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Title: Peripheral arterial catheters (AC) as a source of sepsis in the critically ill -overrated or underemphasised- a narrative review.

Running Title – Arterial lines and sepsis – a review

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Summary

Intravascular devices (IVD) are essential in the management of critically ill patients however IVD related sepsis continues to remain a major complication. Arterial lines (AC) are one of the most manipulated IVD in critically ill patients. When bloodstream infection (BSI) is suspected in a patient with an IVD in situ clinicians have focussed their attention on the central venous catheter (CVC) whilst largely ignoring the AC. Whilst it would be routine for the CVC to be cultured and replaced if necessary for suspected IVD or catheter related sepsis the AC may not be treated in the same manner. The reasons for this may in part relate to the patient groups studied. In lower acuity patients with short dwell times AC sepsis rates are indeed low. In the higher acuity patient earlier studies suggested that the AC had an infective potential at least equal to short term CVCs, a finding that has translated poorly into clinical practice. However it has been estimated that there may be up to 48,000 BSI per year arising from AC in the USA alone suggesting a very significant clinical problem. Recent evidence now suggests that the infective potential of the AC is comparable with that in short term CVCs in terms of both colonisation (which precedes BSI) and BSI consolidating earlier studies. In critically ill patients suspected of catheter related blood steam infection (CR- BSI) it is suggested that both the AC and CVC must now be regarded together.

Introduction

Peripheral arterial catheters (AC) have become indispensable tools for continuously monitoring blood pressure, and providing a convenient access for repeated blood sampling for arterial blood gas analyses in the critically ill.[1-6] It would not be uncommon in high acuity critically ill patients to have several ACs sited over the duration of their ICU admission. In the USA alone there may be up to 6 million ACs used per year generating nearly 50,000 bloodstream infections. While one does not dispute the essential benefits of AC's and other intravascular devices, catheter-related bloodstream infection (CR-BSI) has remained a leading cause of nosocomial bloodstream infection in intensive care units (ICUs).[7-9] Nosocomial bloodstream infections (BSI) have contributed to longer durations of hospitalization, and increases in hospital costs and patient mortality rates.[10-13]

In terms of BSI the central venous line (CVC) has however continued to remain the main focus in critically ill patients. This is illustrated by the recent adoption of "bundled" care programmes such as implemented by the IHI (5 million lives campaign; http://www.ihi.org). In the prevention of bloodstream infection bundle the AC is not mentioned with the focus on only the CVC. Whilst it would be common practice to culture and if necessary replace a suspect CVC in a patient with signs of sepsis the AC may not be treated comparably and in many cases would not be cultured or replaced.[8] There is a somewhat accepted notion that ACs in general have a low infection risk.[14-17] This is in part reinforced by the Centres for Disease Control and Prevention (CDC) guidelines of 2002, which classify AC as having "low infection rates- rarely associated with bloodstream infection".[18] These guidelines however also report the rate of CR-BSI arising from the AC as comparable to that of CVCs so are somewhat contradictory.

Compared with the CVC there is a paucity of data addressing the risk of CR-BSI and colonisation patterns directly attributed to AC.[3,19] Moreover it is difficult to compare the findings of the limited studies that do exist, due to differences in study designs, patient populations, dwell times, techniques for microbial analyses, lack of standardised terminology used, and the way results are presented.[4,5,8,15,19,20] Recent evidence has now turned the focus back onto the AC with pooled results from prospective studies providing further evidence that AC related BSI and colonization rates approach that seen in short term non tunnelled CVCs. Additionally recent studies have confirmed that in the same populations of critically ill patients concurrent infection rates of the two device types are comparable.[8,19,21] Clinical acknowledgement of these facts however has continued to remain poor.

Aims

The primary aim of this review is to critically appraise the relevant literature on infection rates arising from ACs. The review examines the literature as it pertains to the critically ill ICU patient using a chronological approach. In particular we will focus on recent findings that suggest short term CVC and AC infection rates are comparable in the critically ill.

Methods

A bibliographic search was performed from 1970 through until October 2008 using the databases Pub Med and Google Scholar. The paucity and heterogeneity of literature did not lend itself to either Meta analysis or systematic review. We chose instead to critically review the literature using a narrative review. Search terms used to select articles included "arterial catheter, sepsis, bloodstream infection, critical illness, catheter related blood stream infection, intra-arterial access, intravascular access device".

Results

Historical perspective

Interest in the AC as a potential infective risk is not new. The first report of sepsis arising from an AC occurred in 1970 with a case of endarteritis.[22] A number of other reports implicated the fluid within the transducer and monitoring system as a significant cause of bacteraemia, in particular with gram negative organisms.[23, 24] Other early reports focussed on differing aspects of arterial cannulation such as thrombosis rate and anatomical placement[25, 26] and provided no real detail on infection rates or potential.

Later studies provided further data linking the AC with nosocomial sepsis. Davis[27] prospectively examined 113 radial artery catheters, all of which were cultured, in patients undergoing elective cardiothoracic surgery. Culture of tips was performed in broth media for 48 hours after syringe flush of the AC lumens and then enrichment culture. The authors report a total contamination rate using the enrichment culture media of 39% but only 9% when routine culturing was performed. Six cases of pathogenic bacteria were isolated but there was no clinical correlate between contamination and AC management. A larger prospective study of nearly 500 catheters also in low risk primarily cardiovascular surgery patients was subsequently conducted by Gardner .[28] This study was somewhat unusual in that the AC were inserted without sterile technique and primarily by one operator. The average in situ time was less than 4 days. Two hundred non selected cases from the 495 studied were cultured in a broth medium. Eight (4%) were positive but none of these was associated with bacteraemia.

Improved diagnostic methodology

The early studies cited above have been criticized due to varying and non-standardised methodology in bacterial culture technique and lack of routine culture of the AC. A major advance came with the more accurate reporting of catheter tip culture[29]. Band and Maki [9] studied 95 critically ill patients many with multi organ failure. A total of 130 AC were studied, over 70% inserted into the radial artery with the remainder inserted into the brachial, femoral and dorsalis pedis arteries. The authors reported a positive semi quantitative (SQ) catheter segment (> 15 colonies) as denoting local catheter infection. Blood cultures were obtained from those patients with fever or other signs of infection. Twenty- three (18%) ACs had a positive SQ tip culture. The most frequent pathogens isolated were *Candida albicans, Entercoccus faecalis,* followed by *Staphylococcus epidermidis.* Five catheters (4%) were associated with CR-BSI. Bacteraemic disease was more common in those with catheters in situ for more than 4 days. Additionally the incidence of infection was higher in AC inserted into the femoral artery. Importantly this study was one of the first to report an AC BSI rate comparable to that of short term CVCs.[29] The authors emphasised that removal of the offending device is clearly the most important aspect of management of IVD related sepsis this being applicable to both the CVC and AC. As subsequently demonstrated this is often overlooked by health care personnel leading to inappropriate device retention.[30]

Focus towards the critically ill- earlier prospective studies

Russell [31] set out to compare the complications from 178 radial and 114 femoral catheterisations in 231 critically ill adult patients. The catheters were inserted using sterile gloves and iodine as skin preparation. Catheter maintenance included use of heparin in flush solutions. Insertion sites were examined daily for inflammation or purulent discharge and AC sepsis defined as isolation of same organism from both blood and AC tip. Both blood culture and catheter tip culture were however only ordered at the discretion of the clinician. No details on AC tip culture method were provided. The duration of catheterisation was higher for those with femoral AC compared with radial (5.8days v 3.9days, p=<0.001). Catheter sepsis as defined by a positive blood culture and catheter tip culture, occurred in 1 (0.6%) radial AC and 2 (2.3%) femoral AC with site inflammation only occurring at the radial in 3(1.7%) cases.

Singh [32] studied both peripheral AC (both radial and femoral sites) and pulmonary artery (PA) catheters in 51 critically ill patients using the SQ method of tip culture. Of the 89 catheters studied (52 AC and 37PA) the overall colonisation rate was 10% (9 catheters) with a 4.8% positive blood culture return (4 catheters). For AC only the overall rate of positive SQ culture was 11.5% or 6 ACs. These authors also found a difference in the rates of colonisation between AC sited in the radial and femoral position Skin swabs taken from around the insertion sites of the catheters revealed a correlation between skin colonisation and positive catheter tip thus supporting the role of superficial swabs in identification of infected devices.Leroy[4] in a prospective study of

complications associated with prolonged radial artery cannulation in 112 critically ill patients found that of 164 radial AC removed, 37 cases were colonised. This produced a rate of 22.5% using SQ culture. No cases of CR-BSI were observed. The mean duration of catheterisation was over 6 days and all catheters were inserted using aseptic technique. Transducer fluid was contaminated in 23.5% of cases but bacteriologic concordance between catheter cultures and infusate was seen in only 4 cases.

Gurman [33] reporting their experience with the cannulation of 350 large arteries (Femoral and Axillary) could ascribe the arterial catheter as a cause of systemic sepsis in only 6 (2.2%) out of 266 survivors. This study however relied on cultures drawn via the AC and catheter tips were not cultured in all cases. Positive catheter tip cultures were noted in 7.6% of axillary arterial catheters and 11.1% for femoral catheters. Norwood [34] examined infection rates in ACs sited for more than 96hours in 56 critically ill surgical patients. Catheter tips were cultured SQ and superficial skin/site swabs were also taken. Overall 96 catheters were studied from radial, femoral and axillary sites. Of those catheters left in situ for more than 96 hours 14 (27%) developed positive skin cultures. In those with negative skin site culture no catheter segments were ever positive however 57% of sites with positive skin cultures developed a positive SQ (>15 CFU) catheter culture (p<0.001). The infection rate (as evidenced by a positive SQ culture result) from axillary lines was significantly higher than from radial and femoral combined (9.5% v 44%). These authors also highlighted the value of skin cultures from the catheter site as help in determining when the AC should be removed and cultured. Such cultures if negative have been shown to have high negative predictive value for excluding CVC infection. [35]

In a prospective randomised study Mimoz [36] examined the influence of alcohol based chlorhexidine 0.25% v povidine iodine solution on infection rates of both CVCs and AC. All catheters were cultured quantitatively. Overall 157 AC were studied in 162 critically ill patients. The major finding was the enhanced efficacy of the chlorhexidine based product in terms of colonisation and bloodstream infection rates per 1000 catheter days this was particularly evident for gram positive infections. When the rates of AC infection were considered chlorhexidine reduced colonisation from 32 to 15 per 1000 catheter days compared with povidine iodine (RR 0.5,p=0.05) whereas the rates of CR-BSI were similar at about 8-10 per 1000 catheter days. Finally a study designed to examine the correlation between blood cultures drawn through an in situ AC and cultures from the AC tip, Thomas [37] found no correlation between blood drawn through the AC and catheter tip culture suggesting that AC blood cultures are not predictive of AC infection. About 20% of AC tips were positive using a SQ broth culture method but no peripheral venous blood was sampled precluding comment about rates of BSI.

Hence when prospective studies are considered that utilised SQ tip culture the colonisation rates of AC varied from 7-22.5% with a not insignificant BSI rate of around 4-5%. These studies are summarised in table I. Despite this as late as 1996 the CDC guideline for the prevention of intravascular device related infection[38] continued to

understate the infective potential of these devices and did not advocate surveillance of AC BSIs.

Focus towards the critically ill- later prospective studies

These earlier studies have now been consolidated with new data which is summarised in table II.

An important systematic review of the risk of bloodstream infection stratified according to device type was published in 2006.[8] When data was pooled from prospective studies that reported on AC sepsis rates and compared with pooled data from short term multi lumen CVC BSI rates the AC posed a risk not dissimilar (1.7; 95% CI 1.2-2.3 versus 2.7; 95% CI 2.6-2.9 per 1000 catheter days for ACs and CVCs respectively). Rijnders and colleagues[39] performed a prospective randomised study designed to assess the effectiveness of full sterile barrier precautions (gloves, mask, gown, cap, large drape and 0.5% Chlorhexidine in 70% alcohol) versus standard care (sterile gloves, hand washing and skin disinfectant with 0.5% Chlorhexidine in 70% alcohol) on infection rates. A total of 272 critically ill patients were studied with a mean duration of catheterization of about 8 days. They noted no difference in colonisation between the two groups (20.2 v 15.8 per 1000 catheter days, p >.1). When AC infection rates were examined the incidence of CR –BSI was 1.5 per 1000 catheter days (95% CI, 0.6-3.4) and the incidence of catheter infection of any kind including local phlebitis arising from these devices was 3.2 cases per 1000 catheter days (95% CI ,1.8-5.8). The authors compared this incidence directly with a systematic review of all short term CVC related infection they had previously performed which included data on nearly 100,000 catheter days.[40] This revealed a colonisation rate of 13.5 and a BSI rate of 2.7 cases per 1000 catheter days similar to that of ACs. Lorente [20] also reported AC infection rates compared with contemporaneously sited short term CVCs. The authors reported catheter related local infection (CRLI) which was local infection plus catheter tip colonisation and CR-BSI of each access type. Although the incidence of CRLI was higher for CVCs there was no difference reported in the incidence density of CR-BSI between the CVC and AC (1.4 v 0.4/1000 device days, NS).

Two recent studies which concurrently examined both AC and CVC in the same population have also supported these findings. Traore and colleagues[19] in a population of 212 critically ill patients studied all patients who required both an AC and CVC concurrently for greater than 48 hours. The catheters were cared for in a uniform manner and inserted under the same aseptic conditions. Overall 607 catheters (308 CVCs and 299 ACs) were studied. Nearly 70% of the AC were inserted into the radial position the rest femoral and brachial. The authors reported their findings as positive quantitative culture (PQC) of catheter tip (>10^3 CFU /ml) and catheter related bacteraemia (PQC plus bloodstream infection with same organisms). The epidemiology and incidence of both types of infection was similar between the two catheter types. For

CVCs the incidence density of PQC was 12 per 1000 days of CVC use and for AC 9.3 per 1000 days (p=0.34, Log rank Test). Quantitative culture of the catheter tip indexed to number of catheters inserted similarly revealed no significant differences between the two types of device with a rate of 9.4% for CVCs and 7.7% for ACs(p= 0.44). The rates however of CR-BSI were very low for both devices with only two BSIs producing an incidence density below 0.5%/1000 catheter days for both the AC and CVC.

Work carried out by ourselves[21] which compared directly the infection rates in concurrently sited and identically managed CVCs and ACs has recently shown that both AC colonization and CR-BSI rates were also similar between the two device types. Two hundred and fifty two mainly adult critically ill patients were studied. Into these patients 321 AC were sited, the majority into the radial artery. Concurrently 618 CVCs sited into 410 patients were also studied. All patients were managed under standardised conditions and all catheters were inserted using aseptic technique. Both catheter types were cared for by a consistent team of critical care staff. All catheters were removed as clinically indicated, for suspicion of device infection, when no longer required or if malfunctioning. Catheters were analysed SQ. Blood cultures were only taken where clinically indicated. Fig 1 demonstrates that colonisation over time was not different between the two device types with colonisation rates of 15.71 and 16.83 per 1000 catheters days for AC and CVCs respectively (p=0.77). The incidence of BSI was very low for both device types (0.92 and 2.23 per 1000 device days for AC and CVC respectively).

Does insertion site make a difference?

Infection between differing insertion sites for AC insertion has been reported briefly in some of the studies quoted above.[31, 32] A randomised study conducted by Thomas [41] also attempted to define the risk of infection between the radial and femoral sites in 155 critically ill patients. Overall 186 catheters were studied. The authors found that there was no difference in local infection, catheter related bacteraemia or catheter related infection between the two sites and concluded the femoral site was preferred due to ease of insertion and no difference in infection rates. Although catheter tips were cultured quantitatively no definitions were given for cut off thresholds and it would appear that any growth from the catheter tip in broth was considered positive. Thus contamination and infection were not reliably differentiated.

Our own work[21] has revealed a distinct difference in infection rates dependent on insertion site with femoral sited devices more heavily colonized than those at the radial site. This finding has recently also been confirmed by others.[1, 42] Lorente in a prospective study examined nearly 3000 arterial catheters placed in 2,018 patients.[1] The catheters were all inserted under optimal sterile precautions and replaced every 10 days as routine. The authors reported their findings based upon whether the catheter developed CR-BSI, was simply colonised (>15 CRU) or developed catheter related local infection (CRLI, local infection at site and catheter tip colonisation). The overall

incidence of CRLI and CR- BSI were 1.17 and 0.59 per 1000 catheter days. The femoral site developed a significantly higher incidence of both local and bacteremic sepsis than the radial site. In another publication[20] same authors also reported infection rates compared with contemporaneously sited CVC and reported no difference in incidence density between CVC and AC (1.4 v 0.4/1000 CVC days). Khalifa[42] and colleagues set out to determine if a conservative approach to catheter relocation was detrimental. They studied 295 peripheral arterial catheters from the same number of patients. Catheters were cultured quantitatively. They found the risk of colonisation was significantly lower for catheters inserted into the radial as opposed to the femoral artery site [incidence density 33.8vs 16.4 per 1000 catheter days].The insertion of the catheter in the femoral artery was the only independent predisposing factor for catheter colonisation (RR 2.41; 95%CI, 1.30-4.48, p= 0.005) when compared to the radial site.

Should AC's be changed routinely or in response to signs of infection?

Finally the issue of regular interval change versus change as clinically in AC remains largely unanswered. A significant earlier study demonstrated a major risk factor for bacteraemia was catheter duration. AC in place for greater than 4 days being significantly associated with bacteraemia compared with those in place for less than that time and concluded that AC should be replaced after 4 days. [9] Our own work has suggested that AC are progressively more colonised over time.[21] However we were unable to make recommendations of whether AC should be routinely changed or not at an interval. Current CDC guidelines recommend that peripheral ACs need not be routinely replaced to prevent catheter-related infection.[18] This guideline was based on two previous studies conducted on ACs.[43, 44] However, these studies seem to contradict each other. Eyer in a randomized study of three methods of long-term catheter maintenance advocated that ACs should be left in-situ and not be changed unless indicated.[44] Raad on the other hand advocated that ACs should be routinely changed every 4 days[43] a recommendation justified based upon the study's patient population, in main immune-compromised. Khalifa [42] reported a consistent increase in colonisation density with time. These authors also calculated the relative risk of colonisation with five day increasing in situ times. Although colonisation increased over time the authors found this was most prominent at day 14 and recommended routine change at this time period if not done so already.

Discussion

———Whilst the focus on CR -BSI in the critically has remained on the CVC it is now clear that both the overall rate of colonisation and CR -BSI arising from AC are at least comparable to the rates observed with short term non medicated CVCs. Although this finding is not new [9] it has translated poorly into clinical practise and the CVC continues to remain the dominant focus of attention in the critically ill patient with suspected IVD sepsis. Although there are

now high quality evidence based guidelines for the diagnosis and management of intravascular catheter related infection [18,11,47, 11, 47] little direct evidence exists detailing how clinicians deal with invasive devices (both CVC and AC) when they become suspect of infection or in the case of unexplained fever in patients with a intravascular device in situ. The practice is likely to vary. This is however as illustrated by a survey that examined the practice of routine CVC replacement, an area where significant evidence exists supporting a no routine replacement strategy. The authors found that contrary to current evidence the practise of routine CVC replacement was still widespread in many UK ICUs. [4508] More recent data from The Centre for Outcome and Resource Evaluation (CORE) affiliated to the Australian and New Intensive Care Society (ANZICS) has however found a more consistent approach to these devices. On a recent survey of all member units throughout Australasia only 36% of units routinely replaced short terms CVCs and over 80% of units surveyed managed the short term AC as they would a short term CVC when suspect of sepsis i.e. replace and culture (personal communication, K.Drennan, ANZICS CORE).

As for short term CVC access there are several other areas of uncertainty with regard to AC sepsis. Certainly it would appear reasonable that if a guide wire was being used to insert the device full sterile procedure should be followed. It remains unclear however if ACs not inserted with guide wire assistance should be subject to full sterile procedure[3] and further research in this area would seem warranted. Other strategies that have shown benefit in reducing infection rates in CVCs, including the use of chlorhexidine impregnated sponges, bio patch devices and antiseptic or antibiotic impregnated catheters may well have a role in preventing AC infection. As of this time the commercial availability of these devices in particular antiseptic catheters is still not reality. Further study of these strategies would seem warranted.[8] Overall with strict attention to aseptic insertion technique, careful site selection and good after care including appropriate early removal when no longer required the incidence of CR -BSI from both CVCs and AC should be low.

The Ddiagnosis of infected short term intravascular devices continues to remain a major challenge with clinical for both CVCs and short term AC. Clinical findings are generally unrelaibleunreliable., [for the diagnosis of Cr BSI arising from both CVC and AC .4735] The most sensitive clinical finding fever has poor specificity. The traditional method of diagnosis of CR-BSI will reliesy onf the device being removed and both peripheral and catheter tip cultures taken simultaneosly. This however has an attendant high rate of negative catheters with estimates of up to 80% of all devices removed for suspected sepsis being sterile or non contributory. As noted above many of the studies examining aspects of infection in AC use varying diagnostic terminology and to this end little data exist on diagnosis of sepsis in these devices. However there is no reason to assume the colonisationthe colonisation patterns of AC would differ substanatiallysubstantially from that of short term CVCs with the majority of infection occurring via the skin

insertion site and colonising the outer catheter lumen. This may change with longer term devices where intraluminal colonisation may become more dominant. The recommended routine clinical ~~microbilogical~~microbiological technique for short term ~~cathter~~catheter tip cultures of both CVC and AC remains the roll plate ~~tecahnique~~semi quantitative technique. [47]   This has high sensitivity in devices in for short time periods (< 14 days)~~.~~ but obviously will necessitate device removal. The in-situ diagnosis of CR~~r~~ BSI from AC has not been studied however limited data from CVCs suggests that both ~~differetila~~differential time to posistivity (DTP) ~~of blood cultures drawn via lumens and peripherally and~~ and paired quantitative blood cultures (QC) taken from cathter blood and a peripheral venous sample , have both shown good sensitivity~~vit~~ and specificity for the in -situ diagnosis of CR-BSI~~.~~, Bouza [49]~~8~~ has recently compared these ~~three m~~methods of in –situ diagnosis of short term CVC related CR-BSI ~~without cathter withdrawal~~ in critically ill non neutropenic patients. Methods studied included ~~These included both~~ DTP~~, and~~ QC ~~and combined with~~ semiquantitative cultures from around the ~~cathter~~catheter insertion sites and device hubs. All three methods~~a~~ displayed equivalent ~~accuaracy~~accuracy with very high negative predicative values for the exclusion of CR-BSI . ~~P~~ ~~Previuos~~Previous studies have ~~alos~~also demonstrated ~~shown~~ very high negative ~~predictaive~~predictive values of ~~for~~ superficial cultures in excluding the ~~cathter~~catheter as an infection source.~~ with ne~~ Negative gram ~~satining~~staining and or culture of superficial swabs will practically rul~~eing~~ out the cathter as a source of infection . [50]~~49~~ Although these studies have all been performed in short term CVCs it is likely that they apply just as well to short term AC however further confirmatory data are needed in this area .

The issue of whether an arterial line should be changed routinely at regular intervals or changed as clinically indicated currently remains unanswered .Although data on the pathogenesis of AC colonization is lacking there is no reason to assume it differs markedly to that of CVCs. Data from the CVC literature would suggest that scheduled replacement either de novo at 7 days or every 3 or 7 days has failed to find a benefit. Indeed morbidity including, risk of infection is increased with scheduled change.[44, 45] Although in some studies a risk factor for AC BSI was catheter duration[9], and colonization of both ACs and CVCs appears cumulative over time, routine change of these devices to prevent infection currently remains unjustified and requires further investigation . Data on infectivity risk with relation to anatomical site of catheter placement is also sparse. However from the available studies the catheters inserted into the femoral site appear in general to be more heavily colonised and more likely to be a source of sepsis than those inserted into the radial position. On balance avoidance of the femoral position if clinically appropriate, would appear advantageous from the point of view of infection prevention.

Consideration of the above studies would suggest that we need to be as equally vigilant with ACs as with CVCs in terms of preventing IVD infection. It has been estimated there may be up to 48,000 AC related BSI in the US per alone per year [46] equating to a very significant problem. We should not be surprised that the AC has an appreciable infection rate. They remain one of the most manipulated devices in the critically ill patient. Although evidenced based literature is not as abundant ,application of the same infection prevention strategies as have proven effective in CVCs may be applicable.[46] In particular prevention "bundles" with measurement of their impact would seem justified. It has been suggested that AC BSI rates should be monitored in individual ICUs and reported along with those from the CVC. Bundles of care should be accompanied by education of both physicians and nurses regarding the correct insertion and ongoing care of ACs including removal when no longer required. Insertion kits and carts should therefore contain all components needed for aseptic technique during insertion.[46]

At this point in time it would seem there is enough evidence to suggest that in the critically ill patient if an IVD is suspected of causing sepsis both the AC and CVC should be considered together with the AC sepsis rates at least comparable to those observed with short term CVCs.

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Table 1: Summary of early prospective studies on AC infection rates

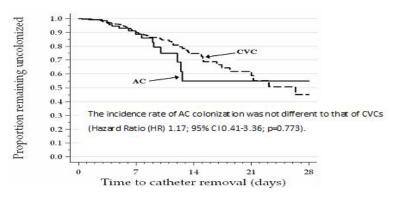| COHORT	SITE/DEVICE STUDIED	SEPSIS RATES	COMMENT	REFERENCE
231 adult ICU patients	Radial/Femoral AC	Radial -0.6% Femoral -2.3%	Dx : positive blood and catheter tips	31
51 adult ICU patients	Radial/Femoral AC PA catheters	Radial and Femoral-11.5%	Dx: Positive SQC tip culture only	32
112 adult ICU patients	Radial AC	Radial-22.5% Infusate-23.5%	Dx: Colonisation only reported-No definite CR-BSI	4
290 adult ICU patients	Femoral/Axillary AC	Femoral -1.1% Axillary-7.6% CR-BSI-2.2%	Dx: Culture details not provided. CR-BSI -positive AC tip and peripheral blood	33
56 Surgical ICU patients	Radial AC Femoral AC Axillary AC	Radial/Femoral - 9.5% Axillary-44%	Positive SQC only Devices in situ >96h	34
162 adult ICU patients	Radial AC Femoral AC	Radial/Femoral Colonisation:15/ 1000 device days CR-BSI:8 /1000 device days		36
65 adult ICU patients	Radial AC Femoral AC	Radial/Femoral-20%	Positive broth culture- No BSI rate reported	37
95 adult ICU patients	Radial AC Femoral AC Brachial AC DP AC	Colonisation -18% CR-BSI -4%	PSQ culture> 15 CFU CR-BSI correlates with time in situ(>4d)	9

Foot note: CR-BSI (Catheter related blood stream infection), PSQ (positive semi quantitative culture), AC (arterial line), and Dx (diagnosis), DP (Dorsalis pedis).

Table11: Summary of later studies documenting AC infection rates with comparable short term CVC infection rates

COHORT	SITE/DEVICE STUDIED	SEPSIS RATES	COMMENT	REFERENCE
Systematic review of 200 prospective studies reporting rates of intravascular device blood stream infection (BSI)	*All intravascular device types-AC reported as a subgroup*	*CR-BSI :* *AC: 1.7 / 1000 device days* *CVC:2.7/ 1000 device days*	*AC:14 studies* *CVC:* *79 studies* **short term ,non medicated ,non tunnelled*	8
272 critically ill adult ICU patients. PRCT of AC insertion under maximal sterile precautions (SBP) or standard care (control)	*Radial Femoral Brachial DP*	*Colonisation: AC:20.2 / 1000 device days (SBP) and 15.8/ 1000 device days(control) CVC : 13.5/ 1000 device days* *CR-BSI: AC:1.5/1000 device days CVCI: 2.7 /1000 device days*	*Culture –quantitative vortex sonication –PSQ > 1000 CFU* *CVC data taken from previously published systematic review.*	39 40
212 critically ill adult ICU patients	*Radial (68%) Brachial Femoral*	*Colonisation : AC :7.7% or 9.3/1000 device days CVC :9.4% or 12.0/1000 device days* *CR-BSI : AC and CVC: 0.5/1000 device days*	*Quantitative culture- PQC=>10^3 CFU/ml*	19
252 Predominantly adult critically ill ICU patients	*Radial Femoral*	*Colonisation: AC:5.3% or 15.7/1000 device days CVC :11% or 16.83/1000 device days* *CR-BSI: AC:0.92 /1000 device days CVC: 2.23/1000 device days*	*PSQ =>15 CFU/ tip* *Direct comparison with concurrently sited and identically managed CVCs*	21
988 adult ICU patients	*Radial Femoral Brachial DP*	*Catheter related local infection (CRLI): AC: 0.9/1000 device days CVC: 4.7/1000 device days P<0.001* *CR BSI: AC: 0.4/1000 device days CVC: 1.4 /1000 device days*	*AC: changed every 7 days* *Colonisation:> 15 CFUs* *CRLI: Local infection and catheter tip colonisation*	20

Foot note: CR-BSI (Catheter related blood stream infection), AC (arterial catheter), CVC (short term central venous catheter), PSQ (positive semi quantitative culture).

Figure 1: Proportion of arterial and central venous catheters remaining uncolonized on removal

Footnote: Figure adapted with permission from Koh et al (21).