

TITLE:

***“CENTRAL VENOUS CATHETER PLACEMENT BY ADVANCED PRACTICE
NURSES DEMONSTRATE LOW PROCEDURAL COMPLICATION AND
INFECTION RATES – A REPORT FROM 13 YEARS OF SERVICE”***

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ABSTRACT

Objective: To report procedural characteristics and outcomes from a central venous catheter placement service operated by advanced practice nurses.

Design: Single centre observational study.

Setting: A tertiary care university hospital in Sydney, Australia.

Patients: Adult patients from the general wards and from critical care areas receiving a central venous catheter, peripherally inserted central catheter, high flow dialysis catheter or midline catheter for parenteral therapy between November 1996 and December 2009.

Interventions: None

Measurements: Incidence rates by indication, site and catheter type were assessed. Non parametric tests were used to calculate differences in outcomes for categorical data. Catheter infection rates were determined per 1000 catheter days after derivation of the denominator.

Results: A total of 4560 catheters were placed in 3447 patients. The most common catheters inserted were single lumen peripherally inserted central catheters (n=1653; 36.3%) and single lumen central venous catheters (n=1233; 27.0%). A small proportion of high flow dialysis catheters were also inserted over the reporting period (n=150; 3.5%). Sixty one percent of all catheters placed were for antibiotic administration. The median device dwell time (in days) differed across cannulation sites ($p<0.001$). Subclavian catheter placement had the longest dwell with a median of 16 days (Inter Quartile Range 8 – 26 days). Overall catheter dwell was reported at a cumulative 63071 catheter days. The overall catheter related blood stream infection rate was 0.2 per 1000 catheter days. The incidence rate of pneumothorax recorded was 0.4% and accidental arterial puncture (simple puncture - with no dilation or cannulation) was 1.3% using the subclavian vein.

Conclusion:

This report has demonstrated low complication rates for a hospital wide service delivered by advance practice nurses. The results suggest that a centrally based service with specifically trained operators can be beneficial by potentially improving patient safety and promoting organizational efficiencies.

INTRODUCTION:

Over 5 million central venous catheters (CVCs) are inserted each year in hospitalized patients in North America¹. Essential for many therapies, they are associated with adverse events contributing to patient morbidity and mortality^{1,2}. Foremost of these adverse events is catheter related blood stream infection (CRBSI). Each year an estimated 250,000 potentially preventable bacteraemia attributable to intravascular catheters occur in United States (US) hospitals resulting in a cost of 2.3 billion US dollars to the health care system and 31,000 deaths annually¹⁻⁴.

Prevention of CRBSI has been successfully demonstrated when predetermined care bundles are implemented during CVC insertion and routine care¹⁻⁵. The success of such prevention strategies in specialised and confined settings such as intensive care units (ICUs) has prompted the US Department of Health and Human Services to target a 50% reduction in intravascular bacteraemia in general ward areas as one of its key 5 year national prevention objectives^{6,7}. Currently, there are limited data on the success of care bundles in a general ward environment compared to specialised areas such as ICUs.

Poor insertion technique and a lack of operator experience can lead to procedural complications such as pneumothorax, accidental arterial puncture and catheter malposition^{4, 7-10}. Several investigators have identified clinician procedural volume as an important predictor of reduced adverse events¹¹⁻¹⁵. Similarly, increased experience with CVC placement has shown to improve both catheter and patient related outcomes^{16,18}.

Operator experience is not always synonymous with professional qualification and there have been some documented benefits regarding nurse led CVC placement. Notably, the improvement in organisational efficiency through earlier catheter placement and patient follow up along with regular surveillance and consultation to clinicians on appropriateness of device selection, maintenance and removal¹⁹⁻²¹. Despite existing studies published on the effectiveness of nurses inserting central venous catheters and peripherally inserted central catheters – PICCs (collectively referred to as central venous access devices - CVADs), the paucity of large sample investigations with scientific rigor, warrants this model to be further investigated.

This study reports the characteristics and outcomes of patients from the general ward areas that had CVAD placement by a centralized service managed through the ICU, and delivered by three advanced practice nurses (APNs) over a 13 year period.

MATERIALS AND METHODS:

Data Source and Study Population

The study setting is an 850 bed, tertiary care university hospital situated in Sydney, Australia. A CVAD placement service operating within the ICU provides elective catheter placement for patients on the general wards of the hospital and occasionally for patients in critical care areas. The service was established in December 1996 when the hospital underwent significant redevelopment which impacted greatly on the workload of the ICU. Competing work demands for the ICU physicians affected their ability to provide a timely and efficient CVAD placement service for non-emergent

(general ward) patients. Due to fiscal restraints with employing more ICU medical trainees, the ICU physicians used in-house resources and trained a senior ICU nurse to undertake some duties to relieve medical staff workload¹⁹.

The service currently operates with three APNs who are certified clinical nurse specialists in intensive care nursing. The APNs have undertaken further hospital based training to be credentialed in CVAD placement. Training involved theoretical and practical assessment including 20 supervised catheter insertions for each anatomical site (internal jugular, femoral, subclavian and brachial veins). The APNs have also been formally trained in ultrasound guidance for CVAD placement since 2006.

With executive support from medicine and nursing, the CVAD service is operated exclusively by the APNs who are responsible for inserting the catheters, providing follow up clinical support and organising hospital wide educational activities. The service is also responsible for assisting in the training of ICU medical trainees in central venous cannulation.

Device and vessel selection is based on duration of parenteral treatment, number of catheter lumens required and patient assessment. The funding model for the service is shared between the ICU and the general wards of the hospital. The ICU is responsible for funding the nursing positions (currently 1.2 full time equivalent) whilst the clinical wards reimburse the ICU for all consumables.

All patients receiving a vascular access device through the service are entered into an administrative database which has been operating since service inception. Data were extracted and loaded into statistical software (STATA Version 9) for analysis.

Ethical approval for this study was granted by the regional health service human ethics committee. Report cases are categorised in accordance with the four divisional streams of the hospital - Medical; Surgical; Critical Care; as well as Women and Child Health.

Outcome Measures

Outcomes of interest were based on CVADs placed in adult patients between November 1996 and December 2009 and included:(1) patient and device characteristics; (2) procedural complications; and (3) incidence of catheter related blood stream infection. The authors used the Centres for Disease Control and Prevention (CDC) definitions for laboratory-confirmed CRBSI^{22,23}.

Statistical Analysis

Details of patient demographics, incidence rates for indication of catheter insertion, site of insertion and type of catheter are documented. Differences in each categorical variable were assessed using the chi-square test, in instances where the assumptions for chi-square tests were violated; the Fisher's Exact test was used. The median dwell time (in days) was calculated for each insertion site along with their inter quartile ranges, the Kruskal Wallis test was then used for comparing a continuous

variable against a categorical variable to calculate any differences between median catheter dwell times for each site.

The incidence rates of CRBSIs per 1000 catheter days were calculated for each insertion site and clinical division after clinical record review for derivation of denominator. Date of hospital discharge was documented as the date of catheter removal for those patients who were discharged with catheter still in place.

RESULTS:

Patient Characteristics

Between November 1996 and December 2009, a total of 4560 catheters were placed by the service in 3447 patients (Table 1). This amounted to a total of 63,071 catheter days. Seventy five per cent (75%) of patients had one occasion of catheter placement. Some patients received more than one episode of catheter insertion due to therapy requirements with the uppermost being 7 occasions. The medical division had the highest number (n=2528, 55.4%) of catheters placed followed by the surgical division with 1969 (43.3%) catheters. The lowest number of catheter placements by the centralised service was for the critical care division (n=20 – 0.4%). Specialised areas such as intensive care, emergency rooms and operating rooms commonly insert their own catheters.

Gender distribution differed across the clinical categories, more males had catheters inserted than females (56.5% vs. 43.5%, $p = 0.05$). This was the case across the

clinical divisions except, of course, for the division of women and child health (incorporating obstetrics and maternity). When we re-analysed gender distribution without the division of women and child health to assess any influence of this division on the overall distribution, we found a significant difference in the distribution of males and females in the other three divisions ($p < 0.001$). The mean age across all cases was 56 years (SD 18 years).

Catheter Characteristics:

In 61% of all cases ($n=2788$), antibiotic administration was the primary reason for catheter insertion. Surgical patients received the most catheter placements for antibiotic therapy ($n=1482$), proportionately, this was 75% of all catheters inserted for this division. Nearly all patients receiving catheter placement for chemotherapy or stem cell transplant were represented in the medical division ($n=770$ – 98.6% of all catheters). The divisions of medicine and surgery had similar numbers of patients that received catheter placement as a result of poor peripheral vascular access ($n=176$ vs. $n=160$) (Table 1).

There was a difference amongst the distribution of catheter placement across the four divisions ($p < 0.001$). The most common of devices inserted overall were standard (uncoated) single lumen peripherally inserted central catheters (PICCs; $n=1653$ – 36.3%) followed by standard single lumen CVCs ($n=1233$ – 27.0%). Standard triple lumen CVCs comprised 17.3% of catheters inserted ($n=790$). A small number of antiseptic coated single lumen CVCs ($n=55$ – 1.2%) and triple lumen CVCs ($n=74$ – 1.6%) were also inserted (Table 1). The service likewise inserted a small proportion of high flow dialysis

catheters (n=158 – 3.5%) and (although not a CVAD), a small number of midline catheters (n=97 - 2.1%).

Procedural Outcomes

There was minimal difference in total procedural complications between the central venous cannulation sites (internal jugular, subclavian and femoral veins). Approximately 92% of all central venous cannulations reported over the 13 years were uneventful. A difference was found with only inadvertent arterial puncture (simple puncture - with no dilation or cannulation, $p = 0.01$). The femoral approach had the highest proportion (n=7 - 4.3%) of simple arterial puncture, this is despite the highest number reported were from the subclavian approach (n=30, 1.3%), thus reflecting the large denominator and favoured choice of this vessel (Table 2 and Figure 1).

There were a total of 9 pneumothoraces reported over the 13 year period (0.4%), and all were attributed to the subclavian approach. No pneumothoraces occurred using the internal jugular approach. The median dwell time (in days) differed across the three central venous cannulation sites ($p<0.001$) with subclavian catheters having the longest median dwell of 16 days (IQR: 8-26 days – Table 2).

In comparison, a difference was found across peripheral cannulation sites (basilic, antecubital and cephalic veins – $p<0.001$). Just over 69% of all peripheral cannulations were uneventful over the 13 years of service. The cephalic vein approach had the lowest success rate with 162 of the 377 catheters (43%) being placed without impediment. The

success rates for the antecubital and basilic vein approaches were higher (75.4% vs. 79.5%, $p < 0.001$ - Table 2 and Figure 2). Ninety one cephalic approaches (24.1%) were reported to have difficulty in feeding the PICC through the vessel. This culminated in 42 (11.1%) catheter tips terminating in the axillary / subclavian vein (presented in Table 2 and Figure 2 as mid clavicle catheter tip termination).

A difference was also found in the median dwell time between the peripheral insertion groups ($p < 0.001$) with the basilic vein approach having the longest median dwell of 12 days (IQR: 3-23 days). The range was also spread with the antecubital approach (median: 10 days, IQR: 4-26 days) and cephalic approach (median: 10 days, IQR: 3-20 days – Table 2).

Since the implementation of ultrasound guidance into daily procedural practice for catheter insertion (in 2006), the service has observed a small reduction in procedural complication rates with central venous cannulation sites, as the complication rates for these sites were already low; no statistical difference was found (Table 3).

A reduction was also found in procedural complication rates with peripheral cannulation insertions. We observed a reduction in catheter malposition rates for the basilic vein approach (8.7% vs. 1.7%, $p < 0.001$) and also the cephalic vein approach (8.0% vs. 0.25%, $p < 0.001$). We also observed a reduction in failed vascular access rates (11.4% vs. 1.6%, $p < 0.001$) and difficult feed of catheter rates (23.6% vs. 0.5%, $p < 0.001$)

with the cephalic vein. Table 3 illustrates a breakdown of procedural complication rates for CVADs pre and post ultrasound guidance.

Incidence of Catheter Related Blood Stream Infection

There were no differences in diagnosed CRBSI rates between the central venous cannulation sites ($p=0.33$) with a total of 12 intravascular infections reported. The subclavian approach had the highest number with 10 CRBSIs (0.3 per 1000 catheter days). Interestingly, this vessel also had the highest median dwell. The femoral approach had the highest rate of CRBSI ($n=1$, 0.8 per 1000 catheter days). One CRBSI was also reported with the internal jugular approach (0.1 per 1000 catheter days).

Similarly there were no differences in diagnosed CRBSI rates between peripheral cannulation sites ($p=0.27$). There was 1 intravascular infection that was reported with a cephalic vein approach (0.25 per 1000 catheter days).

Overall, there were 13 diagnosed CRBSIs across all clinical divisions; surgical patients had the highest number with 9 occasions. The overall CRBSI rate reported by the service was 0.2 per 1000 catheter days.

DISCUSSION:

Over a 13 year period, a dedicated, hospital wide service has demonstrated insertion of 4560 catheters, with a pneumothorax rate of 0.4% and simple arterial puncture rate of 1.3% using the subclavian vein. Complication rates for CVCs meet or

exceed previously published international standards^{16,24}. Similarly, the overall CRBSI rate of 0.2 per 1000 catheter days meets or exceeds previous rates. A recent study found the CRBSI rate across 10 US hospitals to range between 0.2 – 4.2 per 1000 catheter days in patients from the general wards²⁵. Other studies have reported hospital wide catheter related bacteraemia rates at up to 12.2 per 1000 catheter days⁶.

The low procedural complication rate in this series (compared to published rates)^{16, 17} can potentially be explained by the level of training and credentialing required by the operators and the skills and competence achieved by high volume. Credentialing involved didactic learning with tutorials administered by senior ICU physicians. Written examination involved pre insertion assessment, intra procedural complication management and post insertion assessment and management. Practical tuition included the nurses observing a number of catheter insertions prior to undertaking the skill¹⁹. Procedural volume also played a role where nurses undertook 20 supervised catheter insertions for each anatomical site (internal jugular, subclavian, femoral and brachial veins). The intensive care physicians supervised the credentialing of the advanced practice nurses.

Operationally, the CVAD placement group (known as: The Central Venous Access Service - CVAS) functions within established hospital guidelines. All patients are required to have informed consent prior to the procedure; pre-assessment must include patient history, allergies, medications taken such as anticoagulants and blood pathology results are reviewed. In particular, coagulation parameters for CVC placement to proceed

include an activated partial thromboplastin time (APTT) between 35-45 seconds, platelet count greater than $50,000 \times 10^9/L$ and an international normalised ratio (INR) no greater than 1.5¹⁹. If patients are anti-coagulated, this is often corrected prior to catheter insertion but is dependent on patient status and urgency of catheter placement.

The CVAD insertion service described in this report employs an integrated, person-centered approach where catheter placement is only a single dimension. The service is involved in catheter surveillance and staff education which includes maintenance of devices. Part of the role of the APNs is to assist the ICU in the training and supervision of ICU medical trainees in CVAD placement. The service also provides consultancy to the general wards on care and management issues related to vascular access devices¹⁹. Other CVAD insertion services involve the insertion of catheters by numerous individuals with varying levels of skill and competencies²⁶. A dedicated service using best practice recommendations may be efficacious in improving patient outcomes^{19,20}.

One outlier for our procedural complications was catheter tip malposition and difficult feeding of PICCs, particularly with the use of the cephalic vein. This could be explained by the tortuous pathway of this upper peripheral vessel. The advent of ultrasound guidance has limited the need to use this vessel^{26,27}. The service has observed a decrease in catheter malposition rates since the implementation of ultrasound guidance with the ability to use this technology in undertaking vessel assessment prior to catheter

insertion and for intra procedural scanning.

Our catheter tip malposition rate can also be explained by the manner in which the service operates, it uses a bedside insertion model without the aid of fluoroscopic or ECG guidance. These technologies have been shown to significantly reduce the incidence of catheter tip malposition and provide optimal tip placement^{28,29}.

The results from our report should be interpreted in the context of a number of potential limitations. **First**, we report on CVAD placement by APNs from a single centre where we did not undertake any comparison. Small studies have been undertaken previously that have shown comparable outcomes between APNs and medical practitioners with CVC placement²⁰.

Another potential limitation to the findings of our study may be Type I error. In particular, we have used multiple tests of significance and individual patients had multiple catheters inserted. Both these factors would increase the risk of Type I error, however the overall interpretation of our results we feel would be unchanged using more advance statistical approaches to adjust for multiple tests (such as Bonferroni's correction) and to deal the repeated catheters among individuals.

The increased use of CVADs can impose pressures on medical teams in terms of the time needed to reach safe and proficient skill levels. Specialisation and workload requirements have increased the dependence on a multidisciplinary approach to clinical care as it is increasingly difficult to maintain all the skills and knowledge necessary to

manage all aspects of a patient's illness³⁰. There have been a number of small studies supporting the role of nursing staff inserting CVADs as an organisational solution resulting in increased efficiency, reduced cost and improved clinical care^{21, 31-33}. Moreover, increased procedural load has been shown to improve patient care in many specialty areas¹¹⁻¹⁵.

This report suggests that a dedicated hospital wide catheter placement service can achieve procedural and infection rates across the hospital that are consistent with rates achieved by medical staff in specialised environments such as ICUs. The results indicate that a well trained and dedicated service employing a high procedural volume can have beneficial patient and device related outcomes that are not necessarily linked to the clinician's professional background. Absence of randomized comparison data limits the capacity to determine causality. However, this large data set of prospective, consecutive data provides some insight into a model of intervention that can potentially improve patient safety and quality of care.

CONCLUSION:

This report reviewed outcomes of patients who had catheters inserted by a hospital wide service operated by specialist nursing staff over a 13 year period. It reports on the insertion of 4560 catheters with procedural and CRBSI complication rates equal to or better than those previously published. The results suggest that a centralised service with a small number of specifically trained personnel may be more important to procedural success than clinician grade.

The large sample reported on consecutive catheter placement by APNs with low procedural complication rates and infection rates makes this report significant and of interest to intensivists and hospital administrators internationally.

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