Clinical Investigation

Mechanical and infectious complications of central venous catheterizations in a tertiary-level intensive care unit in northern India

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ABSTRACT

Background: Central venous catheters (CVC) are associated with mechanical, infectious and thrombotic complications. **Aims:** To study (a) the incidence of mechanical and infectious complications of CVC insertions and to compare, (b) the rates of these complications between the internal jugular venous (IJV) and the subclavian venous (SCV) accesses. **Settings and Design:** An adult intensive care unit of a tertiary care hospital. Prospective, observational study. **Methods:** All landmark-based CVC insertions performed between 1st October 2008 and 30th September 2009 were prospectively studied for mechanical and infectious complications. **Statistical Analysis:** SPSS software for Windows, Version SPSS 16.0, and Epi Info (3.5.1) software. **Results:** Four hundred and eighty central venous catheterizations were studied (IJV route, 241 and SCV route, 239). Mechanical complications occurred in 86 patients (17.9%, bleeding complications-48, catheter-related complications-27 and pneumothorax-11). The IJV route was associated with a significantly higher incidence of bleeding complications (P=0.009). Forty-seven patients had infectious complications (9.79%), like exit site infections (n=17), catheter tip infections (n=22) and catheter-related bloodstream infections (CRBSIs) (n=8). The risks of infectious complications increased significantly if the CVC was *in situ* for longer than 7 days (P=0.009), especially with IJV cannulae. The incidence density of CVC tip infections was 7.67 per 1000 catheter days and of CRBSIs was 2.79 per 1000 catheter days. **Conclusions:** Bleeding complications occurred more frequently with IJV insertions and infectious complications occurred more commonly in cannulae that were left *in situ* for longer than 7 days.

Key words: Central venous catheterization, infectious complications, intensive care unit, mechanical complications

INTRODUCTION

Central venous catheters (CVCs) are an integral part of patient care in the intensive care unit (ICU). However, complications associated with CVCs occur in nearly 15% of patients, mainly mechanical complications (5–19%), infectious complications (5–26%) and thrombotic complications (2–26%).[1] These result in prolongation of ICU and hospital stay, increased hospital costs, morbidity and mortality.[2] Despite the advent of ultrasound-guided vascular cannulation, which has reduced the incidence of insertion complications drastically, many hospitals in India and other developing countries still rely on the landmark-based technique for cannulation, which has a reported success rate of 75–99%.[3] However, there has been very little data reported from adult Indian ICUs on the rates of complications associated with CVC insertion and use, especially of infectious complications.

Hence, we undertook the present study to prospectively audit (a) the incidence of mechanical and infectious complications of CVCs inserted by the landmark-based technique in the ICU and (b) to compare the

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rates of these complications when CVCs were inserted via the internal jugular vein (IJV) and the subclavian vein (SCV).

METHODS

We prospectively studied all landmark-based CVC insertions performed in our ICU between 1st October 2008 and 30th September 2009. After approval from the hospital ethics and research committee, written permissions were obtained either from the patients themselves or from the next of kin or a legal surrogate. We recorded baseline data on each patient, like primary diagnosis, presence of any co-morbid illnesses, date of ICU admission and APACHE II score. Each CVC insertion attempt was considered as a new event and if a cannulation attempt failed and was subsequently performed by another operator, these were considered as separate insertion events. Central venous cannulations were performed only when the platelet count was more than 50,000/cumm and the prothrombin time international normalized ratio was less than 1.5 s, as per the ICU protocol. CVC insertions that were performed on patients without verifying their coagulation profile (as in an emergency) or on patients with uncorrected coagulopathy were not included in the study. All cannulations were performed either by an ICU consultant or by a 2nd or 3rd year registrar (with a minimum prior experience of at least 25 CVC insertions, under the supervision of a consultant). Complete sterile-barrier precautions were followed for all CVC insertions. The choice of the CVC insertion site (either IJV or SCV) was left to the discretion of the performing doctor. After insertion of the CVC, sterile non-occlusive dressings were used over the sites. The date, site and side of cannulation and the number of punctures required for successful cannulation as well as complications, if any, were noted for each insertion procedure. Chest radiographs were performed on all patients to verify the position of the tip of the CVC and to detect delayed complications like pneumothorax or haemothorax. All patients were followed-up daily and the CVC insertion site was examined for purulence or soiling. If an exit site infection was suspected, exit site swabs were sent for microbiological analysis. If catheter tip colonization/infection or catheter-related blood stream infection (CRBSI) were suspected, the CVC was removed and the tip of the catheter along with two sets of blood were sent for culture analysis. All CVC tips were cultured using the semi-quantitative method. No CVCs were changed or sent for microbiological analysis on a "routine" basis, but were removed when no longer required or when suspected to be infected. We noted the outcomes of all patients included in the study at the end of ICU stay, i.e. died or discharged.

Catheter-associated infections were defined as follows[4]: (1) exit site infection – erythema, tenderness, induration or purulence within 2 cm of skin at the insertion site of catheter along with microbiological growth on culture of the purulent exudates. (2) Catheter tip colonization – growth of more than 15 colony forming units on culture of the distal segment of the CVC with clinical signs of infection. (3) CRBSI – isolation of the same organism from the catheter tip culture and from at least one of the two blood cultures, along with signs and symptoms of infection.

Thus, patients with clinical signs of infection and in whom the CVC tip yielded a positive growth (but without associated bacteraemia) were considered as catheter tip infections while patients with clinical evidence of infection along with positive growth of the same organism on blood culture as well as CVC tip were diagnosed to have CRBSI.

Statistical analysis

The SPSS software for Windows, Version SPSS 16.0 (SPSS Inc, Chicago, IL, USA) and the Epi Info software (3.5.1) were used to process the data and generate the statistics. Mean and standard deviation (SD) were calculated as required for numerical variables. Univariate analysis was performed to compare the survivor with the non-survivor groups, and $P<0.05$ was considered significant.

RESULTS

A total of 480 CVC placements fulfilled our inclusion and exclusion criteria. Of these, 239 were SCV cannulations and 241 were IJV cannulations. There were no differences between the two groups in terms of age and gender distribution, presence of co-morbid illnesses, APACHE II scores and number of insertion attempts required for successful cannulation. The IJV route, however, was significantly associated with a higher number of failed cannulation attempts ($P=0.0087$). [Table 1] Mechanical complications occurred in 86 insertion attempts [Table 2]. This included bleeding complications (48 patients), catheter-related complications (27 patients) and pneumothorax (11 patients). We found that the risk of bleeding complications (arterial puncture and haematoma formation) were significantly higher with

Table 1: Univariate analysis comparing the demographic profile and insertion characteristics between the patients in the two groups

Variable studied	Total	IJV	SCV	*P* value
Total CVCs	480	241	239	0.145
Mean age (±standard deviation)	52.73 (18.07)	53.69 (18.06)	51.77 (18.03)	0.244
Gender (male/female)	311/169	153/88	158/81	0.547
APACHE II score; mean (±standard deviation)	16.46 (2.97)	16.62 (2.93)	16.29 (2.92)	0.165
Co-morbid illnesses				
Diabetes mellitus	183	94	89	0.690
Hypertension	132	70	62	0.446
Coronary artery disease	49	17	28	0.079
Others*	22	9	7	0.623
Characteristics of insertion				
Right side	316	162	154	0.520
≥2 insertion attempts	96	52	44	0.191
Failed attempts	40	29	11	0.008

Values are number (percentage) unless otherwise indicated *Others include patients with coronary artery disease, COPD, dilated cardiomyopathy and dysrrthmias *P*<0.05 was considered significant ; CVCs - Central venous catheterizations; IJV - Internal jugular venous; SCV - Subclavian vein

Table 2: Mechanical complications associated with CVC insertions

Complications	Total	IJV (*n*=241)	SCV (*n*=239)	*P* value	1 puncture (*n*=384)	>2 punctures (*n*=96)	*P* value
Bleeding							
Haematoma	20	16	4	0.0094	3	17	0.0034
Arterial trauma	28	21	7	0.0095	3	25	0.0005
Catheter-related							
Guidewire kinking	11	8	3	0.1091	5	6	0.0089
Catheter tip malposition	15	6	9	0.2053	11	4	0.2515
Others*	1	0	1	0.1641	0	1	0.0489
Pneumothorax	11	6	5	0.5172	3	8	0.0058

Values are in number (percentage) *P*<0.05 was considered significant *Others include an instance of a growth along the clavicular border that caused a mechanical obstruction; CVC - Central venous catheterization; IJV - Internal jugular venous; SCV - Subclavian vein

IJV insertion attempts (*P*=0.009) and in patients who had "two or more" needle attempts during the insertion procedure (*P*=0.003). Catheter-related complications included guidewire kinking (11 patients) and catheter tip malpositions (15 patients). Guidewire kinking occurred significantly more frequently if "more than one" needle attempt at CVC insertion was made. The SCV and the IJV routes had similar numbers of catheter-related complications. Eleven patients developed pneumothorax during CVC insertion, and this complication occurred significantly more often in those who had "two or more" attempts at needle insertion (*P*=0.0058). The site of CVC insertion did not influence the occurrence of this complication in our study. The total duration of CVC use in 480 patients was 2868 days, with a mean (standard deviation) duration of use of 6.45 (3.75) days per catheter [Table 3]. In 357 patients, the CVCs were *in situ* for less than 10 days while in 21 patients, the cannulae were used for longer than 20 days. We also noted that SCV catheters were used for significantly longer periods of time than IJV catheters (*P*<0.0001). Forty-two patients developed infectious complications, which included exit site infections (12 patients), catheter tip colonization/infections (22 patients) and catheter-related blood stream infections (CRBSIs, eight patients) [Table 3]. Exit site infections, based on clinical signs of inflammation at the exit site, were suspected in 62 (12.92%) patients, but were microbiologically confirmed in only 12 patients. Catheter tip colonization/infections were diagnosed in 22 (4.58%) patients and CRBSI was diagnosed in eight (1.67%) patients. The incidence of catheter tip infections and CRBSIs were similar between the IJV and SCV routes [Table 3]; however, we noted a significantly higher incidence of both CVC tip infections/colonizations (*P*=0.006) and CRBSIs (*P*=0.009) in patients with catheters *in situ* for longer than 7 days, especially with the IJV inserted catheters. Catheters inserted via the SCV route had a higher incidence of CRBSIs when left *in situ* for longer than 7 days. The incidence density of infections was 10.43 versus 5.23 (IJV versus SCV catheters) per 1000 catheter days for catheter tip infections and 3.73 versus 1.96 (IJV versus SCV catheters) per 1000 catheter days for CRBSIs.

On microbiological evaluation, the most common organisms cultured were gram negative bacteria like

Acinetobacter species (25 patients) and *Eschericia coli* (18 patients), followed by Staphylococcus aureus (seven patients).

All patients were followed-up to study their outcomes from the ICU. In all, 215 patients were discharged to ward (44.79%) and 265 expired (55. 21%). There was no significant relation between occurrence of mechanical or infectious complications and the overall crude mortality rates of patients [Table 4].

DISCUSSION

Complications associated with CVCs have a major impact on the hospital course of patients admitted to the ICU due to the morbidity, mortality and increased health care costs associated with them. In the reported literature worldwide, the overall rates of unsuccessful CVC insertion attempts have been 12% for SCV insertions and 12–20% for IJV insertions.[5,6] Unsuccessful insertion attempts are reported to be the strongest predictor of mechanical complications, and are reported to occur in up to 28% of failed insertions.[7] In our study, we noted that CVCs inserted via the IJV route had a significantly higher proportion of failed cannulations, possibly contributing to the greater number of mechanical complications via this route.

Bleeding complications were the greatest among all mechanical complications encountered in our patients, especially when the IJV route was used and when more than two insertion attempts were required for successful cannulation. This is similar to the figures reported in other studies.[8,9] Other mechanical complications seen in our study were guidewire kinking and catheter tip malposition, and the former was significantly associated with "2 or more" needle insertion attempts. In many instances, guidewires have been reported to be entrapped, knotted, fractured, embolized and even lost inside patients,[10]

Table 3: Characteristics of CVC usage and infectious complications in the two groups

	Total	Percentage	IJV site	SCV site	*P* value
Total catheter duration (days)	2868	–	1341	1527	–
Average catheter duration (in days ± standard deviation)	6.45 (±SD 3.75)	–	5.56 (±SD 3.69)	6.39 (±SD 3.78)	<0.0001*
Number of CVCs inserted longer than 7 days	192	40	87	105	0.079
Catheter days among CVCs inserted longer than 7 days (days)	1850	64.51	757	1093	<0.0001*
Overall infections	42	8.75	26	16	0.112
Exit site infections	12	2.5	7	5	0.154
Catheter tip infections	22	4.58	14	8	0.124
(a) CVC§ < 7 days	4	1.39	2	2	0.601
(b) CVC§ > 7 days	18	9.38	12	6	0.080
P value‡ (comparing CVCs inserted for shorter than 7 days versus longer than 7 days)	0.0062	–	0.0064	0.1447	–
Incidence density of catheter tip infections (infection days per 1000 catheter days)	7.67	–	10.43	5.23	0.111
CRBSIs	8	1.67	5	3	0.237
a) CVC§ < 7 days	1	0.35	1	0	1
b) CVC§ > 7 days	7	3.65	4	3	0.703
P-value‡ (comparing CVCs inserted for shorter than 7 days versus longer than 7 days)	0.0093	–	0.0473	0.0497	–
Incidence density of CRBSIs (infection days per 1000 catheter days)	2.79	–	3.73	1.96	0.371

*P<0.05 was considered significant †CRBSI=Catheter-related blood stream Infections, §CVC=central venous catheter ‡P-value noted here compares the rates of infection (catheter tip/CRBSI) between central catheters used *in situ* for less than 7 days versus greater than 7 days, i.e. (a) versus (b) ; IJV - Internal jugular venous; SCV - Subclavian vein

Table 4: Comparison of mortality rates among patients who developed catheter-related immediate complications versus those who did not

Complications	Yes	No	*P* value
Bleeding	16/38 (42)	169/442 (38.23)	0.3507
Catheter-related	10/24 (41.67)	185/456 (40.57)	0.9477
Pneumothorax	3/11 (27.27)	192/469 (40.94)	0.1808
Catheter tip infections	1/22 (4.55)	194/458 (42.35)	0.0004
CRBSI	0/8 (0.00)	195/472 (41.31)	0.1004

Figures in parenthesis are in percentage

while catheter malpositions may result in vascular perforations and dangerous arrhythmias.[11] Catheter tip malpositions are reported to occur equally with both IJV[9] and SCV insertions.[8,12] Pneumothorax, one of the most feared complications of CVC insertions, occurs in up to 0.1–3.1% patients undergoing the procedure, with increasing risk with larger needle size and number of passes made, use of the SCV route and in emergency insertions.[7,13] In our study, this complication occurred equally with the IJV and SCV insertion routes; however, "2 or more" attempts at needle passes were associated with a significantly higher risk of pneumothorax (P=0.0052).

Catheter related infections in the ICU are a cause of significant morbidity and add tremendously to the burden of health care costs. A study among 55 ICUs in eight developing countries in the International Nosocomial Infection Control Consortium (INICC) revealed that CVC-related blood stream infections accounted for 30% of all device-associated infections, with an incidence density of 12.5 cases per 1000 catheter days, which was four-times higher than that reported from American ICUs in the NNIS system.[14] The occurrence of catheter infections is shown to increase the average length of ICU stay by 2.4 days, and hospital stay by 7.5 days.[15] In all, our study revealed a total of 9.79% of CVC-related infections. This included exit site infections (2.5%), catheter tip infections (4.58%) and CRBSI (1.6%). World over, the reported incidence of exit site infections vary from 6 to 15%, catheter tip infections from 4 to 15% and of CRBSIs from 1 to 13%.[16,17] While the IJV route is implicated to be more commonly associated with greater infectious complications,[1,18] in our patients, both routes of CVC insertion showed similar incidences of all three infectious complications.

However, when we subanalysed the rates of infectious complications with the duration of CVC use, we found that CVCs that were used for greater than 7 days had a significantly greater association with infectious complications. This was more evident with IJV routes of insertions. In a related study, when 2595 CVC insertions were studied, both CVC-related infection as well as CRBSI-related incidence densities were found to be significantly higher with IJV catheters as compared with the SCV catheters (7.65 versus 1.57 per 1000 catheter days and 2.99 versus 0.97 per 1000 catheter days, respectively).[16] It has been postulated that this difference is due to the proximity of the IJV insertion site to the mouth and the oropharyngeal secretion, the higher density of local skin flora due to the higher local skin temperature and the difficulties in maintaining occlusive dressings.[16] The risk of infectious complications with CVCs has also been reported to be more with increased duration of use.[17,18]

Microbiological yields from CVC tips predominantly grew Acinetobacter species in our study. Data on CRBSIs collected from Indian hospitals reveal patterns of infections similar to ours, and include Enterobacteriaceae, Pseudomonas, Acinetobacter and Candida species.[19] This is in contrast to the Western literature, which mainly report coagulase-negative Staphylococci and Staphylococci aureus species.[16,18]

We found that the mortality rates did not differ in patients developing either mechanical or infectious complications as compared with other patients. Crude mortality rates from CRBSIs are 35.2% in the Indian literature,[14] with a greater all-cause in-hospital mortality among ICU patients (odds ratio of 1.81).[20]

Thus, this paper reveals that the mechanical and infectious complications associated with central venous catheters are still high. Such complications pose huge burdens to critically ill patients in terms of morbidity, mortality and health care expenditure. Estimates of costs incurred by CVC-related infectious complications range from $4888 to $56,167, with an associated increase in hospital stay by 7–19 days.[17,21] This is a huge economic burden on any critically ill patient, especially among Indian ICUs, where more than 80% of the patients are self-paying.[22]

This paper adds to our knowledge on the rates and some of the risk factors of mechanical and infectious complications associated with landmark-based techniques of CVC insertions. Data such as this is valuable for planning and implementing infections prevention and control strategies in any population. Following the results of this audit, we have begun to ensure that all invasive vascular catheters that are not essential, especially those that have been *in situ* for longer than 7 days, are removed. Basic standards of care, like hand hygiene protocols and use of closed infusion systems, need to be repeatedly emphasised and continued regular surveillance need to be carried out to bring our infection rates on par with our Western counterparts.

There were two main limitations in our study. We did not randomise the site of CVC insertion but left it to

the choice of the operator. This might have introduced bias in operators who have sufficient expertise performing a particular vascular cannulation, causing them to choose that route preferentially, especially when performing procedures among patients with mild coagulopathies. Secondly, we excluded all emergency CVC insertions and those performed on patients with uncorrected coagulopathy, and this might have excluded a significant number of patients, precluding the study of complications associated with emergency insertions.

We conclude that the rates of mechanical and infectious complications associated with CVCs are high. The IJV route, as compared with the SCV route, is associated with a greater number of bleeding mechanical complications. Seeing the high incidence of complications during central venous cannulation in the study, ultrasound-guided insertion should be considered. Cannulae inserted via the IJV route are also at a greater risk of infectious complications like catheter tip infections/colonizations and CRBSIs especially when they are used for durations longer than 7 days.

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