ORIGINAL ARTICLE

Central Venous Catheter-Related Blood Stream Infections: Incidence and an Analysis of Risk Factors

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SUMMARY

Six hundred and fifty-five central venous catheters (CVC) in 496 patients in the intensive care unit of Hospital Sultanah Aminah were studied to determine the incidence and risk factors for central venous catheter-related blood stream infection (CR-BSI). CR-BSI was diagnosed in 38 catheters, giving an incidence of 9.43 CR-BSI per 1000 catheter days. The mean duration in situ was 8.4 ± 4.9 days for infected CVCs and 6.0 ± 3.8 days for non infected CVCs (p=0.001). CVCs inserted in ICU had the highest infection rate (9.4%) compared to those inserted in the operating theatre (1.4%) and ward (2.8%) (p=0.001). The highest rate of CR-BSI occurred with 4-lumen catheters (usually inserted when patients needed total parenteral nutrition) with a percentage of 15.8%. The majority of the CVCs (97.9%) were inserted via the subclavian or the internal jugular routes and there was no statistical difference in CR-BSI between them (p=0.83). Number of attempts more than one had a higher rate of CR-BSI compared to single attempt with percentage of 7.0% vs 4.8% (p=0.22). The top two organisms were *Klebseilla pneumoniae* and *Pseudomonas aeruginosa*. In conclusion, the incidence of CR-BSI in our ICU was 9.43 CR-BSI per 1000 catheter days. The risk factors were duration of CVC in situ, venue of insertion and use of 4 lumen catheter for total parenteral nutrition. The site of insertion, number of lumen up to 3 lumens and the number of attempts were not risk factors.

KEY WORDS:
Central venous catheter, Bloodstream infection, Risk factors, Intensive care

INTRODUCTION

Intravascular devices are indispensable in modern day medical practice and central venous catheters (CVCs) are commonly inserted in critically ill patients for the administration of fluids, medications, blood products or parenteral nutrition and for monitoring hemodynamic status. In the European Prevalence of Infection in Intensive Care (EPIC) study[1], 78.3% of critically ill patients had some form of intravenous catheterization while in the National Audit on Adult Intensive Care Units (NAICU) of Malaysia[2], an average of 70% of patients in the intensive care unit (ICU) had CVC inserted.

However, central venous catheterisation may cause complications such as arterial puncture, major bleeding, occlusive thrombosis and systemic sepsis. Central venous catheter-related blood stream infections (CRBSI) are of particular interest as indwelling vascular catheters have been shown to be responsible for about 62% of ICU acquired blood stream infections[3] which added to the morbidity and mortality of ICU stay[4]. In addition, CRBSI has been shown to increase both ICU and hospital length of stay[5, 6].

In Hospital Sultanah Aminah, 84% of our ICU patients (a percentage higher than the national average of 70%) had CVC inserted. The aim of this study is to determine the incidence of CR-BSI and to compare catheter characteristics in those with and without definite CR-BSI in an attempt to ascertain risk factors for CR-BSI.

MATERIALS AND METHODS

This is a prospective observational study conducted in a 16-bed multi-disciplinary intensive care unit of the 989-bed Hospital Sultanah Aminah, Johor Bahru in the year 2005. All CVCs in the ICU were inserted using a Seldinger technique by either anaesthetic medical officers or specialists. The catheters used were radio-opaque polyurethane catheters and not anti-microbial-coated. The insertion and maintenance of catheters were performed according to the following protocol. Insertion was carried out under full aseptic conditions (surgical hand washing, sterile gowns, gloves and masks). The skin insertion site was cleaned with 2% chlorhexidine and allowed to dry. For insertion in the general ward, the insertion site was cleaned with 10% povidone iodine followed by 70% alcohol. A sterile field around the insertion site was bordered by large sterile drapes. After insertion the catheter was fixed to the skin with 2-0 silk suture and the area covered with transparent semipermeable polyurethane dressing (Opsite).

Catheter-site dressings were changed only if the dressings became damp, loosened, or soiled with blood. The administration sets (including 3-way stop clocks, secondary sets and add-on devices) were changed only if they were contaminated with blood except tubings and syringes used to administer propofol infusions which were replaced every eight hours. All injection ports of the CVC were cleaned with a pre-packed alcohol wipe before accessing the system.

There was no routine replacement of CVCs. Catheters were removed when they were no longer needed. The percutaneous entry sites were examined for the presence of local inflammation and purulence by the ICU nurse in charge of the patient and the doctors on their daily round. If a local

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infection or CR-BSI was suspected, the CVC would have been removed. The CVC tip and a peripheral blood sample were sent for culture.

Data were collected on all CVCs in the year 2005 with regard to date and venue of CVC insertion and the date of removal, number of attempts of insertion, type of catheter (number of lumen) and site of insertion.

Catheters which stayed less than two days or which were inserted in patients less than 12 years old were excluded in the analysis.

Criteria for the diagnosis of catheter-related infection were defined as the presence of either one of the following situations:

1. Presence of pus at the CVC exit site
2. Systemic infection that proved to have identical organisms cultured from both the tip of the CVC and blood obtained peripherally without other identified sources of infection for that particular bacterium
   OR a positive blood culture obtained from a peripheral vein and signs of systemic infection (fever, and /or hypotension, and /or raised or lowered white cell count) with the catheter as the only obvious source of infection and catheter tip colonization with the same organism
3. Defervescence within 48 hours after removal of the CVC

The first criterion was classified as central venous catheter-related local infection while criteria two and three were considered as central venous catheter-related blood stream infection (CR-BSI).

Statistical analysis was performed with SPSS 11.0. Continuous variables were analysed with the unpaired t-test while discrete variables were analysed with the chi-square test. CR-BSI rates were calculated by dividing the number of CR-BSI by the total number of catheter days and multiplying the result to produce a figure per 1000 catheter days.

RESULTS

Over the study period, 655 CVCs were assessed in a total of 496 patients, representing 4029 catheter days. Central venous catheter-related local infection was found in 36 catheters. Central venous catheter-related blood stream infection (CR-BSI) was diagnosed in 38 catheters, giving an incidence of 9.43 CR-BSI per 1000 catheter days (Table I).

The subsequent analysis of risk factors is based on the 38 catheters which caused CR-BSI and the results are shown in Tables II and III.

The commonest 4 organisms were *Klebseilla pneumoniae* (14 catheters), *Pseudomonas aeruginosa* (7 catheters), *Acinetobacter baumanii* (5 catheters) and *MRSA* (5 catheters). Out of the 14 *Klebseilla pneumoniae*, 7 (50%) were ESBL (extended spectrum ß lactamase) inducers. Out of the 7 *Pseudomonas aeruginosa*, all were sensitive organisms among which one was ß lactamase hyper-producer. Out of the 5 *Acinetobacter baumanii*, 4 (75%) were multi-resistant *Acinetobacter baumanii*.

DISCUSSION

The incidence of central venous catheter-related blood stream infection (CR-BSI) was 9.43 per 1000 catheter in situ days. Based on the North American data compiled from the National Nosocomial Infection Surveillance System from

Table I: CVC and the criteria for diagnosis

Criteria for diagnosis	Number (%)
Criteria 1: pus at exit site	36 (48.6)
Criteria 2: same organism/s from CVC tip culture and peripheral blood pperipheral	21 (28.4)
Criteria 3: defervescence after removal of the CVC	2 (2.7)
Criteria 1 and 2	11 (14.9)
Criteria 2 and 3	4 (5.4)
Criteria 1 and 3	0 (0)
Total	74 (100)

Table II: The mean duration in situ of CVC and risk of infection

CVC	Number	Mean duration in situ (days)
CVC with CR-BSI	38	8.45 ± 4.90
CVC without CR-BSI	617	6.01 ± 3.83
Total	655	6.15 ± 3.94
		p = 0.001

The mean duration in situ of infected CVCs was higher than in non infected CVCs (p=0.001).

Table III: Venue of insertion and risk of infection

Venue of CVC insertion	Number with CR-BSI	Number without CR-BSI	Total
Ward	5	175	180
Operating theatre	2	144	146
ICU	31	298	329
Total	38	617	655
			p = 0.001

CVCs inserted in ICU had the highest infection rate (9.4%) compared to those inserted in the operating theatre (1.4%) and the ward (2.8%) (p=0.001)

Table IV: Number of lumen of CVC and risk of infection

Number of lumen of CVC	Number with CR-BSI	Number without CR-BSI	Total
One lumen	1	20	21
Two lumen	2	14	16
Three lumen	29	551	580
Four lumen	6	32	38
Total	38	617	655

$p \leq$ or = 0.05

The highest rate of CR-BSI occurred with 4-lumen catheters with a percentage of 15.8%. If the 4 lumen was excluded from the Chi-square calculation, then there was no significant difference among single, double or triple lumen catheters.

Table V: Routes of insertion and risk of infection

Sites of CVC	Number with CR-BSI	Number without CR-BSI	Total
Subclavian vein	30	481	511
Internal jugular vein	8	122	130
Other routes	0	14	14
Total	38	617	655

p = 0.826

The majority of the CVCs (97.9%) in this ICU were inserted via the subclavian or the internal jugular routes. The route of insertion had no bearing on CR-BSI (p=0.83).

Table VI: Number of attempts at inserting CVC and risk of infection

Number of attempts of CVC insertion	Number with CR-BSI (%)	Number without CR-BSI	Total
One attempt	17 (4.8)	339	356
>1 attempts	21 (7.0)	278	299
Total	38	617	655

p = 0.22

CR-BSI occurred more often if more than one attempt at insertion was required but this did not reach statistical significance.

Table VII: Organisms grown from both CVC tip culture and peripheral blood culture

Organisms	Number	%
Klebseilla pneumoniae	14	38.9
Pseudomonas aeruginosa	7	19.4
Acinetobacter baumanii	5	13.9
Methicillin resistant staphylococcus aureus (MRSA)	5	13.9
Enterobacter species	3	8.3
Methicillin sensitive staphylococcus aureus (MSSA)	1	2.8
Coagulase negative staphylococcus	1	2.8
Total	36	100.0

October 1986 to December 1990, CR-BSI rates ranged from 2.1 per 1000 catheter days for respiratory ICUs, through 5.1 and 5.8 for medical-surgical and trauma ICUs, respectively, to 30.2 for burn units[7]. More recent data from 1 May 2000 to 30 April 2003 showed a CR-BSI rate of 2.79 per 1000 catheter days[8]. Maki DG *et al* analysed 200 prospective studies published between January 1, 1996 and July 1, 2005 and found an incidence of short-term noncuffed and nonmedicated central venous catheter-related blood stream infection to be 2.7 per 1000 catheter days [9]. Data from National Nosocomial Infections Surveillance System from January 1992 through June 2004 showed that the median rate of catheter-related bloodstream infection in ICUs of all types ranged from 1.8 to 5.2 per 1000 catheter-days [10]. The rates of CR-BSI in our ICU would therefore be considered high.

Several variables have been quoted as contributing to the infectious complication rate of CVCs such as catheter selection (composition, number of lumen, whether antibiotic or antiseptic coated), insertion site (route, care and technique of insertion), skill of the person inserting the catheter, emergent or elective insertion, patient characteristics including severity of illness, extreme of age and immunosuppression and, finally, type of infusate and apparatus used.

We analysed some of these variables in our ICU to see if several variables were significant risk factors. These were: duration of catheterisation, venue of insertion, number of lumen, routes of insertion, and number of attempts at inserting CVC.

It would be expected that the longer the CVC is in situ, the higher the risk of catheter-related infection. Indeed, duration of catheterisation has been suggested as an important risk factor in the development of CR-BSI in some studies [11, 12, 13]. However, other studies showed no relationship between prolonged catheterisation and incidence of infection [14, 15]. In our study (Table II), we found a significant relationship between prolonged catheterisation and incidence of infection.

Very few studies looked at the venue of CVC insertion as a risk factor for CR-BSI. Charalambous C *et al* in their retrospective study showed that placement in the operating room versus the intensive care unit a significant factor [16]. We postulated that CVC inserted in the ward would have a higher incidence of CR-BSI as the wards in our hospital were busy and crowded, making infection control practices more difficult to adhere to. However, that was not the case. Catheters inserted in the ICU had higher rates of CR-BSI instead, suggesting that the assumption of poor infection control practices in the ward was unfounded (Table III).

Whether the number of lumens in the CVCs was associated with a higher rate of infection is controversial. Two meta-analyses have been published with conflicting conclusions. Dezfulian C *et al* in their meta-analyses of 15 studies comparing the prevalence of CR-BSI or catheter colonization among single, double, and triple-lumen central venous catheters concluded that multi-lumen central venous catheters might be associated with a slightly higher risk of infection when compared with single-lumen catheters; however this relationship diminished when only high-quality studies that controlled for patient differences were considered [17]. However, Zurcher M *et al* in their meta-analysis of 5 randomized comparisons of single-lumen and multi-lumen catheters concluded that for every 20 single-lumen catheters inserted, one bloodstream infection that would have occurred had multi-lumen catheters been used would be avoided [18]. We demonstrated that there was a significant difference among CVCs with different lumen (Table IV). However, if the 4 lumen CVCs were excluded, then the difference was not statistically significant. This finding may be explained by the fact that the 4-lumen CVCs were invariably inserted for total parenteral nutrition (TPN). It is our protocol to change a CVC to a 4-lumen even if it was inserted one day ago if TPN is ordered for the patient and one of the 4 lumen would be reserved for the infusion of TPN. Hence we think that the use of 4 lumen catheter for TPN is a risk factor for CR-BSI.

Which site for CVC insertion is associated with the highest risk of infection remains controversial. No randomised trial has satisfactorily compared infection rates for catheters placed in jugular, subclavian and femoral sites. Merrer J *et al* performed a randomized controlled trial comparing complications of femoral and subclavian venous catheterisation in critically ill patients and found that femoral catheterisation was associated with a higher incidence of clinical sepsis with or without bloodstream infection which did not reach statistical significance (p=0.07) [19]. In a systematic review of all prospective comparisons of internal jugular versus subclavian catheter insertion by Ruesch S *et al*, the authors could not reach any conclusion on predisposition to CR-BSI between the two routes [20]. Deshpande KS *et al* however concluded in their epidemiologic, prospective, observational study that there was no statistically significant difference in the incidence of central venous catheter infection and colonisation among the three sites when optimal insertion sites were selected, experienced operators inserted the catheters, strict sterile technique was present, and trained intensive care unit nursing staff performed catheter care [21]. Our study (Table V) also showed no statistical difference in terms of CR-BSI between subclavian or jugular route of insertion. Note that in our ICU, almost all CVCs were inserted via subclavian or internal jugular veins.

It is generally believed that the skill of personnel inserting the CVC has an impact on catheter-related complications. However, its impact on CR-BSI is not clear. We looked at the number of attempts as a surrogate indicator of the skill of the personnel inserting the CVC and found that number of attempts more than one had a higher incidence of CR-BSI but the difference did not reach statistical difference (Table VI).

A survey of 112 medical ICUs in the United States revealed the following microbial spectrum in primary hospital-acquired bacteremias (mostly caused by indwelling catheters)[22]: coagulase-negative staphylococci, mostly *Staphylococcus epidermidis* (36%), enterococci (16%), gram-negative aerobic bacilli (*Pseudomonas aeruginosa, Klebsiella pneumoniae, E coli,* etc) (16%), Staphylococcus aureus (13%), *Candida species* (11%), and other organisms (8%). A number of studies also reported coagulase-negative staphylococci as the most common organism [8, 10, 15, 23, 24]. Our studies on the contrary showed that gram negative rods were more commonly the causative micro-organisms with *Klebseilla pneumoniae* (38.9%) being the commonest (Table VII). Note that 50% of these *Klebseilla pneumoniae* were ESBL inducers.

Our study has three limitations. First is the CR-BSI definition. As our microbiological laboratory did not do semi-quantitative culture nor quantitative culture, any growth of the catheter tip culture was considered significant. This may partly explain the high incidence of CR-BSI in our ICU. Second is the absence of a multivariate analysis to control for possible confounders. Third, different sites were not randomly assigned. Only in the study of Merrer *et al*[19] were patients randomly assigned to undergo CVC at the femoral or subclavian site.

CONCLUSION

The incidence of CR-BSI in our ICU was 9.43 CR-BSI per 1000 catheter days which is high compared to international standards. The risk factors were duration of CVC in situ, venue of insertion and use of 4 lumen for total parenteral nutrition. The site of insertion, the number of lumen of CVC and the number of attempts were not risk factors.

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