EDITOR'S CHOICE

# Elimination of central-venous-catheter-related bloodstream infections from the intensive care unit

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**Introduction:** Central-venous-catheter (CVC)-related bloodstream infection (CRBSI) is a complication of intensive care stay which can have important adverse consequences for both patient and institution. There are a number of evidence-based interventions that reduce CRBSI, but it is recognised that consistently applying the best evidence every time is a challenge.

**Methods:** The authors set out to reduce CRBSI and introduced interventions in our intensive care unit (ICU) over a 4-year period using a quality improvement approach. In a setting supportive to change and improvement, the authors established infection surveillance and introduced bundles of care processes relating to insertion and maintenance of CVCs. The changes were supported by educational interventions. The authors measured care processes and outcomes, and used statistical process control charts to illustrate changes. The final 18 months of the work was performed in the context of a national safety improvement programme (The Scottish Patient Safety Programme).

**Results:** Following interventions, the annual CRBSI rate fell from 3.4 to 0/1000 patient days with zero episodes during the final 19 months of the study.

**Conclusions:** The authors describe a significant reduction in CRBSI for the first time in a UK ICU. The authors summarised and simplified what to do, measured and provided feedback on outcomes, and improved expectations of performance standards for care processes. The authors believe that these approaches are worthy of serious consideration elsewhere.

## INTRODUCTION

Central-venous-catheter (CVC)-related bloodstream infections (CRBSIs) are an important cause of hospital-acquired infection associated with morbidity, mortality and cost.[1–3] Several interventions prevent them,[4] and a study in 103 intensive care units (ICUs) in Michigan[5] demonstrated a reduction from 7.7 to 1.4/1000 catheter days following implementation of five care processes including hand hygiene, chlorhexidine skin antisepsis, barrier precautions during insertion, avoidance of femoral site and removal of unnecessary catheters. The Michigan Keystone interventions were introduced in the context of an organisational framework designed to support translation of evidence into practice.[6] Some have called for widespread implementation and adoption of evidence-based guidelines[7] and these five care processes[8] as part of a central line bundle.[9 10] Others have concluded that these practices might be worthy of wider implementation but that a further study would be helpful.[11] Reduction of CRBSI has not been described in a UK ICU setting. We set out with this intention.

## METHODS

Stirling Royal Infirmary is a general hospital serving 270 000 people within Forth Valley. ICU CRBSI incidence was measured over a continuous 4-year period from 1 September 2005 to 31 August 009. Every patient admitted for more than 48 h in the adult medical and surgical nine bedded ICU who during part or whole of their admission had a CVC had a daily assessment until discharge for the occurrence of a CRBSI using Hospitals in Europe Links for Infection Control Surveillance (HELICS)[12] dataset (online appendix 1) and definition Catheter Related Infection 3 (CRI 3) (online appendix 2). CVC was defined as any intravenous catheter ending at or near the heart. Flow charts to support definitions and diagnostic category were used (online appendices 3, 4). A device day was defined by a patient having a single CVC for a whole or part 24 h period; two

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catheters for a part or whole 24 h period was defined as two device days and so on. The method of counting all catheter days as the denominator used by HELICS differs from that used by the National Nosocomial Infections Surveillance System[13] and Centers for Disease Control and Prevention who use a single patient day as the denominator, even if the patient has two catheters on that given day. Infection incidence per 1000 device days and 1000 patient days was displayed on statistical process control (SPC) charts.[14 15] Confirmation that every patient was captured was made by crosschecking all names against the ICU admission book and the ICU 'Ward Watcher' database. CVCs removed had their tips routinely sent for modified Maki roll[16] testing (online appendix 5).

Between 1 September 2005 and 31 December 2006, we focused on infection surveillance (ventilator associated pneumonia (VAP), methicillin-resistant *Staphylococcus aureus* and CRBSI) and performed interventions aimed at improving hand hygiene practices. The first year's CRBSI incidence was 3.4/1000 catheter days. We noted that CRBSI preventive practices at insertion including using chlorhexidine antisepsis and full aseptic technique were not consistently performed. For established CVCs, there was variation in hand-hygiene practices, techniques for commencing injections and infusions, and an inconsistent approach for removal. Common practice was to suggest routine replacement after 7 days sometimes using catheter exchange over a guide wire. These practices are not widely accepted as strategies to prevent CRBSI. There was no daily prompt to remove established CVCs. Although aware of these inconsistencies, we were unable to measures process reliability.

We formed a group consisting of three of our nine consultant clinicians, our infection surveillance nurse and two ICU charge nurses whose stated aim was to reduce CRBSIs in ICU. Two consultants had responsibility for training doctors in Anaesthesia and Intensive Care. Interventions were gradual and iterative commencing January 2007 and were supported by the Critical Care Development Group (our management forum). The ICU had a culture supporting improvements having previous success amalgamating two units into one and introducing renal replacement therapy. Initially, there was minimal hospital administrative role in the project, and although we had no prior experience with performance change (improvement programmes) there was palpable local ownership of the improvement efforts which were seen to come from within the ICU. Ethical approval was viewed as unnecessary, and confirmed by the local ethics committee, since there was no specific research question, and activities were viewed as good practice and routine in other centres. Interventions to reduce VAP[17] ran from March 2007 to August 2009.

We agreed interventions derived from published strategies and developed insertion and maintenance bundles. Although these might appear slightly different from those described in Michigan,[5] aseptic technique and maximal sterile barrier precautions rather than 'hand hygiene' were stipulated at the time of insertion, since this correlated with evidence.[18] The daily prompt for catheter removal was included under maintenance, not insertion.

### Insertion bundle

1. Use aseptic technique and maximal barrier precautions (cap and mask, surgical scrub, sterile gown and gloves).
2. Use 2% chlorhexidine/70% alcohol solution skin antisepsis.
3. Avoid femoral site for insertion where possible (use the internal jugular or subclavian route).
4. Use CVC insertion checklist. This self-adhesive checklist highlighted the points above and other details including the operator name and whether they had completed the CVC education package. The 'checklist sticker' served as a record of the procedure in the clinical notes.

We stipulated that the operator and assistant should be trained (as defined by having performed the CVC insertion education package and having placed three supervised CVCs).

### Maintenance and removal

- CVC removal as soon as not required using a daily removal prompt.
- Perform hand hygiene before handling CVC.
- Clean injection ports with alcohol wipe before use.
- Avoid use of three way taps where possible and use needle-less adaptors for injection ports.
- Perform daily dressing inspection and, if soiled, clean site with chlorhexidine and replace dressing.
- Use a dedicated lumen for total parenteral nutrition.
- We discouraged blood sampling from CVCs unless absolutely necessary.
- We discouraged catheter exchange over guide wire.

## BEHAVIOUR CHANGE INTERVENTIONS AND IMPLEMENTATION STRATEGIES

Introduction of the bundles was supported by active engagement of staff, educational programmes, measurement and feedback of outcomes, organisational change and, later, the introduction of the Scottish Patient Safety Programme[19] and measurement of insertion bundle processes (online appendix 6).



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## RESULTS

Figure 1 shows all or none insertion bundle reliability over time annotated to show identification and resolution of causes of incomplete reliability. Detail is given in the online appendix 6. Reliability increased between March 2008 and August 2009.

Table 1 lists the patient characteristics comparing the baseline preintervention from the 1st year with that of the 3rd and 4th years. Interventions commenced halfway through year 2 and continued iteratively until the end of year 4.

Figures 2, 3 show monthly and quarterly SPC charts demonstrating a reduction in infections over time. There is an association with the fall in incidence and the start of interventions and commencement of process measurement.

Table 2 lists the infections, patients, patient days and infection incidence per annum from 2005 to 2009. The incidence ratio was calculated as postintervention year rate/year 1 rate; exact CIs and p values calculated using Stata v 10.0. CRBSI incidence fell from 3.38 to 0.46/1000 device days between year 1 and 3 with an incidence rate ratio of 0.137 (95% CI 0.003 to 0.990) representing a significant 86.3% reduction (p=0.0134). Between year 1 and 4, the incidence fell from 3.38 to 0/1000 device days with an incidence rate ratio of 0 (95% CI 0.0 to 0.63) representing a significant reduction (p=0.0025).

## DISCUSSION

The understanding of how to change behaviours and reliably deliver evidence-based interventions is evolving. Although impossible to establish causality, we noted a close association between reliable implementation of interventions known to prevent CRBSI and a fall in the annual CRBSI incidence from 3.38 to 0/1000 device days. High insertion bundle reliability (>80%) was demonstrated over a continuous and prolonged period (18 months) and associated with zero infections. Incomplete reliability was due to failure to place a checklist in the notes, presumably a less important intervention than the other insertion bundle elements. Changes and interventions were iterative and in the context of the social conditions of our ICU overlain latterly by the Scottish Patient Safety Programme[19]; a national breakthrough collaborative[20] including national learning meetings, leadership engagement, access to content and improvement experts, support with collection and interpretation of data and the goal of reducing CRBSI. There are similarities to the Michigan Keystone project[5 6] which included designation of clinical and nurse leaders, teams receiving supporting information on the efficacy of components of the intervention, suggestions for implementation and instruction on methods of data collection, training in safety, regular conference calls, coaching and twice-yearly statewide meetings. Key components have been summarised as a focus on systems, engagement of local interdisciplinary teams to assume ownership, centralised support for technical work, encouragement of local adaption of intervention and the creation of a collaborative culture in the local unit and larger system.[6] In this sense, it is important to acknowledge that the outcome changes we witnessed are likely to be more complex than the simple introduction of a checklist or bundles and probably reflect more complex social and cultural behaviour changes.[21] The observed reduction in CRBSI could be seen as a surrogate and indirect measure of staff performance change.[22] Further study and understanding of the relationship between social behaviour-change interventions and staff behaviours is required. It is not clear how long this kind of improvement can be sustained, and what the key elements will be to maintaining it.

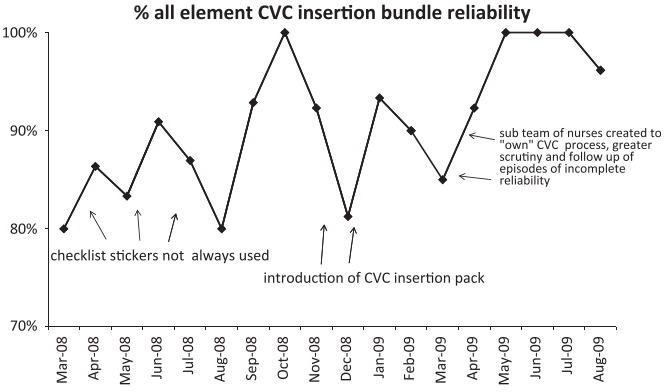


**Figure 1** All or none insertion bundle reliability over time annotated to show identification and resolution of causes of incomplete reliability. Detail is given in the online appendix 6. Reliability increased between March 2008 and August 2009.

As with the Michigan[5] study, data collection and interventions were non-blinded using non-controlled before and after cohorts. Insertion processes were measured only for ICU-placed CVCs. We did not measure maintenance processes; nor did we perform a health economic assessment, although others have demonstrated significant potential cost savings from preventing infection.[23–25] We made no formal assessment of potential adverse effects of the intervention, although none were brought to our attention. Although we described educational interventions, we did not objectively quantify the dose or staff knowledge before or after.

Regression to the mean is an unlikely explanation for improvement, since the baseline infection rate was similar to the rates reported from other Scottish ICUs

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**Table 1** Patient characteristics comparing baseline (first) year (before interventions) with third and fourth years (following introduction of interventions)

| | Preinterventions baseline year 1 (1 September 2005 to 31 August 2006) | Year 3 (1 September 2007 to 31 August 2008) | Statistical test results comparing year 1 with year 3 | Year 4 (1 September 2008 to 31 August 2009) | Statistical test results comparing year 1 with year 4 |
|---|---|---|---|---|---|
| Total patients admitted to ICU | 439 | 465 | | 358 | |
| Percentage of patients ventilated | 69 | 74 | | 73 | |
| Median LOS | 2.2 | 2.5 | p=0.18‡ | 2.3 | p=0.72‡ |
| ICU death rate (%) | 20 | 22 | p=0.48* | 22.6 | p=0.38* |
| Study group | 255 | 235 | | 225 | |
| Male | 143 (56.1%) | 127 (56.2%) | | 125 (55.5%) | |
| Deaths | 54 (21.2%) | 49 (21.7%) | p=0.328* | 36 (16%) | p=0.013* |
| Mean APACHE II (SD) | 19.8 (8.4) | 21.0 (7.3) | p=0.89† | 18.7 (8.7) | p=0.38† |
| Median LOS ($Q_1$, $Q_3$) | 9.7 days (4, 20) | 8.9 days (4, 13) | p=0.64§ | 6.0 (3, 11) | p=0.63§ |
| Mean LOS (SD) | 5.4 days (3.9) | 5.3 (3.7) | p=0.65‡ | 5.9 days (3.7) | p=0.13‡ |
| No of patients with CVC (%) | 240 (93) | 226 (82) | p=1 | 178 (79) | p=1 |
| Days' duration CVC, mean (SD) | 4.94 (4.11) | 6.11 (3.6) | p<0.001‡ | 9.6 (8.46) | p<0.001‡ |
| Site of CVCs | | | | | |
| Internal Jugular (%) | 332 (80.2) | 283 (89.3) | p<0.01* | 227 (91.1) | p<0.01* |
| Subclavian (%) | 63 (15.2) | 24 (7.6) | p<0.01* | 15 (6.02) | p<0.01* |
| Femoral (%) | 19 (4.6) | 10 (3.1) | p>0.33* | 7 (2.81) | p<0.01* |
| Total CVCs used | 414 | 317 | p<0.01* | 249 | p<0.01* |

Interventions commenced halfway through year 2 and continued iteratively until the end of year 4.
*$\chi^2$ Test.
†f Test.
‡t Test.
§Mann–Whitney U test.
APACHE II, Acute Physiological and Chronic Health Evaluation Version II; LOS, length of stay; Study group, patients who had a central venous catheter (CVC) during part or whole of admission and were in intensive care unit (ICU) for more than 2 calendar days.

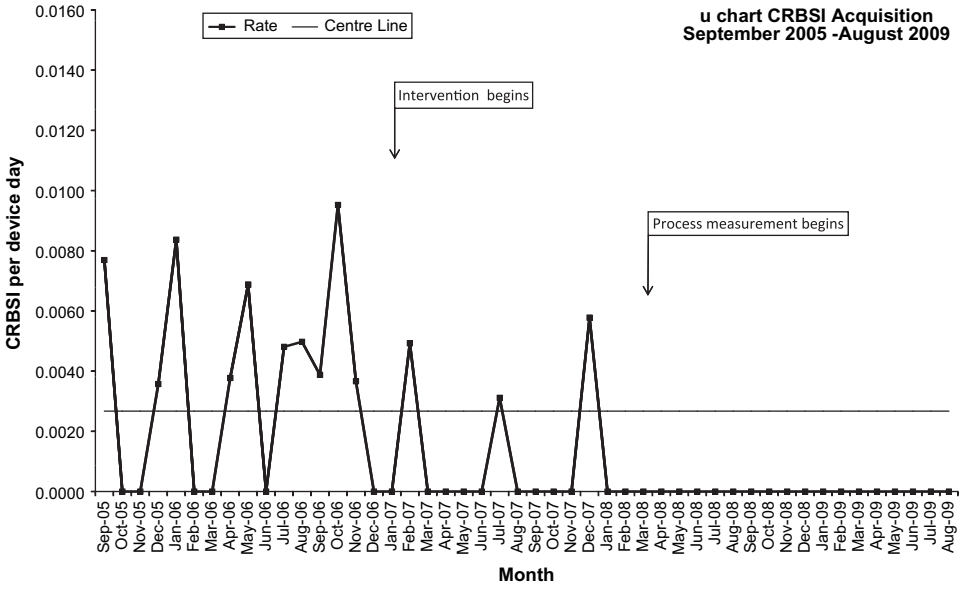


**Figure 2** U chart. Monthly central-venous-catheter-related bloodstream infection (CRBSI) acquisition as rate per device day (number of infections divided by the device days/month). The plot demonstrates the common cause variation before the interventions start. Special cause variation (downwards shift) is evidenced by a run of >6 points below the centre line from February 2008.

(4.2/1000 device days).[26] The SPC chart demonstrated a common cause variation in the baseline period, further supporting the likelihood that the change to zero infection rate represented special cause variation.

The following discussion concerns results shown in table 1. There is no difference in mean Acute Physiological and Chronic Health Evaluation Version II score from year to year. However, there were some important differences. The total number of CVCs used fell significantly from 414 in year 1 to 317 in year 3 and 249 in year 4. There is a non-significant reduction in the percentage of patients per year with a CVC from 93% (baseline) to 79% (year 4). There was a higher mean duration of CVC placement postinterventions, increasing significantly from 4.9 days (baseline) to 6.1 and 9.6 days in years 3 and 4 respectively. This might reflect a cohort of patients who previously had a CVC for a short duration of time but who are now managed without. Fewer CVCs would predispose to reduced infection incidence, but longer catheter placement durations would predispose to increased incidence. Internal jugular catheters increased significantly from 80.2% (baseline) to 89.3% (year 3) and 91.1% (year 4). Femoral catheters fell significantly from 4.6% (baseline) to 2.8% (year 4). Subclavian catheters fell significantly from 15.2% (baseline) to 6.0% (year 4). The increased internal jugular and decreased

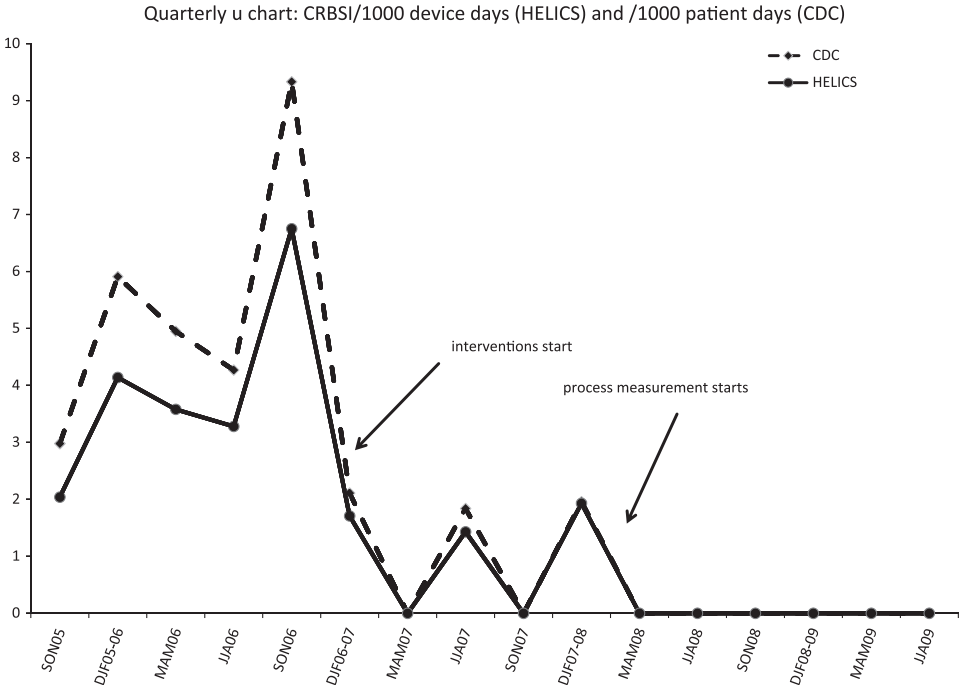


**Figure 3** Quarterly central-venous-catheter-related bloodstream infection (CRBSI) acquisition as rate per 1000 device days and per 1000 patient days (number of infections divided by the device days and patient days respectively ×1000 per month). CDC, Centers for Disease Control and Prevention; HELICS, Hospitals in Europe Links for Infection Control Surveillance.

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femoral site is consistent with the insertion bundle, but it is unclear why there was a reduction in subclavian catheters. There was a non-significant reduction in median length of stay from 9.7 to 6.0 days. Unadjusted mortality fell from 21.2% (baseline) to 16% (year 4) in patients with CVCs. Multiple factors influence mortality.

## CONCLUSION

We describe a significant reduction in CRBSI (with zero episodes in the final 19 months of study) in a UK ICU. We summarised and simplified what to do, measured and provided feedback on outcomes, and improved the culture by building expectations of performance standards for work processes.[21]

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**Competing interests** AGL has recently completed a Scottish Patient Safety Programme Fellowship. SM is currently undertaking the same. LB is Nursing Lead for the Critical Care work stream of the Scottish Patient Safety Programme at Stirling Royal Infirmary.

**Provenance and peer review** Not commissioned; externally peer reviewed.

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**Table 2** Annual infection incidence

| 12 month time period | No of central-venous-catheter-related bloodstream infections | Patients | Patient days (National Nosocomial Infections Surveillance/CDC denominator) | Incidence per 1000 patient days (CDC denominator) | Catheter days (HELICs denominator) | Incidence per 1000 device days Helics denominator |
|---|---|---|---|---|---|---|
| September 2005–August 2006 (year 1) | 9 | 255 | 1918 | 4.69 | 2660 | 3.38 |
| September 2006–August 2007 (year 2) | 7 | 257 | 1990 | 3.52 | 2613 | 2.68 |
| September 2007–August 2008 (year 3) | 1 | 235 | 1800 | 0.56 | 2155 | 0.46 |
| September 2008–August 2009 (year 4) | 0 | 225 | 1562 | 0.00 | 2138 | 0.00 |

CDC, Centers for Disease Control and Prevention; HELICS, Hospitals in Europe Links for Infection Control Surveillance.

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Appendix 6

**Behaviour Change Interventions and Implementation Strategies**

Introduction of the bundles was supported by active engagement of staff, educational programmes, measurement and feedback of outcomes, organisational change and later by the introduction of the Scottish Patient Safety Programme [19] (SPSP) and measurement of insertion bundle processes.

Staff Engagement:

We publicised the interventions. Presentations were made at Hospital and Anaesthetic Department Meetings and a regional Intensive Care meeting. Patient stories were told and harm described. The other 6 Intensive Care Consultants and also Anaesthetic Consultants working outwith ICU were engaged and there was open discussion and debate around the evidence base and bundles and sometimes modification of proposals to resolve areas of debate. Some staff members found it difficult to see the area of skin which had been prepared with 2% chlorhexidine / 70% isopropyl alcohol. We agreed that they could use betadine (povidone iodine) initially to colour the skin, followed by the chlorhexidine in alcohol solution before then allowing the site to dry. There was debate with two Consultant Clinicians about the requirement and benefit of using a full aseptic technique for insertion. This was resolved after sharing the evidence on this subject [18]. During 2007 the group met regularly and liaised closely with members of the local Infection Control Team and also representatives of Health Protection Scotland (a national organisation with an interest in infection control).

Education

A self guided education programme was developed that included information on the insertion and maintenance bundles, the pathogenesis, recognition and consequences of CRBSI. Trainee doctors were asked to complete this and perform 3 supervised CVC insertions before working alone and to perform and pass a brief “test” involving simple questions relating to the education. A record of names and completion was kept. Training of the nursing staff occurred in the same way with regular updates, presentations and tutorials. Quarterly compulsory education as part of ongoing nurse development programmes (groups of 9-18 from a pool of 64 staff) covered rates of infections and preventative behaviours (insertion and maintenance bundles). We used transient informal methods (discussion and visual displays) and lasting visual information (in form of statistical process control charts) displayed within the ICU. In late 2008 we commenced a requirement for nursing staff to complete the self guided education slide show and test. By May 2009 47 of 60 nurses had successfully completed the training and test.

Organisation

CVC insertion checklist prompt stickers were made easily available on the ward. KE (the infection surveillance and quality improvement nurse) initially provided a daytime presence on the unit and prompted medical and nursing staff at the bedside during CVC insertion to follow the insertion bundle as specified and to use the insertion checklist sticker. Staff placed the checklist into the medical notes at the end of the procedure as a record of insertion. We audited handwashing behaviours prior to handling the CVCs and reported results to staff. CVC insertion trays and storage racks were organised to ensure

that the necessary equipment for catheter was insertion easy to locate. Chlorhexidine (2% chlorhexidine gluconate / 70% isopropyl alcohol) was applied using a ChloraPrep stick. Default catheters were non impregnated four or five lumen CVCs (Arrow-Howes: Arrow International) which were dressed with IV 3000 semipermeable transparent dressing (Smith and Nephew).

Scottish Patient Safety Programme

In March 2008 the Scottish Patient Safety Programme (SPSP) [19] was launched in our ICU and the final 16 months of the study were performed in the context of this national improvement programme using a breakthrough collaborative model [20]. The programme involved a number of resources including national learning sets and meetings, leadership engagement, access to content and improvement experts, telephone calls, coaching, support with collection and interpretation of data and goals including the reduction of CRBSI as defined by either more than 300 days between episodes or zero incidence. The programme had the overt support of the Scottish Government and significant positive implications for leadership, administrative support, prioritisation and infrastructure.

Insertion Process Reliability

Full aseptic technique, use of chlorhexidine skin preparation and avoidance of femoral site were quickly accepted and adopted as routine behaviours during 2007 and early 2008. Placing the self adhesive "insertion checklist" in the patient record occurred frequently but not every time. Despite two attempts we had been unsuccessful in setting up a system for measurement of insertion bundle reliability until March 2008 (the launch of SPSP). We had been unable to gain agreement for an individual or group to agree to collecting process measurements over the 24hour 7days cycle of ICU work. We were unable to agree a format for data collection that ensured both clinicians and potential data analysts were supportive and we had difficulties with the cultural concept that data collection be embedded as part of routine work. The SPSP highlighted reduction in CRBSI as a goal and expressly supported process measurement, which was also supported by the Scottish Intensive Care Society Audit Group who added new fields to Ward Watcher (Scottish ICU computer database) to support this. We commenced process measurement against the 4 elements of the insertion bundle.

Any patient who had had a CVC inserted in the preceding 24hrs had the case notes inspected by the patient's nurse for evidence of performance of each element of the bundle which was then recorded. Lack of the "insertion bundle checklist sticker" in the medical notes was taken as evidence that the checklist had not been used. In these cases the evidence for the other elements of the bundle (full aseptic technique, chlorhexidine skin preparation and avoidance of femoral insertion site) was taken from the medical record in the clinical notes. The prompt for the case note inspection came from the Charge Nurse responsible for the shift and the necessity to complete a daily central line insertion bundle as part of the routine data entry into "Ward Watcher". Reliability was in this sense self reported as entered in the case notes by the operator but actually recorded by a third party (namely the bedside nurse). Process measurements were thus taken from clinician entries in the case notes and we did not seek to further enhance validity of the process measurement. Process reliability was recorded in an "all or nothing" manner for each patient episode; that is, there had to be documentation of use of all 4 elements of the

insertion bundle to be recorded as compliant or reliable. Local exclusions included the following; use of the femoral site if there was a clear clinical contraindication to use of the subclavian or internal jugular sites, use of chlorhexidine if the patient was allergic or hypersensitive to it. Daily data entry into Ward Watcher was already routine in our unit and the difference was the addition of the requirement to complete an additional field. Full completion of the daily CVC insertion data is a mandatory field when it comes to discharging patients from the system at the end of their stay in ICU. We did not perform any other actions to ensure a complete dataset.

When we commenced measuring process reliability was recorded at 80% reliability. We sought to better understand reasons for incomplete process reliability and found that the single cause for non compliance was failure to have placed the “checklist” in the notes. Further enquiry established that this was associated with occasional night time placement of CVCs by medical staff who had multiple competing priorities and who were not always completely familiar with the process. We noted that the checklists were stored in a filing cabinet away from the bed spaces. In November and December 2008 we started testing then introduced the use of a self contained CVC insertion pack that contained nearly every piece of essential equipment and also included a self adhesive checklist within the pack with the aim of making it easier for health care workers to “do the right thing”. In March 2009 a team of three nurses was formed to take more ownership of the CVC maintenance and insertion bundles and greater scrutiny of process reliability was commenced that included root cause analysis when process reliability was incomplete and reasons for failure addressed. If a clinician had not performed all elements of the bundle a discussion was undertaken to gain greater understanding and ascertain why. Insertion bundle reliability was communicated to staff at regular meetings and results displayed in the unit.

Appendix 2: HELICS CRI (Catheter related infection) Classification; including CRI-3.

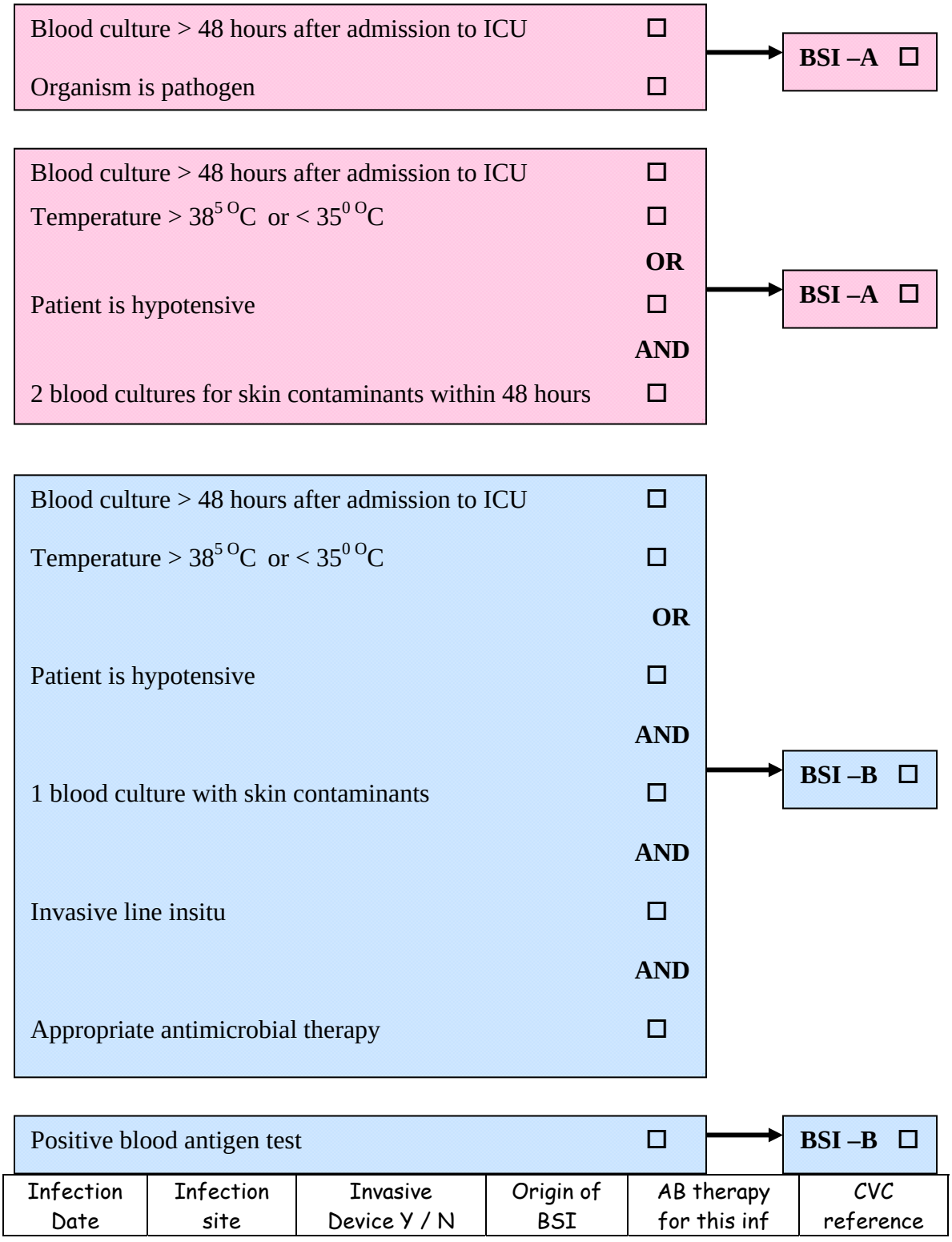
CRI 1: Local CVC-related infection (no positive blood culture): Quantitative CVC culture ≥ $10^3$ CFU (colony forming units)/ml or semi-quantitative CVC culture > 15 CFU and pus/inflammation at the insertion site or tunnel
CRI 2: General CVC-related infection (no positive blood culture): Quantitative CVC culture ≥ $10^3$ CFU/ml or semi-quantitative CVC culture > 15 CFU and clinical signs improve within 48 hours after catheter removal
CRI 3: CVC-related BSI (bloodstream infection): BSI occurring 48 hours before or after catheter removal
and positive culture with the same micro-organism of either: quantitative CVC culture ≥ $10^3$ CFU/ml or semi-quantitative CVC culture > 15 CFU or quantitive blood culture ratio CVC blood sample/peripheral blood sample > 5, or differential delay of positivity of blood cultures or CVC blood sample culture positive 2 hours or less before peripheral blood culture (blood samples drawn at the same time) or positive culture with the same micro-organism from pus from insertion site.

HELICS BSI (Bloodstream Infection) Classification
BSI-A:
1 positive blood culture for a recognised pathogen
or
Patient has at least one of the following signs or symptoms: fever (>38°C.), chills, or hypotension and 2 positive blood cultures for a common skin contaminant (from 2 separate blood samples drawn within 48 hours). (skin contaminants = coagulase-negative staphylococci, *Micrococcus sp., Propionibacterium acnes, Bacillus sp., Corynebacterium sp).*

BSI-B: Patient has at least one of the following signs or symptoms: fever (>38°C.), chills, or hypotension
And either
1 positive blood culture with a skin contaminant in patient with an intravascular line in place and in whom the physician instituted appropriate antimicrobial therapy.
or
positive blood Antigen test (e.g. *H.influenzae, S.pneumoniae, N. meningitidis* or Group B *Streptococcus*)

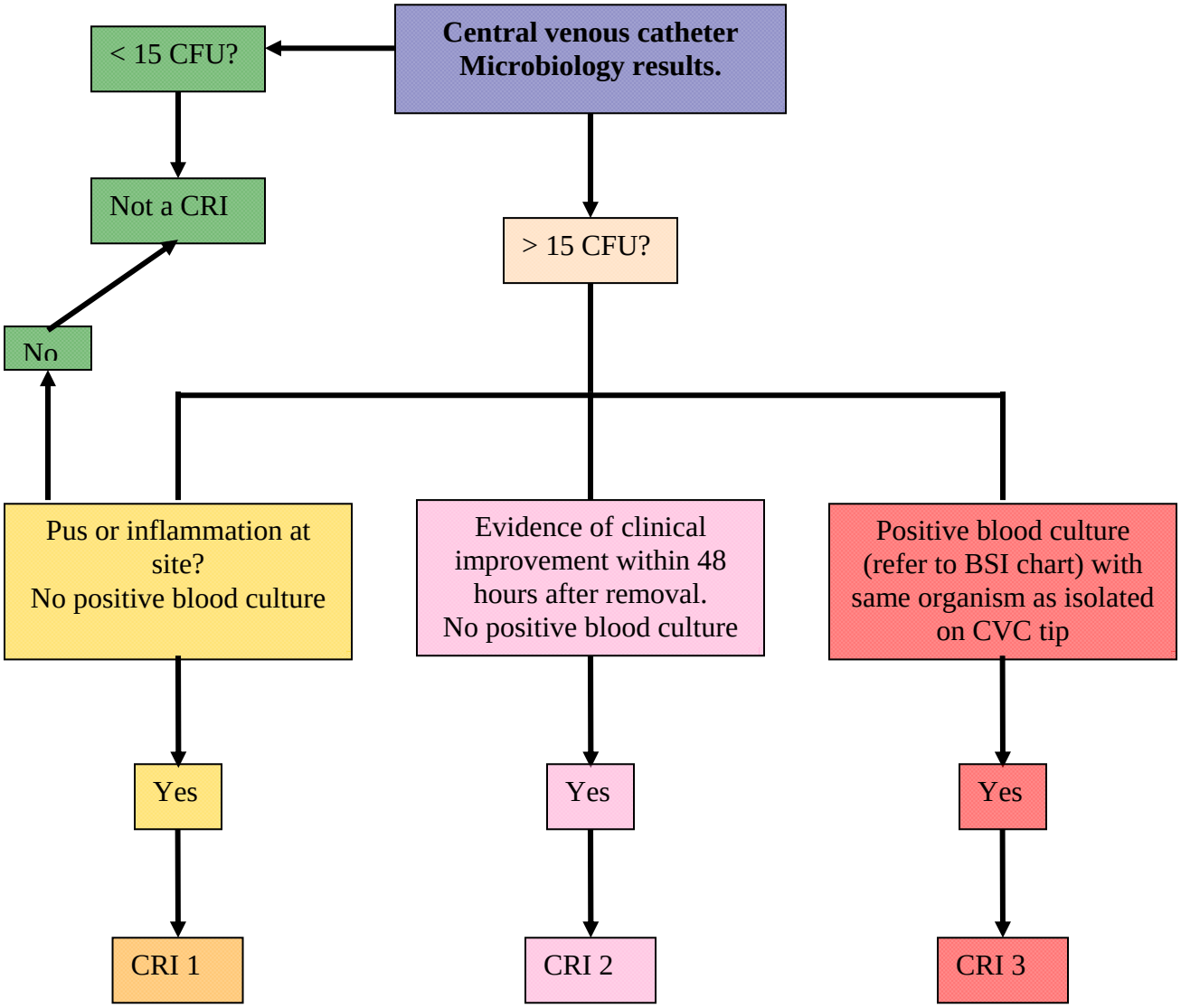
Appendix 3: Flow charts to support diagnosis of HELICS definitions of Blood Stream Infection (BSI)

## Blood stream infection (BSI).



Appendix 4: Flow charts to support diagnosis of HELICS definitions of Catheter Related Infection-3 (CRI-3)

## Catheter Related infection.




| Infection Date | Infection site | Invasive Device Y / N | Origin of BSI | AB therapy for this inf | CVC reference |
|---|---|---|---|---|---|
| | | | | | |

## HELICS Critical Care Infection Surveillance data collection tool

**Patient ID:** _____ **Gender:** M / F **Age:** _____

**Admission date in hospital:** ____/____/_____ Admission type(hospital) _____**Date ICU admission:** ____-____-_____

**:Type of admission (ITU):** Medical ☐ Unscheduled surgical ☐ Scheduled surgical ☐

**Origin of the patient (ITU)**: Ward ☐ ICU ☐ Community ☐ Long-term care ☐

**Surgery site** (within last 30 days before admission, incl. day of admission):

No surgery ☐ Major vascular ☐ Abdominal ☐ Other sites☐

**Trauma:** Yes ☐ No ☐ **Impaired immunity:** Yes ☐ No ☐

**Acute coronary care** Yes ☐ No ☐

**Antimicrobial treatment** *(within 48 hours of admission)* Yes ☐ No ☐

**SAPS II score** ____ **APACHE II score** ____

**Date ICU discharge:** ____-____-_____ **Discharge status:** Alive ☐ Death in ICU ☐ DNR ☐

| DAY | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DATE** | | | | | | | | | | | | | | |
| **Central venous catheter(s)** | | | | | | | | | | | | | | |
| **Intubation** | | | | | | | | | | | | | | |
| **Urinary catheter** | | | | | | | | | | | | | | |
| **Mechanical ventilation non-invasive** | | | | | | | | | | | | | | |
| **Mechanical Ventilation invasive** | | | | | | | | | | | | | | |
| **Re-intubation** | | | | | | | | | | | | | | |
| **Naso / oro-intestinal tube present** | | | | | | | | | | | | | | |
| **Feeding via naso / oro-intestinal tube** | | | | | | | | | | | | | | |
| **Parenteral nutrition** | | | | | | | | | | | | | | |
| **Antimicrobial data (Use generic names)** | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | |

**P** (prophylaxis) **E** (empiric) **M** (gram stain) **A** (anti-biogram)

| CVC number | date inserted | Site | ATB perfusion | date removed | Other infection at removal | >1 organ failure at removal |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |

**C** = central line **Q** = Haemofilter line **P** = pulmonary artery catheter **S** = subclavian **J** = jugular **F** = femoral
**R** = right **L**=left

**HELICS Level 1 complete** ❒

**HELICS Level 2 complete** ❒

**Microbiology review complete** ❒

**Data in-put complete** ❒

Addressograph

**HELICS Critical Care Infection Surveillance data collection tool**

| Date | Temp | WBC / CRP | CXR | Sputum | Breath sounds | $O_2$ levels | Ventilation | | Inotropes | CVVH |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Mode | Support | | |
| | | | | | | | | | | |
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Notes:

Appendix 5: Details of modified Maki roll and microbiological analysis of CVC tips

The terminal four centimetres of catheters were rolled 5 times across the surface of a horse blood agar plate (Oxoid,UK) before being returned to the sterile container. Ten ml of fastidious anaerobe broth (Oxoid UK) was added to the container. Following incubation at 37$^{o}$C for 18 to 24 hours, the plates were examined for growth; and any colonies counted, with isolate identification performed as required. Sensitivity tests were performed on isolates considered to be pathogenic regardless of number of colonies, and on other organisms if present at ≥ 15 colonies. In the event of no growth on the rolled plate, the broth was further investigated to detect potential intra-luminal colonisation. In these cases the broth was subcultured to Blood agar, CLED agar (Oxoid,UK) and Fastidious Anaerobe Agar with Neomycin (Oxoid,UK). These plates were incubated at 37$^{o}$C for 18 to 24 hours. Blood agar and CLED agar were incubated in 5% $CO_2$ and the anaerobic neomycin agar plate was incubated under anaerobic conditions. Following incubation the plates were examined for growth and isolates processed as before and reported as being present from subculture. Isolates from subculture only would have been present either in very small numbers on the external surface or would have been present on the internal surface of the catheter.