<td>Right</td>
<td>Central</td>
</tr>
<tr>
<td>HDU</td>
<td>Left</td>
<td>PICC</td>
</tr>
<tr>
<td>EC</td>
<td>Subclavian</td>
<td>Vas Cath</td>
</tr>
<tr>
<td>Radiology</td>
<td></td>
<td>Other: _______</td>
</tr>
<tr>
<td>Theatre</td>
<td>Basilic</td>
<td>Antibacterial</td>
</tr>
<tr>
<td>M5C</td>
<td>Cephalic</td>
<td>Antiseptic</td>
</tr>
<tr>
<td>MMH</td>
<td>Femoral</td>
<td>None</td>
</tr>
<tr>
<td>Other: ___________________</td>
<td>Other: _______</td>
<td></td>
</tr>
</tbody>
</table>

**Line Coating:**

- Antibacterial
- Antiseptic
- None

**Date Line Inserted:**

**Date Line Removed:**

**INSERTION BUNDLE:**

To be completed by the observer and signed by both proceduralist and observer.

1. **Hand Hygiene - Did the proceduralist?**
   - Yes
   - No
   - Perform hand hygiene using chlorhexidine solution

2. **Chlorhexidine Skin Antisepsis - Did the proceduralist?**
   - Yes
   - No
   - Prep the procedural site using chlorhexidine 2% in 70% alcohol for 30 seconds and allow solution time to dry completely

3. **Maximum Barrier Precautions - Did the proceduralist?**
   - Yes
   - No
   - Wear a hat
   - Wear a mask
   - Wear a sterile gown
   - Wear sterile gloves
   - Use a large sterile drape that covered the entire patient
   - Maintain sterile technique during procedure
   - Maintain sterile technique when applying the dressing

**Has a Biopatch been applied to insertion site (NB: only for use in high risk patients)**

- YES
- NO

**Proceduralist Name:**

**Proceduralist Signature:**

**Observer Name:**

**Observer Signature:**

**PLEASE RETURN THIS FORM TO:**

THE QUALITY COORDINATOR/FACILITATOR OF YOUR SERVICE
Figure 2. Maintenance bundle

<table>
<thead>
<tr>
<th>MAINTENANCE BUNDLE CHECKLIST: To be completed on all central lines.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ward/Unit: Today’s Date: Line Day:</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Was the Central Line reviewed for necessity today?</td>
</tr>
<tr>
<td>Is there a dedicated port being used for the TPN? (If no TPN infusing then please tick NA)</td>
</tr>
<tr>
<td>Did you check the site today for inflammation? (If any signs of infection are seen the catheter should be reviewed promptly)</td>
</tr>
<tr>
<td>Prevention measure in use e.g. Biopatch disc or chlorhexidine gluconate (CGH) dressing</td>
</tr>
<tr>
<td>Before accessing injection ports did you clean with 2% CHG in 70% alcohol?</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
A CLAB trolley was kitted out with all the necessary equipment for line insertion, including copies of the checklists. In early 2010 we commissioned a central line insertion pack with all the elements (hat, gloves, mask, full-sized drape) necessary to satisfy the checklist and this replaced the trolley. Nursing staff completed the insertion and maintenance checklists and the results were entered into a database. Compliance with the checklist was a continuous process with every checklist entered. All elements of the checklist were included but compliance was measured as an ‘all or nothing’ indicator – all elements had to be completed for the checklist to be considered compliant.

Data from the laboratory and the tally of central lines was used to determine two key measures:

- The number of days between CLAB
- The number of CLAB per thousand line days.

Statistical Process Control methods were used to establish whether our improvements were statistically significant. Process control charts are dynamic displays of variation in data over time. Process Control charts display the median and control limits and determine whether the variation found is special cause variation and therefore significant or the normal background common cause variation. When examining rare events (e.g. CLAB), the best way to display the performance over time is to measure the days between such events.

The 6-month rolling average was used to smooth the CLAB/1000 line day rate.

In a prominent place in the ICU, the number of days since the last CLAB was displayed and updated daily (see Picture 1).

**Picture 1. Days since last CLAB displayed in ICU**

![Days since last CLAB displayed in ICU](image)

Central to the programme was the establishment of a quality facilitator within ICU who ran the programme, encouraged staff, analysed the data and fed the results back to the staff.

**Results**

In 2008 before the CLAB initiative started, the ICU had 14 patients with CLAB, a median of 28.1 days between cases and a rate of 6.8/1,000 line days. (see Table 2). In June 2008 the ICU was expanded from 10 physical beds (7 resourced) to 18 (12 resourced) beds, and in March 2009 a 6-bedded HDU was added. Admission numbers
to the Critical Care Complex nearly doubled over this time (876 admissions in 2008, 1365 in 2009 and 1627 in 2010).

Despite the increased workload in 2009 4 cases of CLAB were identified, the median days between cases increased to 75.8 (see Figure 3) and the CLAB rate dropped to 3.0 CLAB/1,000 line days (see Figure 4). In the first 6 months of 2010, there has only been one CLAB, a rate of 0.9 CLAB/1,000 line days. This CLAB occurred in a central line inserted in another hospital.

**Table 2. CLAB results**

<table>
<thead>
<tr>
<th>Variables</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAB cases</td>
<td>14</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Median days between CLAB cases</td>
<td>28.1</td>
<td>75.8</td>
<td>N/A</td>
</tr>
<tr>
<td>CLAB/1,000 line days</td>
<td>6.8</td>
<td>3.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Cost of CLAB cases</td>
<td>$280,000</td>
<td>$80,000</td>
<td>$20,000</td>
</tr>
</tbody>
</table>

**Figure 3. Days since last CLAB**

![Days since last CLAB graph](image-url)
Table 3. Characteristics of CLAB cases

| Number of patients with CLAB 2008–July 2010 | 19 |
| Infection sites                  |    |
| Femoral                         | 2  |
| Internal Jugular                | 14 |
| Unknown                         | 3  |
| Organisms                       |    |
| Coagulase-negative Staphylococcus | 7  |
| Serratia marcescens             | 2  |
| Candida species                 | 2  |
| Klebsiella pneumoniae           | 2  |
| Enterococcus faecalis           | 1  |
| Acinetobacter species           | 1  |
| Staphylococcus aureus           | 1  |
| Pseudomonas aeruginosa          | 1  |
| Orbrobacterium anthropi         | 1  |
| Average duration of line before infection | 4.8 (SD 2.1) |
| Patients with significant burns injury | 6 |
| In-hospital mortality for ICU patients with CLAB | 37% |
| In-hospital mortality for ICU patients without CLAB | 13% |

The most common pathogen in all CLAB cases was coagulase-negative Staphylococcus (mostly S. epidermidis) and the average line had been in for 4.8 days (SD of 2.1) before infection was found (see Table 3). The majority of lines with associated CLAB were internal jugular lines (14), 2 were femoral and 2 unknown.
We did not collect line site data in 2008 however, of the total lines inserted in 2009 and 2010, 314 (52.5%) were internal jugular, 206 (34.7%) femoral, 14 (2.3%) subclavian and 72 (11%) ‘other’ or ‘unknown’. The in-hospital mortality of patients with CLAB was 37%, compared to the in-hospital mortality for ICU patients without CLAB at 13%.

The documented compliance with the insertion checklist was 43% in December 2008, 83% in April 2009 and 95% (ICU) /100% (HDU) in August 2010.

The cost to the unit from CLAB cases in 2008 was estimated to be $280,000, dropping to $80,000 in 2009 and just $20,000 in the year to date.

**Discussion**

We introduced a multifaceted quality improvement approach to prevent CLAB in the Critical Care Complex (ICU and HDU). The approach included staff engagement, education, the introduction of procedure checklists, and real-time feedback to the staff involved.

We observed a dramatic reduction in the absolute numbers of CLAB (despite an increase in bed census and a doubling of admissions), from 14 in 2008, to 4 in 2009 and only 1 in the first 6 months of 2010. We also saw a reduction of the rate of CLAB/1000 line days from 6.6 to 0.9. The time between CLAB cases also extended from one a month to one every 3 months. Another indirect benefit of the CLAB initiative has been the realisation amongst staff that other practices in the ICU could be improved.

We were encouraged to undertake this work based on the success of similar work internationally. In 2002 a study by Coopersmith et al\(^2^6\) showed that a focussed education campaign for ICU nurses was associated with a 66% reduction in CLAB rates. Higuera et al\(^2^7\) showed that a programme incorporating education, process control and feedback could significantly reduce intravascular device blood stream infections and mortality in Mexico. Berenholz et al\(^8\) had shown in 2004 that five interventions could substantially reduce CLAB rates.

The interventions were: educating staff; creating a line insertion cart; asking providers daily whether lines could be removed; implementing a checklist; and empowering nurses to stop the insertion of a central line if the procedures were not followed. The CLAB rate dropped from 11.3/1000 line days to 0/1000 line days in Johns Hopkins. The same team then showed that the process could be replicated in multiple ICU sites, with a reduction of CLAB rates by 66% (2.7/1000 line days to 0/1000) in 103 ICUs in Michigan state.

When re-surveyed, the median CLAB rate was zero at 16–18 months, and remained zero at 34–36 months post implementation. It was estimated that the initiative had saved over 1500 lives, 81,000 hospital days and $165 million dollars.\(^2^8\) So not only was zero CLAB a realistic target, but the gains were substantial and sustainable.

The Institute for Healthcare Improvement (IHI) adopted the ideas and rolled it out in their Saving 100,000 Lives campaign. This involved 3000 hospitals picking from a suite of patient safety initiatives. The IHI ‘how to guide’ was the blueprint for our work.
It is known that the challenge for quality improvement is the delay from when there is evidence that something is effective, to it becoming common clinical practice. The duration of this lag time is variable, but the average is 17 years. As far back as 2002 Eggimann wrote

"Catheter-related infections should no longer be considered as an indirect tribute to sophisticated care or regarded as a fate, but must become one of the priority targets of a multidisciplinary approach emphasising quality-of-care improvement."

Although Middlemore Hospital’s CLAB rate of 6.8/1,000 line days was lower than many other places, the evidence had been available since 2004 that it could be much better, and that it was in fact possible to eliminate CLAB from ICUs So why has it taken a decade for this programme to be started in New Zealand?

Part of the answer lies in the exponential growth in medical knowledge, no one practitioner can keep up to date. Systematic reviews and synthesis of evidence by Cochrane and others can help, but the most sustainable way of translating evidence into practice, is to find a way to embed it into the normal process of care.

The CLAB bundle with its checklists is an example of this approach. In his book—The Checklist Manifesto—Atul Gawande backs the power of checklists to overcome the burden of our ever expanding knowledge base and human fallibility. Gawande, a U.S. surgeon, headed the development and implementation of the WHO Surgical Checklist. The pilot in 7 countries showed that using the checklist significantly reduced in-hospital surgical complications and mortality.

Although the components of the CLAB checklists are based on evidence, there is also evidence from the patient safety literature that standardisation per se improves patient outcomes. Much of medical practice cannot be standardised, nor should it be. Clinicians are right to protect their autonomy when the best course of action is not clear, or is affected by numerous patient factors. Such nuanced care is the correct course in such cases. However, common interventions such as central line insertion can and should be standardised.

“When placing a catheter, reliability not autonomy is needed.”

The reliability of central line insertion has improved in the Middlemore’s CCC and lines that have not been inserted in this standardised way are seen as a higher risk for CLAB. Lines inserted in other hospitals or in emergency situations are replaced as soon as possible.

Another high-risk group are the severely burned patients (Middlemore has the National Burns Unit) and the severely neutropenic patients. Three of the last CLAB in 2009 were from these high-risk patients.

Limitations—Although this study provides data that a multi-faceted quality improvement programme was associated with a significant reduction in CLAB rates, it has potential limitations. Firstly these findings cannot definitively be attributed to our programme.

We cannot exclude specific temporal trends (although there is no data from other hospitals of a reduction in CLABs) and we did not have a control group to compare with. Secondly, as this was an ICU-specific programme, we have small numbers of
patients with CLAB. With only 19 CLAB since 2007, the data on the isolates implicated in these infections is not as robust as larger studies. For instance, in the study by Shannon et al of 1067 patients with central lines and 49 CLAB, it was found that CLAB isolates were more likely to be virulent strains, which is not what we have found.  

Likewise not too much can be read into the mortality difference between patients with CLAB, and those without as the numbers are small. Our intervention was multifaceted and we can’t say which of the various interventions were most effective in reducing the CLAB rate. However, as all the interventions are low cost and simple, and the risks associated with CLAB are high, we believe that there is enough reason for all the components to be introduced together. The study was not randomised and the adjudicator of CLAB cases was not blinded to the work being done in ICU. However, this was the same key person and process throughout the study and pre-study timeframes.

Finally, as this study and most in the literature confine themselves to the ICU setting, the generalisability to other healthcare settings is uncertain. We are currently in the process of systematising the CLAB prevention programme throughout the hospital and hope to establish its effectiveness in other ward settings.

**Recommendations**—As Paul Batalan says

> …every system is perfectly designed to produce the results that it gets

Prior to this initiative the central line insertion system in the ICU at Middlemore Hospital was ‘perfectly designed’ to harm 10-14 patients a year through central line infections.

Hospitals can choose to stay with the same system, or they can actively choose to have a system that produces zero, or near zero CLAB. Pronovost calls CLAB a bellwether for holding healthcare professionals accountable for patient outcomes.  

We would recommend that ICUs in New Zealand measure their CLAB rates, engage their staff and implement the CLAB prevention toolkit.

Some of our learnings for success include: identification of a clinical leader; the establishment of a quality facilitator within ICU who can run the programme; adoption of the central line pack; and feedback of results in a meaningful way—we found the 6 month rolling rate to be convincing for clinicians’ and the daily up-date of days since the last CLAB to be helpful in keeping the momentum for the programme going.

**Conclusion**—CLAB is associated with significant mortality and morbidity for ICU patients. It is also an economic cost that the health system can ill afford in these constrained times. In this paper, we report on the CLAB initiative at Middlemore Hospital (MMH) which has dramatically reduced the CLAB rate in the Critical Care Complex and make the case for all ICUs in New Zealand to measure their CLAB rates and to adopt a similar approach.
Competing interests: None.

Author information: Mary Seddon, Clinical Director, Quality Improvement Unit; Catherine J Hocking, Quality Coordinator, Critical Care Complex; Pat Mead, Team Leader, Infection Prevention & Control; Catherine Simpson, Intensivist and Clinical Director, Acute Care; Counties-Manukau District Health Board (DHB), Auckland

Acknowledgements: We thank Critical Care Complex staff for their enthusiasm and hard work.

Correspondence: Dr M Seddon, Clinical Director Quality Improvement Unit, Counties-Manukau DHB, Private Bag 93311, Auckland, New Zealand. Fax: +64 (0)9 2593865; email: MZSeddon@middlemore.co.nz

References:
11. Institute for Healthcare Improvement. Saving 100,000 Lives campaign. 2006; Available from: http://www.ihi.org/IHI/Programs/Campaign


