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In situ diagnostic methods for catheter related bloodstream infection in burns patients: A pilot study

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ARTICLE INFO

Article history:
Accepted 9 July 2015

Keywords:
Burns
Sepsis
Catheter-related bloodstream infection
Central venous catheter
Arterial catheter
Intensive care unit

ABSTRACT

Background: One of the most common and potentially fatal complications in critically ill burns patients is catheter related bloodstream infection (CR-BSI). Lack of in situ diagnostic techniques requires device removal if CR-BSI is suspected with 75–85% of catheters withdrawn unnecessarily.

Aims: To assess the sensitivity, specificity and accuracy of two in situ diagnostic methods for CR-BSI in an adult ICU burns population: Differential Time to Positivity (DTP) and Semi-Quantitative Superficial Cultures (SQSC).

Methods: Both arterial (AC) and central venous (CVC) catheters were studied. On clinicians' suspicion of CR-BSI, the CVC and AC were removed. Superficial semi-quantitative cultures were taken by removing the dressings and swabbing within a 3 cm radius of the CVC and AC insertion sites, as well as inside each hub of the CVC and AC. Peripheral blood was taken for qualitative culture and the catheter tip sent for semi-quantitative culture. DTP was considered positive if culture of lumen blood became positive at least 120 min before peripheral blood with an identical pathogen. Superficial and tip cultures were identified as positive if ≥15 CFUs were grown. CR-BSI was confirmed when both catheter tip culture and peripheral blood culture were positive with the same micro-organism.

Results: Sixteen patients (88% male) with an APACHE II score of 22.0 (7.3) were enrolled. The mean age was 45.7 (16.9) years with mean total burn surface area 32.9 (19.4)%. Fifty percent had airway burns. ICU stay was 19.9 (11.1) days. All 16 survived ICU discharge with a hospital survival of 93%. There were 20 episodes of CR-BSI in these 16 patients. For these 20 episodes the exposure time (line days) was 113.15. The CR-BSI rate was 15.6 per 1000 catheter days (95% CI 1.9–56.4). For diagnosis of CR-BSI in either AC and CVC, SQSC had a sensitivity of 50% [95% CI 3–97], specificity 83.3% [95% CI 67–93], PPV 14.3 [95% CI 1–58], NPV 96.8 [95% CI 81–100], accuracy of 81.6% [95%CI 65–92] and diagnostic odds ratio 5.0 [95% CI 0.3–91.5]. To

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http://dx.doi.org/10.1016/j.burns.2015.07.004

diagnose tip colonisation (>15CFU), sensitivity of SQSC was 75% [95% CI 22–99], specificity 88.2% [95%CI 72–96], PPV 42.7 [95% CI 12–80], NPV96.8% [95% CI 81–100], accuracy 86.8% [95% CI 71–95] and diagnostic odds ratio 22.5 [95% CI 1.9–271.9]. For combined DTP blood cultures, sensitivity for CR-BSI was 50% [95% CI 3–97], with specificity 97% [95% CI 82–100], PPV 50% [5% CI 3–97%], NPV 97% [95% CI 82–100], accuracy 94.3% 95% CI 79–99] and diagnostic odds ratio 32 [95% CI 1.1–970.8].

Conclusion: Both DTP and SQSC displayed high specificity, NPV and accuracy in a population of adult burns patients. These features may make these tests useful for ruling out CR-BSI in this patient group. This study was limited by a low number of events and further research is required.

1. Introduction

Patients with severe burns admitted to hospital and particularly those admitted to the intensive care unit are at high risk of developing treatment related complications in addition to those as a consequence of their primary injury. One of the most common and potentially fatal complications in this patient group is catheter related blood stream infection (CR-BSI), generally from the central venous or peripheral arterial catheter [1,2].

Recognition of CR-BSI in this patient cohort is difficult. In particular many patients will have a prominent inflammatory response in which a raised temperature is invariably present. For the clinician managing the critically ill patient with severe burns the assessment of intravascular devices (IVD) as a source of sepsis remains difficult. Many clinicians choose to remove the suspect IVD rather than risk the complications of untreated CR-BSI. Reinsertion may be associated with morbidity particularly if other vascular access sites are limited. Whilst the Centre for Disease Control (CDC) does not recommend routine catheter exchange, this is common practice in burns patients [3,4]. Although there is no evidence to support this practice in any intensive care population, this may be currently justified on the basis of significantly higher infection rates in selected patients [1,5,6].

In general the diagnosis of CR-BSI is still largely retrospective since it is dependent on IVD removal to culture of a device segment, in addition to blood. Accurate clinical assessment to predict the presence of infection in IVDs is known to be poor, and a large proportion (75–85%) of catheters are therefore removed unnecessarily, the majority being sterile [7,8]. Thus techniques for the in situ diagnosis of CR-BSI, which do not require device removal, have been examined.

In situ techniques include catheter internal hub and skin cultures (quantitative or semi-quantitative cultures of skin surrounding the portal of entry and hub of device) either separately or combined. These have been shown to have a very high negative predictive value in excluding the catheter as a source of sepsis when IVD infection is highly suspected, but less so when used in daily surveillance but not in the burns population [9]. Paired quantitative blood cultures drawn through the device and peripheral blood exhibit high sensitivity and specificity in the diagnosis of CR-BSI but are technically difficult, expensive and time consuming to perform. Lastly differential time to positivity (comparing the time to culture positivity from blood drawn simultaneously from device and peripherally), which can be easily performed on modern automated culture machines and has shown good sensitivity and specificity [10]. This technique displays similar accuracy to that of quantitative cultures but is substantially more accessible to clinicians. Although all these methods have been described previously in other patient groups, mainly haematology/oncology cohorts their use in diagnosing CR-BSI in burns patients is to our knowledge unexplored [10–12].

This pilot study had two aims. Firstly, to assess the sensitivity, specificity, negative and positive predictive values and accuracy of differential time to positivity (DTP) and semi-quantitative superficial cultures (SQSC) for the diagnosis of CR-BSI (either AC or CVC) in an adult ICU burns population. The accuracy of these tests was compared to an accepted 'gold standard' of CR-BSI, i.e. IVD removal with positive culture of tip and matching organism growth on peripheral venous blood culture with no other obvious source of the infection. [13] We chose to examine both the arterial catheter (AC) as well as central venous catheters (CVC) as sources of CR-BSI as they have been previously shown to have similar rates of infection [2,14]. Our second research aim was to compare and contrast these in situ methods for diagnosing CR-BSI or catheter tip colonisation in the ICU burns patient cohort.

2. Materials and methods

Patients who had suffered major burn injuries and admitted to the ICU were analysed separately from data taken from a larger prospective non randomised single centre study, The Sepsis Associated with Vascular access–Easier Diagnosis (SAVED study) [15]. During data collection those patients who had a diagnosis of burns were identified and additional demographic data was collected; including percentage body surface area (%BSA) burn and thickness, presence or absence of inhalational injury, whether the patient had been fully grafted on discharge or during the ICU stay. This allowed identification of appropriate records from the original data set.

The SAVED study compared the predictive value of two in situ methods for the diagnosis of CR-BSI and catheter tip colonization (CTC) in a heterogeneous sample of critically ill patients with clinically suspected CR-BSI. The study was a prospective study carried out between August 2008 and May

2009 in the 36 bed adult Intensive Care Unit (ICU) of the university affiliated 900 bed Royal Brisbane and Women's Hospital (RBWH). This is a quaternary hospital that caters to all medical and surgical disciplines except solid organ transplant and cardiac surgery. The ICU admits several categories of adult patients; these include general trauma, neurosurgical, general medical and surgical cohorts, stem cell and bone marrow transplant and subspecialty surgical patients. The RBWH is the only major adult burns referral centre for the state of Queensland. Although the burns unit (distinct in location, structure and function from the ICU) of the RBWH caters for lower acuity patients with burns trauma, all critically ill ventilated burns trauma patients are managed in the general ICU in consultation with dedicated burns surgeons. The ICU operates functionally as a closed unit staffed by certified intensivists with full time 24 h junior medical staff cover. The nursing ratio at the bedside was always 1:1 for any ventilated patient with additional senior nurses assisting with care.

Only short term CVCs and ACs were studied. Patients who had PICC lines or vascular access catheters (dialysis, vascaths, permacaths, Hickmann lines, portacaths) were excluded from the study. All CVCs were either ARROW gard+Blue®, which have an antimicrobial chlorhexidine and silver sulfadiazine coating on the external surface or ARROW plain unmedicated multilumen catheters (Arrow International, Reading, USA). Antibiotic impregnated lines were not used. All ACs (Leader Cath, Vygon, Ecouen France) were inserted into the radial, femoral or dorsalis pedis positions. Both IVD types were inserted using a Seldinger approach with ultrasound guidance preferred. All were secured using 2/0 silk. All catheters were managed using a standardised ICU protocol, which was applicable throughout the study. All catheters were inserted by experienced ICU medical staff using full aseptic precautions including use of a full sized drape, mask, cap, gown and sterile gloves. Chlorhexidine 2% in 70% alcohol was used for skin antisepsis. Insertion site was at the discretion of the attending clinician and was always through either debrided and grafted or unburnt skin. The subclavian site remained the preferred option in those with no contraindications [16]. There were no imposed limitations on dwell time and re-siting of IVDs always occurred at a new site. Guidewire exchange was not routinely performed. Dressings and administration sets were maintained by dedicated ICU nurses using unit protocols and in accordance with best practice evidence [16]. Neither needleless connectors nor chlorhexidine impregnated sponges/dressings on catheter insertion sites were used during this study.

Ethical approval was obtained from the Royal Brisbane and Women's Hospital Human Research Ethics Committee (HREC; Protocol 2008/024) and delayed informed consent was obtained from the patient or patients' next of kin. Any patient with burns admitted to the ICU that was suspected of having or in which CR-BSI could not be confidently excluded by the attending clinician was included. Clinical suspicion of infection was triggered by the presence of two or more of the systemic inflammatory response syndrome (SIRS) criteria in the previous 24 h or clinical instability suggestive of sepsis such as hypotension, rigours or chills with elevation of inflammatory markers and no other obvious source of infection except the IVD.

Patients who had a CVC and AC in situ were screened daily by the ICU research officer/nurse in consultation with the clinical team for suspicion of CR-BSI. On suspicion of CR-BSI, the CVC and AC were simultaneously removed by the research officer/nurse. Superficial semi-quantitative cultures were taken by removing the dressings and swabbing within a 3 cm radius of the CVC and AC insertion sites, as well as the internal surface of each hub of the CVC and AC. Qualitative blood cultures were then taken from the peripheral blood as well as from each catheter lumen (proximal, distal, medial) of the CVC and from the AC. The CVC and AC distal catheter tips were sent for semi-quantitative culture.

Information was obtained from the patients included demographic data (age, sex, diagnosis), clinical data (SAPS/APACHE II Scores, ICU and hospital length of stay (LOS), mortality), burns data (percentage body surface area (%BSA) burn and thickness, presence or absence of inhalational injury, whether the patient had been fully grafted on discharge or during the ICU stay.) and catheter data (type, insertion site, operator experience, lumen number, date inserted and date removed, purpose of catheter use and reason for removal).

A systematic approach to sample collection was undertaken in all patients. For superficial hub cultures a dry cotton swab stick was introduced into the lumen hub of both AC and CVC to repeatedly swab the inner surface. All hubs were assessed. Skin swab samples were obtained from the IVD skin insertion site, within a 3 cm radius, immediately after dressing removal. For DTP blood culture of the IVD lumens the first 5 ml of blood from each lumen of both AC and CVC was inoculated into a separate aerobic blood culture bottle. All lumens of the CVC were sampled. If the lumen was blocked, 1–2 ml of normal saline was used to flush and aspiration was attempted again. Peripheral blood for qualitative culture and assessment of DTP was cultured simultaneously by drawing 10mls and inoculating 5mls into both aerobic and anaerobic blood culture bottles. The distal 5 cm portion of IVD tips was cultured after removal under aseptic conditions.

3. Laboratory process

All samples were sent to the microbiology laboratory immediately for analysis. The BacT/ALERT® Automated Microbial Detection System (bioMerieux Inc., Marcy-L'Etoile, France) was used for the detection and DTP of micro-organism growth in blood culture. Culture positivity was recorded every 15 min using bacterial growth fluorescence changes. Micro-organisms were then isolated and identified according to standard hospital protocol. Superficial swabs were cultured on Horse Blood Agar and MacConkey Agar plates. IVD tips were cultured semi-quantitatively using the roll plate method [17]. All micro-organisms were fully identified and tested for antimicrobial susceptibility.

4. Definitions

SIRS was assessed as per standardised criteria [18]. The culture of skin swab and catheter hubs (surface/superficial cultures) was considered positive when there were more than 15 colony forming units (CFU) per plate [19]. These cultures were also gram stained prior to plating.

CR-BSI was defined as a positive semi-quantitative catheter tip sample from either the CVC or AC combined with a positive peripheral blood culture with the same micro organism and antibiogram with no obvious secondary source of sepsis evident [20]. Differential time to positivity was recorded as positive if the blood cultured from the catheter hubs/lumens yielded a positive result at least 120 min earlier than a blood sample drawn from the peripheral vein [10].

5. Data analysis

Demographic results for CR-BSI and non CR-BSI groups were compared using Mann–Whitney's *U*-test for continuous measures and Fisher's exact test for proportions. Incidence rates of CR-BSI per 1000 catheter days were calculated with a Poisson 95% confidence interval. Accuracy results (sensitivity, specificity, positive predictive value, negative predictive value, accuracy and diagnostic odds ratio) for DTP and SQSC diagnostic techniques used were calculated with an exact binomial 95% confidence interval, and using the CR-BSI diagnosed by traditional methods as the gold standard. The use of superficial cultures (skin swab and hub) versus skin swab cultures alone was also analysed to determine their effectiveness in predicting significant catheter tip colonization (>15 CFU), which is sometimes used as a surrogate of CR-BSI for both ACs and CVCs.

6. Results

The SAVED study demonstrated 120 discrete episodes of suspected CR-BSI in 101 patients [15]. There were 16 patients with burns in this cohort. For these 16 patients, the mean age was 45.7 (16.9), 88% of whom were male. The mean APACHE II score for the cohort was 22.0 (7.3). Mean % BSA burn was 32.9% (19.4) with 50% of the patients having airway burns. All patients survived ICU discharge with a hospital discharge of 93%. There were no incidences of CR-BSI associated mortality.

There were a total of 20 episodes of suspected CR-BSI in 16 unique patients. Two episodes of CR-BSI were confirmed (10%). One with both *Pseudomonas Aeruginosa* and *Staphylococcus epidermidis*, the other with *Acinetobacter Baumannii*. The two episodes involved CVC (not AC) sites, with one episode from the femoral site and one from an internal jugular access site. Baseline characteristics and incidence of CR-BSI are reported in Table 1. There were no significant differences between patients with and without CR-BSI in age, sex, %BSA burnt or presence of airway burn and episodes of CR-BSI. The total number of catheter days for the 20 episodes was 113.15 days. The 95% CI for CR-BSI per 1000 catheter days was 15.6 (1.9, 56.4).

Table 2 compares the validity values for Differential Time to Positivity (DTP) and Superficial Quantitative Skin Cultures (SQSC) in relation to CR-BSI in either CVC and ACs. Overall DTP performed better than SQSC with a diagnostic odds ratio of 32.0 [95% CI 1.1–970.8] vs SQSC 5.0 [95% CI 0.3–91.5]. DTP was also more specific 97.0% [95% CI 82.0–99.9%] versus SQSC 83.3% [95% CI 67–93%] and had a greater positive predictive value 50.0% [95% CI 3.0–97.0%] vs. SQSC 14.3% [95% CI 1–58%]. Both tests had high negative predictive values with DTP 97.0% [95% CI 82–100%] and SQSC 96.8% [95% CI 81–100%].

The results in Table 3 show that skin swab cultures alone performed better on the whole than superficial cultures for catheter tip colonisation, being more specific at 94% [95% CI, 79–99%] versus 88.2% [95% CI 72–96%], with higher positive predictive values of 60% [95% CI 17–93%] versus. 43% [95% CI 12–80%], and marginally higher negative predictive values of

Table 1 – Baseline characteristics of burns patients and incidence of CR-BSI.

Parameter	Total N = 16*	With CR-BSI N = 2	No CR-BSI N = 14	*p*-value
Age, y mean (SD)	45.7 (16.9)	56.5 (19.1)	44.1 (16.7)	0.42
Sex, male (%)	14 (88%)	2 (100%)	12 (86%)	1.0
APACHE ii score, mean (SD)	22.0 (7.3)	29.0 (1.4)	21.0 (7.2)	0.20
SAPS ii score, mean (SD)	46.1 (13.2)	63.5 (6.4)	43.6 (12.1)	0.07
ICU length of stay, *d*, mean (SD)	19.9 (11.1)	26.0 (20.7)	19.1 (10.2)	0.60
Hospital length of stay, *d*, mean (SD)	61.4 (49.3)	111.9 (128.2)	53.0 (28.9)	1.0
ICU survival (%)	16	2	14	N/A
Hospital survival (%)	13 (93%)	1 (50%)	12 (100%)	0.14
Airway burn (%)	8 (50%)	1 (50%)	7 (50%)	1.0
Percentage BSA burns, mean (SD)	32.9 (19.4)	26.0 (31.1)	33.9 (18.7)	0.61
CVC-site (*n* = 20)				
Femoral	10	1	9	N/A
Internal jugular	4	1	3	N/A
Subclavian	6	0	6	N/A
AC-site (*n* = 18)				
Radial	2	0	2	N/A
Dorsalis Pedis	3	0	3	N/A
Femoral	13	0	13	N/A
CVL – in situ time, *d*, mean (SD)	5.7 (1.4)	5.3 (3.3)	5.7 (1.3)	1.0
AC – in situ time, *d*, mean (SD)	5.7 (1.9)		5.7 (1.9)	N/A

* 20 episodes of suspected CR-BSI in 16 unique patients.

Table 2 – Relationship between CR-BSI, DTP and superficial cultures for both CVC and AC combined.

Measure	CR-BSI in CVC & AC combined	
	DTP	Superficial cultures
Sensitivity	50.0%	50.0%
95% CI	3–97%	3–97%
Specificity	97.0%	83.3%
95% CI	82–100%	67–93%
PPV	50.0%	14.3%
95% CI	3–97%	1–58%
NPV	97.0%	96.8%
95% CI	82–100%	81–100%
Accuracy	94.3%	81.6%
95% CI	79–99%	65–92%
DOR	32.0	5.0
95% CI	1.1–970.8	0.3–91.5

Table 3 – Validity scores of superficial cultures (skin and hub) and skin cultures alone as a measure of catheter tip colonization (CTC) in AC's and CVC's.

Measure	Catheter tip colonization in AC's and CVC's combined	
	Superficial cultures (skin + hub)	Skin cultures
Sensitivity	75.0%	75.0%
95% CI	22–99%	22–99%
Specificity	88.2%	94.0%
95% CI	72–96%	79–99%
PPV	42.9%	60.0%
95% CI	12–80%	17–93%
NPV	96.8%	97.0%
95% CI	81–100%	82–100%
Accuracy	86.8%	92.0%
95% CI	71–95%	78–98%
DOR	22.5	48.0
95% CI	1.9–271.9	3.3–697.5

97% [95% CI 82–100%] versus 96.8% [95% CI 81–100%] and a better diagnostic odds ratio of 48.0 [95% CI 3.3–697.5] versus 22.5 [95% CI 1.9–271.9]. The tests had equivalent sensitivities.

7. Discussion

Central venous and arterial access is integral in the management of patients with severe burns. Peripheral access may be impossible and is rarely adequate alone. However, despite their advantages both arterial (AC) and central venous catheters (CVC) are associated with the risk of catheter related blood stream infection (CR-BSI) [14,21–23]. BSI is associated with significantly higher mortality, hospital length of stay, intensive care unit length of stay, ventilator days and hospital costs. This makes prevention and accurate, early diagnosis pivotal in the management of CR-BSI [24]. Burnt skin is often highly contaminated and thus acts as an obvious source of infection [25,26]. Not surprisingly, the rate of CR-BSI is higher in this population and in some reports has been found to be as much as two to three times that of other groups of patients in ICU [14,27,28].

In the critically ill, the diagnosis of CR-BSI remains a challenge as clinical signs are often unreliable [29]. Fever lacks specificity whilst catheter site inflammation is more specific but lacks sensitivity [30]. A systemic inflammatory response syndrome is an inevitable consequence of injuries such as major trauma and burns. Thus detection of infected intravascular devices in this group is even more fraught with difficulty. This often leads to an over diagnosis of CR-BSI and unnecessary catheter removal in a patient group in which vascular access is difficult [31]. Whilst the CDC, IDSA and others have published guidelines on the management of IVDs there is no specific guidelines for burns patients [20]. Practice varies widely and evidence is lacking. Routine IVD replacement, despite some trials showing lack of effect, is common and there is little evidence to support either guidewire exchange or catheter replacement [6,32]. The timing of routine exchange is controversial with King et al. showing a significant increase in CR-BSI when routine catheter exchange was increased from 3 days to 4 days [4]. Whilst O'Mara et al. demonstrated no difference in rates of CR-BSI with increasing line days [32]. If routine replacement is in fact ineffective, much time and resources and patient discomfort could be saved, but leaving lines in place longer would require clinicians to have confidence that infection is not occurring – issues that make the prospect of an in situ diagnostic test for CR-BSI appealing, particularly in this patient group.

Two broad categories have been used in the approach to the diagnosis of CR-BSI; the first of which includes either semi quantitative or quantitative (e.g. sonication) catheter segment culture and peripheral blood cultures. Unfortunately this necessitates removal of the catheter. The second category allows in situ diagnosis and includes quantitative peripheral and CVAD drawn blood cultures, DTP and SQSC; these techniques potentially spare the catheter from removal and replacement.

A meta analysis by Safdar et al. in 2005 [33] demonstrated that quantitative or semi-quantitative culture of the catheter combined with two blood cultures was the most accurate method for diagnosing IVD related bloodstream infection. Our study used this method to define CR-BSI as our gold standard. Compared to this gold standard, our results demonstrated that both DTP and superficial cultures had very high NPV. These results are in keeping with the results of a prospective trial by Bouza et al. [11]. Their study compared the yield of three microbiological procedures (SQSC, DTP and differential quantitative blood cultures) to assess CR-BSI without catheter removal in a cohort of patients without neutropaenia or blood disorders. The high NPVs coupled with adequate specificities and accuracies of these methods may be useful to the clinician to exclude CR-BSI as a potential source of infection and redirect appropriate antibiotic therapy. We were unable to demonstrate the same degree of sensitivity as previous studies [11] but this was not unexpected due to the low number of events in our study.

Frequent IVD replacement exposes the patient to increased risk of both mechanical and infectious complications. With increased CR-BSI associated with IVDs placed close to burnt skin, this can severely limit the number of available sites and reducing the frequency of catheter changes could have significant benefits [26]. With greater awareness of CR-BSI

and the associated adverse outcome a low threshold for catheter removal is often adopted, robust methods for in situ diagnosis could reduce the need for such frequent catheter exchanges. Rijnders et al. demonstrated the utility of a 'watchful waiting' approach, however their study did not include burns patients and excluded many other high risk patients, making its applicability in burns patients limited [34]. With the increased of risk of CRBSI associated with burns patients the strategy of 'watchful waiting' alone may not be appropriate in symptomatic patients.

The second part of our study aimed to establish the accuracy of the in situ methods for predicting catheter tip infection (growth of >15 CFUs on semi-quantitative culture of the catheter tip), often used as a surrogate for CR-BSI [17]. The results obtained again suggested the potentially valuable use of both SQSC and DTP for the exclusion of CR-BSI by demonstrating high NPVs. Our data suggest that skin swab cultures performed alone, without hub cultures, are just as effective as both tests performed together. This naturally would be significantly less resource intensive were it to be implemented on a wide scale.

The question remains as to how to apply these tests clinically. Bouza et al. [17] suggested combining SQSC and peripheral blood cultures to screen for CR-BSI leaving differential quantitative blood cultures as a confirmatory test in just the cohort of patients admitted to the ICU. This recommendation is based on significantly better sensitivity for SQSC than DTP in their study, a finding not reflected in our cohort, where both tests were useful. Therefore, based on our results the strategy of SQSC screening only may not be appropriate. However a further trial with larger study groups would be beneficial in further investigating this potential in burns patients. DTP and SQSC may have a role in ruling out CR-BSI by virtue of their high NPVs, specificity and accuracy, however more robust data is required.

Further studies need to explore additional questions not addressed in this study. We did not explore how the position of the catheter in relation to the burn affected the validity scores of SQSC. The impact of chlorhexidine impregnated dressings on the study outcomes was not investigated since they were not used in our setting at that time. All central venous catheters in this study were Chlorhexidine–Silver Sulfadiazine impregnated. Antimicrobial catheters have been shown to reduce bacterial growth by the roll plate method for upto 14 days [35]. The mean dwell time of catheters in our study was 5.7 days so this may have led to false negative catheter tip culture. In future studies this may be abated by the use of media containing inhibitors [35]. Our study population was a subset of a larger study [15] and as a result relatively small and the incidence of confirmed CR-BSI was low. This naturally reduced the PPV of these tests [11,29]. However critically ill burns patients represent a smaller sub-population, and studies with large sample sizes would be difficult to perform. It is likely that the PPV of these tests is significantly influenced by the pre-test probability, which, in part, is based on the level of suspicion the clinician holds as well as known risk factors [36–38]. However the potential value of these in situ diagnosis techniques in this specific population warrants further investigation perhaps by combining these techniques with the 'watchful waiting' strategy suggested by Rijnders et al. [34]. Burns patients may be at increased risk of both mechanical and microbiological complications of catheter exchanges and reducing the frequency of exchanges by improvements in in situ CR-BSI diagnosis may have significant benefits [39].

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