Aseptic insertion of central venous lines to reduce bacteraemia

The Central Line Associated Bacteraemia in NSW Intensive Care Units (CLAB ICU) Collaborative

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A catheter inserted with the tip in a central vein is called a central venous line (CVL). Correct insertion technique is important in prevention of central line-associated bacteraemia (CLAB). Patients in intensive care units (ICUs) are at high risk of CLAB, which increases mortality and morbidity rates, as well as costs.[1] Yet, CLAB can be prevented.[2,3] Since 2000, several studies have shown that educational strategies for aseptic insertion of CVLs lower rates of CLAB.[4-7]

In 2002, the Centers for Disease Control and Prevention (CDC) published *Guidelines for the prevention of intravascular catheter-related infections*.[8] These and similar guidelines have been successfully applied in ICUs using collaborative methods.[5,9] For example, Pronovost and colleagues showed that a regimen of hand washing, full barrier precautions, use of an alcohol-based chlorhexidine skin preparation, avoidance of femoral insertion, and early removal of the CVL resulted in an 81% reduction in the mean rate of CLAB.[9]

In 2007, lowering CLAB rates in patients in ICUs was included in the Patient Safety and Clinical Quality Performance Agreements between the New South Wales Department of Health and Area Health Services. The Central Line Associated Bacteraemia in NSW Intensive Care Units (CLAB ICU) Collaborative commenced in March 2007 as a "top-down – bottom-up" quality improvement project conducted by the NSW Clinical Excellence Commission and the Intensive Care Coordination and Monitoring Unit, two quality-focused organisations working in NSW with the support of the NSW Department of Health. We report here the experience of the CLAB ICU collaborative.

METHODS

All 37 ICUs in NSW public hospitals were invited to participate — 10 tertiary, 12 metropolitan, 13 rural and two paediatric units. The Intensive Care Coordination and Monitoring Unit engaged with intensivists working in ICUs. The Clinical Excellence Commission provided expertise in collaborative methods, and the project team facili-

ABSTRACT

Objective: To reduce the rate of central line-associated bacteraemia (CLAB).

Design: A collaborative quality improvement project in intensive care units (ICUs) to promote aseptic insertion of central venous lines (CVLs). A checklist was used to record compliance with all aspects of aseptic CVL insertion, with maximal sterile barrier precautions for clinicians ("clinician bundle") and patients ("patient bundle"). CLAB was identified and reported using a standard surveillance definition.

Participants and setting: Patients and clinicians in 37 ICUs in New South Wales, July 2007 – December 2008.

Main outcome measures: Compliance with aseptic CVL insertion; rates of CLAB.

Results: 10 890 CVL checklists were reviewed for compliance with the clinician and patient bundles: compliance with aseptic CVL insertion improved significantly ($P < 0.001$). The CLAB rate dropped from 3.0 to 1.2 per 1000 line-days ($P < 0.001$). Regardless of CVL type, the relative risk (RR) of CLAB in patients with CVLs inserted by clinicians not compliant with the clinician bundle was 1.62 times greater (95% CI, 1.1–2.4; $P = 0.018$) than the RR with CVLs inserted by clinicians compliant with both bundles. Compliance with both the bundles was associated with a 50% reduction in risk of CLAB (RR, 0.5; 95% CI, 0.4–0.8; $P = 0.004$).

Conclusions: Compliance with all aspects of aseptic CVL insertion significantly reduces the risk of CLAB. A difficulty we experienced was that most ICUs lacked the organisation and staff to support quality improvement and audit.

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tated data collection and generated reports. Project governance was provided by a steering committee, with stakeholder representation. Membership and evaluation are described in the final report of the CLAB ICU collaborative.[10]

Guidelines and data collection

A multidisciplinary expert group was convened to develop a guideline for CVL insertion.[11] It was based on existing guidelines and the premise that CLAB is causally related to insertion technique — compliance with hand hygiene, skin preparation and full barrier precautions are essential. A checklist including the "patient bundle" and the "clinician bundle" (Box 1) was developed to support compliance with the guideline and was also used to collect data.[12] Compliance with each element was recorded by clinicians or assistants on completion of CVL insertion. Complying with a bundle required compliance with all elements. Other data recorded included insertion site, type of CVL and any complications. The checklist was completed for CVLs inserted in patients who had been admitted to an ICU for ≥ 24 hours.

Central line-associated bacteraemia

CLAB episodes were notified by means of the checklist. Only CLAB in patients in the

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1 Aseptic central venous line (CVL) insertion

Patient bundle	Clinician bundle
• Prepare procedure site with 2% alcoholic chlorhexidine	• Scrub hands for at least 2 minutes
• Fully drape the patient with a sterile sheet	• Wear a hat, mask and eyewear
• Check the position of the CVL by imaging and/or pressure transducer	• Don sterile gloves and gown
	• Maintain a sterile technique

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2 Definition of central line-associated bacteraemia (CLAB)*

- The cultured organism is not related to infection at another site

AND

- The presence of a recognised pathogen (eg, *Staphylococcus aureus*) in one or more blood cultures

  OR

- The presence of fever (> 38°C), chills or rigors; or hypotension (episode), within 24 hours of a positive blood culture being collected

AND at least one of the following:

> ➤ isolation of the same potential contaminant from two or more blood cultures drawn on separate occasions within a 48-hour period (isolates identified by suitable microbiological techniques)

> OR

> ➤ isolation of a potential contaminant (eg, coagulase negative *Staphylococcus*) from a single blood culture drawn from a patient with an intravascular line (within 48 hours of the episode and appropriate antimicrobial therapy against that isolated contaminant is commenced.

* Based on the surveillance definition of the New South Wales Department of Health (2005),[13] and the definition of the Centres for Disease Control and Prevention.[8] ◆

ICU, or within 24 hours of transfer out of the ICU, was reported. The definition of CLAB used was the NSW Department of Health surveillance definition (2005)[13] and the definition of the CDC,[8] with the exception of the time variable in relation to ICU discharge, which was changed from 48 to 24 hours to minimise the administrative burden on ICUs (Box 2).

Line-days based on each line inserted

Date of CVL insertion and date of removal, or date on which the patient was discharged to a ward (whichever came first), were recorded on the checklist. ICU discharge was used as a proxy end date (as it was not practical to follow up all patients with CVLs who were discharged to a ward and note the date of removal). Only one CVL per patient was counted in the total days.

Central line-associated bacteraemia rate

CLAB rates were calculated as the number of reported episodes of CLAB (numerator) per 1000 ICU central venous line-days for that ICU (denominator).

Clinician engagement

Personnel from the Intensive Care Coordination and Monitoring Unit and the Clinical Excellence Commission promoted the intervention to intensive care clinicians. ICUs were asked to form improvement teams with physician and nursing representatives from within existing staff. Other engagement strategies are described in the final report of the CLAB ICU collaborative.[10]

It was strongly recommended that ICUs collocate and standardise CVL insertion equipment. During site visits by project team members, collocation of insertion equipment was observed in most ICUs.

Reports and analysis

The Clinical Excellence Commission collated data as these were received and prepared reports for ICUs, Area Clinical Governance Units and the NSW Department of Health. Data entry was done manually, with an ICU nurse checking data on each form. Missing or invalid data were followed up and validity of reported CLAB was confirmed with individual ICUs.

Individual ICU reports showed compliance with the advocated aseptic technique, as well as the number of episodes of CLAB, the CLAB rate per 1000 line-days and the weighted moving average CLAB rate. Aggregated NSW results were reported alongside individual ICU results. Reports were often accompanied by additional analysis of specific issues, such as complications, ongoing participation or compliance with particular elements of the two bundles.

Aggregated analysis

The first 12 months (July 2007 – June 2008) was designated as a run-in period on the premise that a substantial period would be required for the guideline and checklist to be accepted. In addition, given that the distribution of CLAB episodes during the run-in period would be overdispersed, CLAB rates were calculated for the first 12 months (run-in period) and compared with the final 6 months (analysis period).

SPSS version 17.0 (IBM, Armonk, NY, USA) was used for proportions, bivariate and multivariate analysis, and EpiInfo version 6.04d (CDC, Atlanta, Ga, USA) was used to calculate 95% confidence intervals around proportions. Alpha was set at the 5% level. Two multiple logistic regression models were run to predict CLAB, with patient bundle, clinician bundle and line-days entered in a backward stepwise method for the first 12 months and the final 6 months.

Ethics approval

The NSW Department of Health Clinical Ethics Branch considered the intervention a quality improvement activity not requiring ethics approval. Reports to ICUs were de-identified, except for individual rates. Data were stored in a locked electronic folder with a code to identify individual ICUs.

RESULTS

Data were collected from July 2007 to December 2008. All invited ICUs submitted checklists at some time during the first 12 months (July 2007 – June 2008). The total number of participating ICUs ranged from 24 in the first month to 34 during the final 6 months.

We received 11 575 checklists for CVLs inserted in ICUs: 10 890 checklists provided line type, 10 850 provided insertion site and 10 575 provided line type and insertion and removal dates. The CVLs included centrally inserted (72.6%; 7907) and peripherally inserted (13.5%; 1467) CVLs, dialysis catheters (11.9%; 1296), and other/not specified CVLs (2.0%; 220). There was no significant difference (*P* = 0.998) in choice of insertion site for CVLs in the run-in period and the final 6 months' analysis period (Box 3).

Centrally inserted CVLs contributed 78.2% of all line-days over the intervention period. During the first 12 months, these CVLs remained in situ for the same period as in the final 6 months (Box 4). The median in-situ period for peripherally inserted CVLs extended by 2 days to 8 days in the final 6 months; however, peripherally inserted CVLs represented only 8.7% of the total

3 Central venous line insertion sites used (*n* = 10 850)

Insertion site	Jul 2007 – Jun 2008*	Jul – Dec 2008†
Jugular	1 119 (33.0%)	2 452 (32.9%)
Subclavian	999 (29.4%)	2 082 (27.9%
Femoral	772 (22.8%)	1 875 (25.1%)
Cubital fossa	400 (11.8%)	809 (10.8%)
Other or unknown	103 (3.0%)	239 (3.2%)
Total	3 393 (100%)	7 457 (100%)

* Run-in period. † Analysis period. *P* = 0.998; mean ridit, 0.500 (for comparison of insertion sites used in the run-in period and the analysis period). ◆

line-days over the 18-month study period. Dialysis CVLs and other unspecified CVLs contributed 12.2% and 0.9%, respectively, of all line-days, and their median in-situ period decreased by 1 day during the final 6 months of the intervention period.

Bundle compliance rates and CLAB

Compliance with the clinician bundle was assessed for each quarter of the project, and compliance improved from 74% to 81% by the last quarter ($P < 0.0001$; $\chi^2 = 118.83$). Similarly, compliance with the patient bundle improved significantly from 81% to 92% by the last quarter ($P < 0.001$; $\chi^2 = 108.34$). Compliance with both bundles was 1.4 times more likely by the last quarter ($P = 0.0001$; $\chi^2 = 14.325$).

Over the 18 months of the intervention, there was a significant drop in CLAB rate from 3.0 (95% CI, 2.0–4.3) per 1000 line-days to 1.2 (95% CI, 0.6–2.2) per 1000 line-days ($P = 0.0006$; χ^2 of slope = 11.71) (Box 5).

The risk of CLAB was significantly reduced (relative risk [RR], 0.5; 95% CI, 0.4–0.8; $P = 0.004$) in patients with CVLs inserted by clinicians compliant with both bundles. When examined by CVL type, the risk of CLAB associated with centrally inserted CVLs was significantly reduced (RR, 0.5; 95% CI, 0.3–0.9; $P = 0.01$); however, there was no significant risk reduction for peripherally inserted CVLs (RR, 0.2; 95% CI, 0.04–1.0; $P = 0.07$) or other CVL types (RR, 1.1; 95% CI, 0.3–3.8; $P = 1.0$).

CVLs inserted by clinicians who were not compliant with the clinician bundle were 1.62 times more likely to be associated with CLAB (RR, 1.62; 95% CI, 1.1–2.4; $P = 0.018$) compared with CVLs inserted by clinicians who complied with both bundles. When calculated separately, with centrally inserted CVLs (not peripherally inserted CVLs or dialysis CVLs), patients were nearly twice as likely to develop CLAB when CVLs were inserted by non-compliant clinicians (RR, 1.99; 95% CI, 1.2–3.2; $P = 0.004$), and patients with

4 Type of central venous line (CVL), number inserted and duration of insertion (line-days), by intervention period*

Catheter type/ intervention period	CVLs inserted ($n = 10\,575$)[†]	Total (range) line-days ($n = 54\,371$)[†]	CVL in-situ period in ICU (percentile)		
			25th	50th	75th
Centrally inserted CVL					
First 12 months	2 432	13 174 (1–58)	5	8	13
Final 6 months	5 289	29 331 (1–104)	5	8	13
Peripherally inserted CVL					
First 12 months	475	1 352 (1–37)	2	6	12
Final 6 months	992	3 365 (1–242)	3	8	18
Dialysis catheter					
First 12 months	397	2 215 (1–130)	6	9	15
Final 6 months	865	4 434 (1–52)	5	8	13
Other catheter type					
First 12 months	43	210 (1–25)	4	8	14
Final 6 months	82	290 (1–21)	3	6	13
All catheters					
First 12 months	3 347	16 951 (1–130)	5	8	13
Final 6 months	7 228	37 420 (1–248)	5	8	13

ICU = intensive care unit. * First 12 months of intervention (run-in period); final 6 months of intervention (analysis period). † Includes only inserted CVLs for which data on CVL type and line-days were available. ◆

5 Rates (95% CI) of central line-associated bacteraemia (CLAB) per 1000 line-days, by quarters
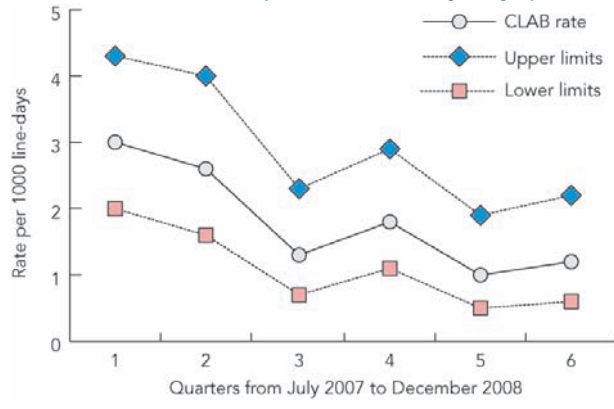
peripherally inserted CVLs were five times more likely to develop CLAB (RR, 5.08; 95% CI, 1.03–25; $P = 0.059$) than when compliant clinicians did the insertion.

Non-compliance with the clinician bundle was mostly attributed to failure to wear a hat, mask and eyewear (94.0%). The risk of CLAB in patients with CVLs inserted by clinicians who complied with the clinician bundle, but not the patient bundle, was not significantly different when compared with CVLs inserted by clinicians who complied

with both bundles (RR, 0.82; 95% CI, 0.3–2.26; $P = 0.891$).

A two-step multiple logistic regression model for the first 12 months of the intervention identified line-days (RR, 1.05; 95% CI, 1.02–1.07; $P = 0.001$) and non-compliance with the clinician bundle (RR, 2.04; 95% CI, 1.1–3.6; $P = 0.016$) as significant risk factors for CLAB. A three-step model to predict risk factors for CLAB during the final 6 months of the intervention did not identify either bundle as a risk factor; in-situ line-days remained the only significant risk factor for CLAB (RR, 1.02; 95% CI, 1.01–1.04; $P = 0.001$).

DISCUSSION

The 60% reduction in CLAB rates achieved during the intervention period — from 3.0 per 1000 line-days to 1.2 per 1000 line-days in NSW — is similar to other CLAB rate reductions published. Pronovost et al reported a reduction to a mean of 1.4 per 1000 line-days at 16–18 months.[9] In 32 hospitals (69 ICUs) in the United States using similar methods, the CLAB rate was reduced by 68% to 1.36 per 1000 line-days over a 4-year period.[14] Comparable results have been obtained in other US hospitals.[15,16]

The CLAB ICU was the first collaborative between the Clinical Excellence Commission, the Intensive Care Coordination and Monitoring Unit, the NSW Department of Health and individual ICUs. The relationship between the Commission and the Intensive Care Coordination and Monitoring Unit worked well. The relationship with individual ICUs was more challenging, as the guideline was not enforceable and the project relied on the goodwill of the ICUs. Most formed improvement teams, but there was variable engagement of key personnel. Some clinicians considered the incidence of CLAB in NSW to be low and doubted the value of the project, as Australian practice was considered to be equal to or better than the methods informing the project. Conversely, in a number of ICUs where senior clinicians gave the project clear support, there was excellent engagement with the project.

Compliance with aseptic insertion improved significantly during the intervention, indicating that the use of bundles and checklists may improve outcomes.[17] The improved compliance occurred within the broader context of a CLAB awareness campaign, and the collaborative encouraged ICUs to improve all aspects of CVL insertion and management. We believe that greater awareness among ICU clinicians of the incidence and surveillance requirements of CLAB contributed to the overall reduction in CLAB rates. The rates of earlier removal of CVLs based on in-situ time and the use of femoral insertion did not change significantly between the run-in period (first 12 months) and the analysis period (final 6 months), suggesting that neither contributed to the reduced CLAB rate in our dataset, contrary to other reports.[18-21]

Compliance with the clinician bundle contributed to a decreased CLAB rate. Non-compliance with the clinician bundle was attributable in 94% of cases to non-compliance with the hat–mask–eyewear element. Hat wearing was identified as the contentious component of the bundle. Clinicians cited a lack of evidence as a reason to omit hats, and four ICUs elected to omit their use as standard practice for CVL insertion. There is no direct evidence linking hat wearing to CLAB. However, hats have been routinely cited as an element of clinician preparation in reports analysing reduction in CLAB rates.[22-24] Compliance with both bundles was promoted in this project, and evidence suggests that hat wearing is a required step during CVL insertion, with our data indicating that the risk of CLAB increases if hats are not worn. At best this is an association, and not wearing a hat may be a surrogate for cultural or other practice issues.

There are several practical issues that may bias our results. Surveillance projects cannot be conducted with the rigour of a trial, and there were problems with identification of CLAB. This was despite dissemination of posters and concise definition notes for quick reference to ensure definition consistency between the ICUs and infection-control practitioners. Many ICUs do not have microbiological support and frequently CLAB was reported without discussion with senior ICU staff. Improved understanding of surveillance definitions, versus clinical definitions, led to reclassification in some cases.

Some ICUs resisted the requirement for clinical staff to follow up CVLs and submit checklists. There is inconsistent data collection and audit in NSW ICUs,[25] with limited staff allocated to quality activities in individual ICUs; in nine referral ICUs surveyed, there were only 2.2 full-time-equivalent (FTE) physicians (three ICUs), 4.73 FTE nursing staff (four ICUs), and 0.4 FTE other staff (one ICU).[26] As a data-quality initiative, two tertiary ICUs and one metropolitan ICU were asked to review data capture: all three reported data capture greater than 90%. This quality test was not completed by all sites, and at least one tertiary unit had low data capture.

From the data provided by the test sites, it is estimated that more than 15 000 CVLs are inserted in patients in NSW ICUs every year. Based on this estimate, data on fewer than 50% of CVLs inserted during the study period were captured. Most clinicians participated in the CLAB ICU intervention in addition to their normal duties. A key lesson is that for effective translation of evidence into practice, ICUs must have pre-existing integrated clinical practice improvement teams to engage front-line staff to incorporate best practice and regular audit into their daily work.

Some checklists were filled in by the proceduralist, as assistance was not always available. The hazards of self-reporting are acknowledged; however, the reporting method was the same throughout the data collection period and a reduction in CLAB rate still occurred. As this was a quality improvement initiative, not a study, these factors could not be controlled.

In summary, a guideline and checklist, backed up by a CLAB awareness campaign, reduced rates of CLAB in NSW ICUs. Strict compliance with maximal sterile barrier precautions by clinicians and full preparation of the patient were critical. This multimodal intervention was considered a success.

COMPETING INTERESTS

None identified.

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